INCREASING CAPACITY AND PRODUCTIVITY IN THE METALS MARKETS THROUGH PNEUMATIC CONVEYING AND PROCESS INJECTION TECHNOLOGIES

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Abstract

Pneumatic Conveying and Process Injection Technologies have been implemented in the metals markets for the last 40 years and have considerably improved the productivity and the performance of many processes. There have been many steps forward in handling technology and this paper seeks to consider those now offered by Clyde Materials Handling who as an established customer-driven solutions provider, which has turned its attention to supporting the Metals Market. Clyde seek to utilise its knowledge, expertise and technologies to transform the production processes of its customers, who operate in the ferrous and non-ferrous metals industries.

With over 30 years experience in the process improvement industry, Clyde Materials Handling has helped their global customer base transform the way in which they operate their processes, which has enabled them to generate sustainable economic benefit and maintain their positions as leaders in their respective markets.

Operators within the metals market have developed and deployed pneumatic conveying and pneumatic injection technologies. These environmentally supportive and sustainable solutions have been used to transport raw materials within operating facilities, from storage to silo, as well as injecting these materials directly into the heart of production processes.

Operators, such as Codelco in Chile, Corus Steel in the UK, and many others across the World have seen pneumatic injection solutions transform their process and costs. To inject a consistent, pulseless and accurate flow of material to a copper concentrate bath smelter, or injecting granular or pulverized coal as a coke substitute into a blast furnace...
via the Tuyeres helps to increase the operational capacity, availability and productivity and reduce the cost of the operation.

This paper will discuss and highlight the ways in which pneumatic conveying and injection technologies, created by Clyde Materials Handling, and applied in partnership with the customer, have helped to improve the operational performance of the production processes of operators across the non-ferrous metals markets with specific reference to applications in the Lead and Zinc Industries.

With examples from Zinc Fuming in Australia, Zinc Calcine and Powder Handling in Korea, Precision coal injection to QSL and TSL Furnaces, and metered distribution of Zinc Calcine to Reactors.

Introduction

The demand for commodities produced from the ferrous and non-ferrous metals markets are at significant highs. The surge in growth has been predominately driven by China and other developing economies. As a result, operators within the metals industry are striving to optimise the performance of their production facilities, in an effort to meet the demand of the industry and maximise on these market conditions.

Industrial production processes require an accurate, stable and consistent feed of raw materials to function efficiently. Generally, the more accurate and consistent the raw material feed, the more stable the process reaction, often with a corresponding increase in efficiency and throughput. A stable process can also reduce the loading on downstream equipment, for example, gas cleaning plants, and hence reduce emissions.

Process improvement technologies for injection to pyrometallurgical vessels must be able to generate an accurate, consistent and stable feed of material into the process, even at substantial back pressure, to support operators desired goal to increase throughput and production efficiency.

In this environment the systems used for transportation of materials between silos becomes important as well a process environment demands high availability and long term reliability.

Pneumatic Conveying Overview

Pneumatic conveying is, generally, the most efficient and effective method of transporting granular and bulk solid materials to storage, or to process within a production environment. There are three main divisions of pneumatic conveying namely, Dense Phase, Medium Phase and Lean Phase pneumatic conveying.
Dense Phase solutions are suitable for transporting difficult, abrasive or friable materials. This method of conveying pushes material along a pipeline in a plug flow at relatively low velocity (2-8 metres per second). This mode of conveying results in minimal wear on pipelines and bends, promoting minimum maintenance and long life on system components. Efficient use of compressed air also generates low power consumption and reduced operating costs.

Medium Phase solutions have the capability to convey a wider range of materials with variable particle sizes using lower positive air pressures. This form of conveying is ideal for continuous, accurate conveying or for injecting controlled amounts of material directly into a process.

Lean Phase solutions use either vacuum or positive air pressure and are low cost, quick and simple to install and dismantle. This form of conveying has the capacity to move materials at high velocities (15-30 metres per second) and is used predominately within the food and pharmaceutical sectors.

Within the metals market even this level of technology has not been consistently delivered by the main pneumatic conveying suppliers. Problems with capacity, valving, and air usage have often led to poor performance at smelter sites.

Clyde Materials Handling has developed a series of reliable solutions to utilise particularly Dense Phase Pneumatic Conveying technologies to move material in an energy efficient and environmentally supportive manner, with equipment delivering high availability and reliability with consistent air usage.

A Clyde Dense Phase Pneumatic conveying system is shown in Figure 1, which consists of a pressure vessel and control valves, used to manage the flow of material fed into, and out of, the conveying vessel. Clyde’s Dense Phase systems can convey materials over significant distances and at high tonnage rates. Distances and tonages are material dependant but Clyde have experience in moving materials over a 1000m and at tonage rates in excess of 250 tonnes per hour which covers most applications in the non ferrous environment.
Pneumatic Injection Overview

Pneumatic injection of process materials to pyrometallurgical vessels has been in use for 40 years using a series of devises to deliver the material initially above process material but more recently to inject the material into metal or slag layers. The initial work delivering materials to the top of vessels was less exacting on the delivery quality but the more recent sub surface delivery requires great accurac and stability as the whole process will lose its stability when the material stops flowing or when a vessel exhausts, or simply due to minute to minute swings.

Clyde first entered this market in Blast Furnace injection where others had failed as the stability of delivery adversely affected the Blast Furnace performance and the concept had been shellved. Clyde Materials Handling developed alongside Corus then British Steel to develop a system which would give the stability needed and commissioned its first system successfully over 20 years ago.

Many of the original systems utilised a conventional blow tank arrangement, where the material discharge from the vessel is controlled by a variable aperture valve at the outlet from the vessel and by controlling the pressure within the vessel relative to the pressure in the pipeline. A closed loop loss-in-weight control was used for controlling the valve position and dispensing vessel pressure. This original configuration is shown in Figure 2.
Investigation of the weight trend for the dispensing vessel showed that over an extended period this method of control appeared accurate, however, closer inspection of the weight trend showed that over a shorter period, from minute-to-minute, the injection rate fluctuated dramatically. This is shown in Figure 3.

Figure 2 - Showing the principle of operation of the original conventional blow tank type injection system

Figure 3 - Showing the vessel weight trend and the variations in injection rate observed minute-to-minute
A solution to the problem was developed by removing the existing discharge valve and pressure control and installing a Rotofeed feeder at the outlet from each vessel. This arrangement is shown in Figure 4.

![Figure 4 - Showing the modification to the original system to improve injection rate](image)

Following the modification of the system in this way, the accuracy was much improved to better than +/-1% of the setpoint. More significantly, the material feed was consistent and without fluctuations, allowing high levels of coke replacement in Blast Furnaces.

Since this time Clyde Materials Handling have seen this same process instability with most of the pneumatic injection systems commercially available and have developed the Rotofeed, Rotoscrew injection system to handle more materials and for injection to a wider range of processes. The system is used from coal to copper concentrate, from 100 kg/hr to 250 tonnes per hour, up to 150m delivery to process and with back pressures up to 40 bar so far.

Clyde Material Handling’s pneumatic injection systems utilise two types of volumetric feeder to accurately control the feed of material into an injection pipeline. These are the Rotofeed and RotoScrew technologies, and the choice of feeder type is dependent on the characteristics of the material to be handled. The Rotofeed is generally used for finer, granular and powdered materials which cannot be accurately handled with a screw such as pulverised coal and copper concentrate, whilst the RotoScrew is particularly suited to coarser lump materials, particularly abrasive of cohesive materials like Zinc Powder or Electronic scrap.

In both cases, the feeder speed, and hence injection rate, is controlled by means of a variable frequency drive (VFD) in conjunction with a standard AC induction motor. The feeder gives a constant volume of material for each revolution and this predictability enables an injection accuracy of better than +/-1% of the setpoint. It also ensures that the material feed is even and does not vary from minute to minute.
The Rotofeed is shown in Figure 5 and consists of a rotor mounted on a vertical shaft within a casing. Material passes from the dispensing vessel into the feeder. As the feeder rotates the material is transferred to the outlet where it is entrained in the injection gas flow and passes through the pipeline to the process.

![Figure 5 – Rotofeed injection system](image)

The RotoScrew is shown in Figure 6 and comprises a helical screw feeder mounted within a pressure vessel. Material is transferred from the dispensing vessel and is discharged into the pipeline where it is entrained in the injection gas flow and transported to the process.

![Figure 6 - RotoScrew injection system](image)
Dome Valve

The valves used in Pneumatic conveying have been its downfall. Many pyrometallurgical process users report the valve as its number one issue with handling. Many valves have a short life hours or days. Clyde’s Pneumatic Conveying and Pneumatic Injection solutions all use a valve known as Dome Valves. The Dome Valve was originally designed and patented by Clyde in 1973 and has been used in a wide variety of materials handling applications; the valve has become an industry standard. The valve configuration, shown in Figure 7, comprises of a dome shaped closure mounted on half shafts that is moved through 90 degrees by means of a pneumatic cylinder. A rubber seal mounted at the entry to the valve is inflated by compressed air when the valve is in the closed position in order to obtain a gas tight closure. When the valve is opened, the seal is first deflated, causing it to retract away from the dome; the dome then moves to the open position. In this way there is no direct contact between the dome and seal while the dome is moving, hence the associated abrasive wear of the seal is avoided.

A seal life of typically 500,000 operating cycles, equivalent to more than 2 years operation, is achieved. This valve is seen as the industry state of the art and is used by many of Users in tough environments as their chosen standard.

Customer Desire

Customers using Pneumatic Handling in Pyrometallurgical environment have been poorly supported in the past. They need suppliers who listen to their needs, and understand their environment and materials. Users are seeking to control costs and availability and running costs of the systems is critical to them. Appropriate delivery to the process itself giving control back to the User is the goal. The User simply wants to adjust the rate not be skilled in Pneumatic handling.
These desires have led Clyde to focus its efforts in creating solutions that meet the exact needs of their customers in the metals market. Clyde Materials Handling embarks on a customer-centric process, as depicted in Figure 8.

![Figure 8 – Clyde Materials Handling Customer-Centric Process](image)

At the first point of customer contact, Clyde Materials Handling seeks to understand the issues and problems the customer is currently facing, how these issues are affecting the performance of their operations and, at the same time, tries to identify what the customer believes is required to alleviate these problems.

The Clyde Research, Development and Testing facility plays an integral role in the formation of a solution. When Clyde ascertains what type of a material the customer requires to be handled, it can call upon a material characterisation database that contains thousands of records, so that the system can quickly cross-reference previously handled materials and instantaneously identify a pneumatic conveying or injection solution which has been used to handle material with the same characteristics.

If the material has never been tested before, Clyde conducts a series of simple tests to measure the bulk density, particle size, particle shape and fluidity of the material. The Clyde Research, Development and Testing Facility is equipped with an infrastructure to replicate exact on-site environments. This process concludes with Clyde Materials Handling recommending a tested, proven solution which can handle the customers’ material.

From these material tests, Clyde Materials Handling discusses the testing and research analysis and outcomes with the customer, where requirements are explored in greater detail. Following these discussions, Clyde submits a formal proposal to the customers’ exact needs. The conveying velocity is minimized to reduce friction factors and therefore wear to a minimum, reliable long life components are developed or sourced to give
long inter maintenance periods, productivity is the key driver. Such systems provide appropriate performance for the metals market.

Clyde discusses the proposal in greater detail with the customer, in terms of investment figures, delivery date, project timescales and deadlines before agreeing and proceeding with the order for a Clyde solution.

No matter where an organisation is located in the world, Clyde Materials Handling has a global network in place to engineer, project manage and deliver a solution. As preferred by the customer, Clyde Materials Handling will supply equipment only or undertake the management of complete solutions with principal contractor responsibility, from concept to completion with full control built in at all key stages.

Clyde Materials Handling insist on commissioning by its own engineers and has a team of commissioning engineers who work with project teams on-site to complete installation and start up systems. Through the implementation of the customer-focused approach, Clyde guarantees rapid start-up, which enables the customer to realise maximum productivity, with minimal disruption.

Clyde Materials Handling endeavours to develop solutions that work at the first time of asking. Clyde’s customer-focused approach ensures that customer requirements are understood and explored in great depth. Materials and proposed solutions are tested extensively, so that Clyde can assure the first time, successful and value added implementation and start-up of a conveying or injection system.

Solutions for the Non-Ferrous Metals Market

Clyde Materials Handling has developed an array of solutions for the non-ferrous metals market. Examples of some of these solutions include:

- Convey and inject metal concentrates, ores, mattes, white metal, silica, coal, dusts, reverts, other additives, alumina, fluorides, cryolite and recycled scraps including aluminium process arisings and electronic materials – the key materials used in the production of non-ferrous metals
- Provide solutions for copper, nickel, zinc, tin, lead, aluminium, and platinum producers
- Provide solutions, regardless of process employed, including Flash, Kivetc, Vanuykov, TSL, Mitsubishi, bath converter, Anode furnaces, aluminium pot lines, carbon houses
- Submerged stable pulseless lance injection for bath processes
- Stable and Pulseless burner feed for flash type processes
- Stable and pulseless tuyere injection to fumers
- Stable and pulseless tuyere injection to Pierce Smith and Anode Furnaces
- Transport an array of aluminium refining materials
The successful implementation of Clyde’s pneumatic conveying and injection systems has generated the following, typical returns for organisations operating in the non-ferrous metals market:

- 99.5% availability for conveying systems
- High Energy Efficiency Pneumatic Conveying
- Greater accuracy of material feed into copper smelting processes
- 50% increase in bath smelter handling capacity per day by offering process stability
- Improved efficiency of smelting process – generating millions of dollars in additional revenue
- 3% increase in overall bath smelter system availability
- 6% increase in injection system availability on bath smelters
- Dramatic reduction in system downtime - 15 days of additional production generated
- Recovery of high value materials from process and recycled materials added to process through environmentally sound injection

**Case Study – Copper Concentrate Conveying and Injection for Codelco**

Prior to working with Clyde Materials Handling, Codelco Norte operated a blow tank arrangement to pressurise and fluidise dry copper concentrate for transportation through pipelines routed to a converter.

However, this process was not able to generate high levels of production due to the relatively inaccurate distribution of concentrate within the smelter. Codelco were also experiencing difficulties with system availability and reliability, which was impacting on the production rate and overall effectiveness of the Codelco Norte operation.

Central to this inefficiency was the life expectancy of the injection lance, used to distribute the copper concentrate within the converter. Utilising the blow tank solution, injection lances were being replaced once every 4 days. This was having a detrimental effect on productivity but it was also generating mounting maintenance costs. Therefore, Codelco were seeking to deploy a solution that could increase productivity, performance, system reliability and availability, whilst reducing the maintenance costs currently being absorbed by the existing application.

In an effort to resolve the key issues facing the Codelco Norte Division, Clyde Materials Handling proposed to deploy a pneumatic transport and injection solution, which would support the objectives set by Codelco. The Clyde solution would seek out to increase productivity, performance, system reliability, availability and help to reduce maintenance costs.
Clyde set about transforming the existing blow tank process into an efficient and effective pneumatic process utilising their Rotofeed application. As Figure 9 shows, two Tandem Rotofeed’s were connected to a single injection pipeline, with the requirement to reach average rates of 120tph, with a design rate of 150 tph, into the liquid bath of their converter, with 100% redundancy.

Figure 9 – Layout of Clyde Transport and Injection System at Codelco Norte

In order to drive up accuracy rates of better than +/-1%, each dispensing vessel is mounted on load cells – this weight signal is used on a closed loop basis to control the feeder speed, which helps to compensate for variations in material bulk density.

Since material is introduced into the pneumatic conveying lines continuously, rather than in batches, as with a conventional feeding system, there is much less chance of plugging the conveying lines. The Rotofeed also has the capability to adjust injection rates in real-time and is responsive to the needs of the system, which enables more precise control of the injection rate at Codelco.

The Rotofeed application also ensures that there is a continual feed of concentrate into the smelter, helping Codelco to drive up the productivity and performance of their converter.

The transport airflow of the system is controlled to achieve low velocity, dense phase pneumatic conveying, which ensures that the power consumption of the injection air is low, as well as reducing the injection pipeline wear.

Material is fed to individual injection lances, see Figure 10, via a 6-way flow splitter. Clyde and Codelco worked tirelessly to resolve the alarmingly short life expectancy of existing lances. These efforts proved to be hugely beneficial as the unique lances that were produced by both organisations, increased lance lifetime from 4 days to 30 days,
which has had a dramatic impact on system availability, reliability and ultimately, cost savings in maintenance. The lance can also be replaced in 10 minutes.

The Clyde solution was commissioned during October 2002 and since its installation, it has added significant benefits to the operations of Codelco Norte.

Within 30 minutes of original start-up, the system was able to achieve normal production injection rates of 100-120 tph.

In the first year of operation, smelter throughput increased 16%, with an average daily rate of throughput rising from 2200 tpd (tonne per day) to 2550 tpd. This has been accomplished partly due to the more stable process conditions and improved distribution along the furnace achieved with the accurate injection rate control provided by Clyde’s Rotofeed’s.

In a separate testing trial, the system demonstrated its ability to operate at a throughput of 3000 tpd.

In summary, the Clyde pneumatic conveying and injection system has generated the following benefits:

- 16% increase in smelter throughput
- 15 days of more production than the previous systems, achieving higher system availability, reliability and revenue
- Better than +/-1% injection accuracy rate
- Increased life expectancy of injection lance – from 4 days to 30 days, creating significant cost savings and improving process performance
- Achieved normal production performance within 30 minutes of process start-up
- Increased system availability
- Substantial reductions in refractory wear
- Substantial reductions in maintenance costs
- Important pyrometallurgical process benefits
Zinc and Lead Industry Solutions

More recently Clyde have been providing lance coal feed to TSL furnaces giving the operator tight control of the flow and smooth operation giving viscosity control in the slag layer. Clyde equipment is in use in the zinc industry in the adapted Korea Zinc TSL.

The QSL furnace is a robust and flexible furnace for the smelting of mixed materials. It uses a pulverised coal feed to control the oxidation and reduction stages of the process. The Clyde injection system offers the process improved control irrespective of metal level in the furnace.

Zinc Fuming from slags utilises pulverised coal injection to control the bath to control the viscosity. Control stability is critical in this process to ensure that Foaming is avoided and that fuming is maintained under control. Clyde have replaced an existing system at Zinifex Port Pirie to bring the furnaces under control each furnace has 30 points of injection and overall coal injection stability of +/-1% on a minute by minute basis. The system it replaced had good long term stability around +/-3% over an hour but over a five minute period was +/-30%.

![Figure 11 – Layout of Clyde Injection System at Zinifex Port Pirie](image)

Over the last 18 months we have been developing systems for the reliable and efficient conveying of Zinc Calcine and Zinc Powder. These materials are very different and not easily conveyed.
Zinc Calcine is very abrasive and leads to high damage in mechanical systems and short pipeline life in most pneumatic conveying systems. Clyde have developed a system which handles the material at very low velocities in the pipeline reducing the pipeline wear to commercially viable levels. This system is now developed for conveying between the roaster and silo storage silo storage and day bins and also for measured delivery to reactors.

Zinc Powder is not abrasive but has a tendency to cohere to the pipe and valves. Conveying this material is usually confined to short distances and high air rates. Clyde has developed a technique which delivers longer distances and lower energy requirements. For example a Clyde system can handle Zinc Powder over 700m at 10 tonnes per hour.

Clyde have provided solutions for injection of Lead Dross and Lead Recycle materials into the Imperial Smelting Process.

Clyde have solutions for Zinc and Lead Refineries including conveying and injection of reductant and pulverised coal supply, soda ash, lead scrap, lead dross, zinc calcine, zinc powder.

**Conclusion**

As operators in the metals markets have been seeking to react to the significant demand placed on their industry through global growth, it is clear that their production processes have needed to be operating continually more efficiently to ensure consistent levels of productivity are achieved.

Pneumatic Handling of materials are clearly an environmentally useful and simple way to deliver the materials where they are needed in increasingly complicated sites. Unfortunately many attempts have failed due to poor valves, high wear rates, poor stability, and unrealistic claims from suppliers. Experience and focused solutions are clearly desired by users.

Clyde Materials Handling has begun to demonstrate that pneumatic conveying and injection technologies can be successful where they are well specified and partnership in definition and execution of the projects is delivered.

Clyde Materials Handling have shown in these markets that reliable and high performing systems can be developed and Users can obtain the benefits they are seeking. Clyde have developed solutions that can transport the raw materials used in metals production from point-to-point or inject directly into process, which has helped to achieve high system reliability, availability and operational performance.
Recommendations to the Industry

The recommendation of this paper is that Users must:

- Clearly define their requirements
- Insist that Suppliers interact with them
- Demand long life components
- Demand high availability
- Focus on process applicable stability

Acknowledgements and References

The authors would like to thank the management of Clyde Materials Handling Ltd for permission to publish this paper and to use details from a series of other papers that the company has published in the past. The writers can be contacted directly or via the company website with any questions or clarifications.

Codelco Study is an extract taken from Chisholm 2005 Ultra Dense Phase Injection of Copper Concentrate to CT Converters

Other useful papers

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