FLOVEYOR

White Paper

White Paper

Optimising Lithium Hydroxide Monohydrate Powder Handling

What process engineers should know about conveying battery minerals

Content

White Paper

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01 Introduction

Understanding how to optimise powder handling for battery minerals conveying systems is key to designing and operating high-yield midstream processing operations.

The growth potential for the battery minerals industry is staggering. A multibillion-dollar battery minerals processing industry is emerging, with investments already being made in battery-grade lithium hydroxide and nickel sulphate plants around the world. Developing midstream battery minerals process operations in local markets provides strategic and economic benefits, including increased access to raw materials, lower transportation costs, improved waste management, and diversification of midstream supply.[1] To achieve this, each country needs to develop midstream processing operations.

The immediate problem is global conversion capacities are expected to be insufficient to process growing upstream supply and satisfy downstream demand. Lithium production has already been flagged as a key constraint for battery manufacturers. Having midstream processing occur locally provides an alternative route to market for miners and explorers, especially as slow supply chains continue to dog the global economy. Modelling designs for manufacturing and mining applications should be a top priority to address the missing conversion capacity in the current market.

However, midstream processing of these strategic minerals requires a new approach from miners. Conveying systems have been around since the early days of mining, but conventional equipment struggles to meet the processing requirements of the battery mineral industry. Although every step in the battery value chain has challenges, the contamination requirements in the parts-per-billion (ppb) range demand each processing step is optimised to achieve optimal value from these new ventures.

Understanding how to optimise powder handling for battery minerals conveying systems is key to designing and operating high-yield midstream processing operations. This white paper is designed to help process engineers and operations managers understand materials handling challenges with battery minerals in general, but specifically lithium hydroxide monohydrate ($LiOH.H_20$). It provides analysis of the suitability of common conveyors used in mining and recommendations for how to select an optimal conveying system for the processing of battery minerals.

1. *Western Australia: A Global Battery and Critical Minerals Hub*, Department of Jobs, Tourism, Science and Innovation, June 2022

02 Market drivers for battery minerals processing

Rising demand for electric vehicle batteries

Global demand for lithium is surging on the back of electric vehicle (EV) sales. Car companies around the world are rapidly accelerating plans to transition to EVs, driven by consumer demand and government mandates. EVs accounted for about 9% of the global car market in 2021, with predictions for EV sales reaching almost 40% of vehicle sales annually by 2030.[2]

EV batteries require critical minerals

Battery-grade lithium carbonate can be used to make cathode material for lithium ion batteries, but most contaminants must be removed for the material to be considered battery grade. While lithium carbonate is a key component of electric batteries used for cars, $LiOH.H_20$ is necessary for some types of cathodes.

Lithium hydroxide monohydrate is the future of lithium batteries

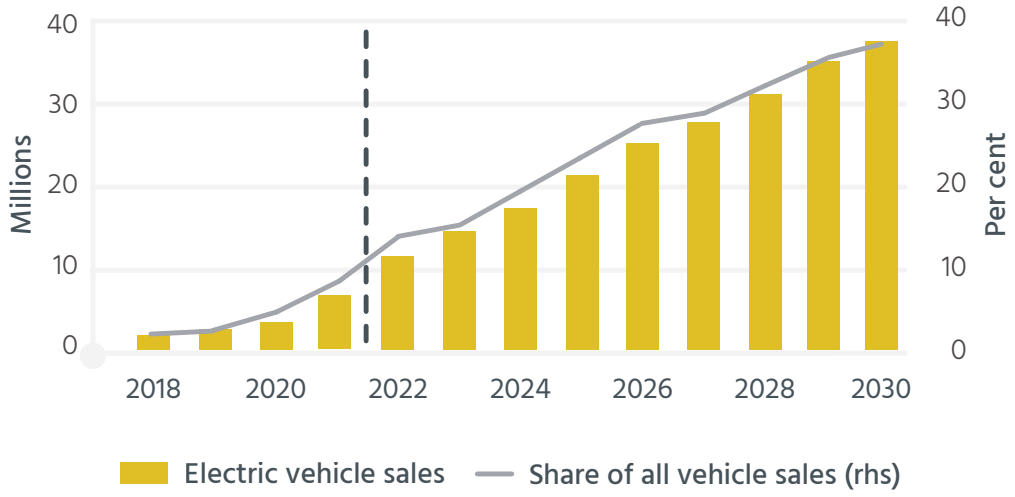
$LiOH.H_20$ decomposes at a lower temperature, which makes battery cathodes more sustainable. The automotive battery manufacturing industry prefers $LiOH.H_20$ because it increases the performance of the battery by providing better power density, larger power capacity and extended life cycles, and it contributes to improved safety features.

Lithium production on the rise but gaps in supply remain

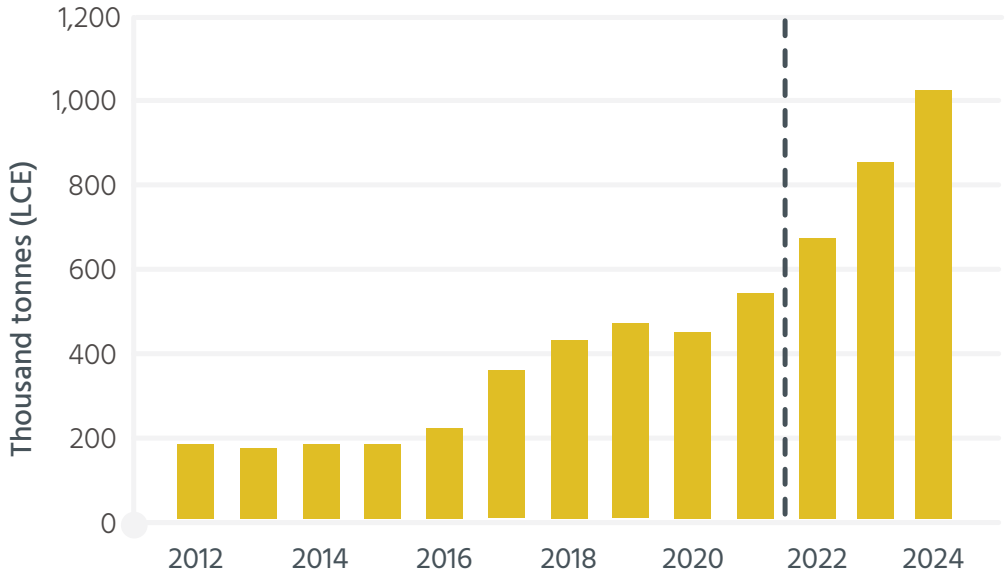
Global output of lithium is forecast to grow by 80% between 2021 and 2024. Australia is currently the biggest exporter in the world, producing 46% of the world's lithium supply, followed by Chile and Argentina. With a global push to reduce dependency on Chinese and Russian supply chains – and shortages of spodumene, $LiOH.H_2O$ and lithium carbonate – investment in localised midstream processing operations for battery minerals is surging.[3] As world economies turn to EV production opportunities, it's crucial to optimise $LiOH.H_2O$ powder handling to maximise the full potential of the battery market.

2. *Resources and Energy Quarterly,* Department of Industry, Science and Resources, September 2022

3. *Resources and Energy Quarterly,* Department of Industry, Science and Resources, September 2022



Source: Wood Mackenzie (2022), Department of Inustry, Science and Resources (2022); IEA (2022).



Source: Department of Industry, Science and Resources (2022); Wood Mackenzie (2022).

03 Complexities of conveying lithium hydroxide

Processing $LiOH.H_20$ requires an understanding of the distinct characteristics of the synthetic chemical compound to ensure it maintains battery-grade quality.

Easily degraded

$LiOH.H_20$ has a crystalline structure, which makes it highly susceptible to degradation. On the Mohs scale of mineral hardness, Lithium comes in at 0.6, which is even lower than talc. It's essential to handle $LiOH.H_20$ as gently as possible throughout processing, and without impacting the particle size distribution.

Susceptible to water

Water presents several problems for $LiOH.H_20$ materials handling. It's hygroscopic and water soluble. It easily absorbs moisture, which leads to lumps that can be difficult to manage in the process line.

Reacts with carbon dioxide

LiOH reacts with carbon dioxide (CO_2) in the air to form lithium carbonate (Li_2CO_3) and water. Due to its high absorption capacity for carbon dioxide – it will absorb its weight in CO_2 – LiOH is used in the space shuttle to protect the crew from CO_2 poisoning. However useful LiOH is to NASA, Li_2CO_3 is not a desirable product in the battery mineral process.

It's essential no exposure occurs at any point during processing because the chemical reaction is irreversible and Li_2CO_3 is considered a contaminant.

To mitigate contamination risks, packaging lines are often located inside a clean room environment to maintain product quality. Areas of possible exposure include:

- Transferring materials from the dryer to storage
- Packing at refining phase
- Sealing materials in packages for transport
- Decanting the bags and moving to the mixers and reactors at the battery plants.

Highly corrosive

$LiOH.H_20$ is a highly corrosive, toxic chemical. With a strong alkaline pH of ~12 it is essential to avoid contact with strong acids and amphoteric metals like copper, tin, aluminium, lead, and zinc.

Safety concerns

$LiOH.H_20$ is an odourless chemical. It is corrosive to the eyes, skin, and respiratory tract. It should not be ingested. Exposure will cause severe burns to eyes, the mouth and throat, gastrointestinal tissue, and the respiratory system. $LiOH.H_20$ dust is considered toxic to humans and severe inhalation overexposure may be fatal.

It's safe practice to carry Diphoterine® solution to neutralise any exposure to $LiOH.H_20$ while in processing vicinity.

04 Contamination problems

Battery-grade $LiOH.H_20$ requires a purity minimum 56.5% lithium oxide (Li_20). The required characteristics of this compound are low levels of impurities and a specific particle size distribution compared to technical-grade $LiOH.H_20$.

Avoiding contamination during processing is a major concern for battery minerals processing. The requirements to limit both ferrous and non-ferrous contamination are extremely strict. $LiOH.H_20$ is especially challenging for the resource industry due to the way it reacts to CO_2. This kind of contamination is an extremely costly problem for the producer. Sensitivity to air and water means conveying solutions for $LiOH.H_20$ are limited. It's simply impractical to use pneumatic conveyors for these applications for several reasons:

1. High likelihood of product contamination
2. High energy costs when blanketing with nitrogen (N_2)
3. Extremely difficult to engineer and operate pneumatic conveyors so they achieve high throughputs, no CO_2 exposure, and no moisture or air impurities.

Metal contamination

Ferrous and non-ferrous contamination is a serious materials handling challenge in the battery minerals process. While some elements are easy to completely avoid any contact with the processed $LiOH.H_20$, other common elements such as Iron (Fe), Chromium (Cr) and Nickel (Ni) found in stainless steel can be problematic if wear particles infiltrate the product.

Even the slightest magnetic contaminant has a massive impact on the battery. For example, in the event a magnetic particle (iron) contaminates a battery cell, it may form dentrites which risk piercing the separator, shorting the cell, and causing a fire.

While inline magnetic separation is essential to maintaining battery-grade $LiOH.H_20$, it is critical to design a system that ensures the product is handled with the least possible risks for impurities to enter the product stream.

Other contamination

Other contaminants, including plastic, are not as critical to the finished product as magnetic contamination or CO_2. However, some polymers may have silica or aluminium additives, which are strictly prohibited as these can leave conductive particles. Polymer wear surfaces and engineered coatings are beneficial where possible.

Clean room environment

Cleanliness is essential to prevent contamination during $LiOH.H_20$ processing, particularly from the dryer to the bagging and packaging lines. This end of the process is often conducted within the confines of a clean room, with a controlled environment and restricted access.

During the design phase it is highly beneficial to integrate a conveying system that will maintain the integrity of the $LiOH.H_20$ out of the dryer and allow the process to be consolidated into a small-area clean room operation.

This results in considerable CAPEX savings, especially when you consider a clean room can be used for other difficult or dangerous materials, like sodium sulphate.

Dry Crystalline $LiOH.H_2O$ quick facts

Bulk density
800-1000 kg/m^3

Moisture content
less than 0.1%

Temperature
atmospheric to a maximum
of 60 degrees centigrade

Particle size distribution
(may vary depending on supplier)
P50: 400-600 micron
P100: 2000 micron

Angle of repose
30-45 degrees

05 Current approach to powder handling in the mining industry

The mining industry already has sophisticated minerals processing systems in place. Here are the common conveying systems used for mining and chemical processing and assessment of how well they are suited to battery mineral applications.

Pneumatic conveying

Pneumatic conveyors come in two common designs: Lean/Dilute Phase and Dense Phase. Both are energy intensive due to the use of pressure or blowers/fans.

Lean/Dilute Phase

Not suitable for battery minerals conveying for several reasons:

» High velocity causes excess product degradation.

» Materials are exposed to air.

» Filtration and separation requirements are unworkable for the fines which can be up to 5-10 micron.

Dense Phase

Somewhat suitable for gentle, low-velocity transfer of battery minerals because the material is moved in slugs. While offering better options for battery minerals conveying, dense phase pneumatic conveyors are still problematic, in part due to:

» High costs
  - High-pressure vessels
  - Large blower and pipe diameter requirements to achieve the TPH with lower velocity conveying
  - Very high CAPEX and OPEX costs for oxygen- and moisture-free air supply (N_2 blanketing)
  - High electricity OPEX costs.

» Highly fluidised and fine powders become captured in the dust reclaim.
  - Incurs lost materials cost.
  - Material contamination when exposed to filter media often requires disposal and cannot be reintroduced to product stream.
  - Filter media may bind and require regular maintenance when used for fine powders that are hygroscopic.

» Extremely difficult to clear blockages or failures in the system.

» Very complex system to commission and install correctly.

» Environmental, social and governance (ESG) considerations, including CO_2 pollution due to the pneumatic air requirements and associated power consumption.

» Ongoing abrasion of pipe walls and elbows.

Bucket elevators

Bucket elevators are widely used in the mining industry and are especially good for elevating materials vertically. They can be fully enclosed and when used in the right applications are known for reliability, high availability, and gentle materials handling. Plastic buckets can be used to avoid ferrous contamination.

Bucket elevators

Somewhat suitable for battery mineral conveying but difficult to clean and known to leave residue, spillage, and product contamination. Specific issues for battery mineral handling include:

- Difficult to bring back online after a breakdown, with days offline.
- Work, health, and safety (WHS) concerns as operators are exposed to a large area of the machine internals, along with a lot of dust and residue.
- Not ideal for fine powders, especially highly fluid ones.
  - Significant residue and spillage within conveyor housing, particularly in the long horizontal sections and at the base of the vertical elevation.
  - Lost product cost incurred due to spillage.
- Better suited to larger particles. Lower availability and higher equipment breakdown rates are experienced with powders.
- Difficult to seal from atmospheric exposure.
  - Requires additional CAPEX investment for modifications.
  - Susceptible to more leaks, given the sheer size and number of joints.
  - Wastes more inert gas.
- Product residue tends to ingress into the chain/belt mechanism, causing breakdowns.
- Plastic buckets will break when internal residue isn't removed and is allowed to harden.
- Many moving parts inside the machine each add to overall contamination risk as wear particles are likely to reach the product.
- Difficult to use over complex routes.
- Requires additional height and gravity chutes to feed into downstream equipment, adding substantial infrastructure requirements.

Tubular drag conveyors (TDC)

Tubular drag conveyors are typically available in two styles:

1. **Chain or link variant** - found in many heavy chemical and industrial applications
2. **Lighter gauge cable variant** - highly popular in many food, manufacturing, and chemical industries.

Both variants work on a simple principle of moulded flights/discs of the conveying element dragging the material at low speed through a series of enclosed tubes and long-sweep radius bends. This method of conveying is very gentle, flexible, and able to span a myriad of complex routes. These systems are relatively easy to purge with inert gases and are often incredibly reliable when specified correctly.

Chain/Link drag conveyors

Not suitable for battery minerals conveying due to iron contamination:

» The chain linking the flights or discs for conveying are designed as a universal joint, often made from Stainless Steel 316 for its strength and reliability. This mechanism is not easily able to be replaced with an engineered polymer.

» In clean and hygienic applications such as food, and particularly battery minerals, the chain cannot be lubricated as with less sophisticated operations.

» As a result, the chain exhibits friction at all points from direct contact, most noticeably at start-up - and exacerbated in applications where chain lubricants cannot be used.

» This constant stainless on stainless friction without lubrication causes excessive product contamination, not acceptable to the food industry, let alone at the sensitivity levels of the battery minerals industry.

Cable drag conveyors

Suitable for battery minerals conveying when supplied from OEMs experienced with hygienic applications.

Benefits:

» Gentle handling will not degrade the crystalline structure of $LiOH.H_20$

» Sealed from atmospheric exposure and can be purged with inert gases

» Total batch transfers that cause no spillage or product loss

» Able to convey over long, multi-plane and complex routes

» Quick maintenance turnaround, with very limited exposure to the product. Due to its design, the TDC retains very little product.

» Minimal number of moving parts contributes to high availability rates

» Small structural footprint

» Extremely low ESG impact of CO_2 pollution, especially compared to pneumatic conveyors.

Considerations:

» Suitable for low to medium throughputs only

» High throughput applications result in lower availability. The system is limited to the breaking strength of the conveying cable which is reduced with long vertical inclines and multiple radius bends.

» High throughput applications are better suited to aero-mechanical conveyors (AMCs). Chain TDCs are traditionally popular in large diameter, high-throughput applications but are not ideal for battery minerals due to the above.

» Look for an OEM who offers a polymer-coated conveying cable to reduce ferrous contact with the $LiOH.H_2O$.

Aero-mechanical conveyors

The AMC is known for high reliability, high availability and little or no contamination risk due to its fully enclosed system. It is one of the easiest technologies to integrate directly with other interfaces, upstream/downstream equipment, and process line technology.

Aero-mechanical conveyors

Extremely suitable for battery minerals conveying for a variety of reasons:

- Gentle handling will not degrade the crystalline structure of $LiOH.H_2O$
- Very high throughputs for the equipment and drive sizes
- Sealed from atmospheric exposure and can be purged with inert gases
- Total batch transfers that cause no spillage or product loss
- Quick maintenance turnaround, with very limited exposure to the product. Due to its design, the AMC retains very little product after air-purge cleaning.
- Minimal number of moving parts contributes to high availability rates
- Small structural footprint
- Extremely low ESG impact of CO_2 pollution, especially compared to pneumatic conveyors.

Considerations:

- Shorter length limitations when compared to other technologies, often requiring interlinked, piggy-backed conveyors to meet long and complex routes.
- Not suited to being run dry for extended periods or with very low volumes of material within the conveyor.

General Advice for all Powder Systems

All the above powder handling systems are susceptible to performance issues when the materials being conveyed are out of specification.

It is important to plan for redundancy when chemical impurities and upstream problems impact the quality of the material out of the dryer. Sticky, moist, or lumpy materials often result in reduced availability, especially during the commissioning and initial ramp-up period.

How the AMC method of conveying works?

A high-efficiency motor drives an internally circulating rope assembly in the conveying tubes, at high speed.

A low-pressure air pocket is created behind each disc on the rope assembly.

Battery minerals are introduced into the feed housing and accelerated into the conveying tubes by the rope assembly.

A fluidising motion suspends battery minerals in the air pockets and the minerals are drawn rapidly but gently to the discharge point, with minimal contact.

Download our Conveying Technologies Comparison Poster

06 Selecting an advanced battery minerals conveying system

Given these challenges, what should process engineers focus on when they're considering conveying requirements for handling the finished powders? Clearly, the AMC method of conveying is the most suitable for battery minerals, not only because other conveying systems have numerous drawbacks, but because the way the AMC functions makes it ideal for handling highly sensitive powders.

Requirements for hygienic design in AMC conveyors

The machinery used in battery minerals materials handling requires extra consideration to eliminate contamination risk and improve safety. This applies to all parts of the conveyor including conveying elements and contact surfaces, guarding and housings, drive arrangements, infeed and discharge transitions, dust filtration and air handling. Knowing the types of materials, welding procedures, and surface finishing used during construction is essential. Make sure your AMC manufacturer offers these additional hygienic features.

Special handling considerations for lithium hydroxide powders

- The "razor blade" structure of $LiOH.H_20$ crystalline makes it aggressive against metals at process pinch points and pipe bends. Conveyors must be made of material that can withstand highly abrasive materials but does not contribute to material contamination.
- AMC conveyors are designed for minimal contact with battery minerals. Where materials are being exposed, look for smooth surfaces and battery-grade compliant coatings.
- Where possible, conveyors should be supplied with polymer contact surfaces for the mitigation of ferrous contamination. Polymers used in the manufacturing of battery minerals conveyors must not use silica or aluminium materials as they have conductive properties.
- Contact surfaces should not have magnetic or conductive particles, something present in all metals.
- There should be a strong ability to integrate inflow magnetic separation at the discharge of the conveyors.

Plant design considerations for lithium hydroxide powders

Manufacturers for battery minerals conveying systems must have experience designing and engineering conveying systems and process line technology for hygienic materials. This experience is often found in manufacturers who specialise in food, beverage and pharmaceuticals conveying equipment.

Small footprint – Dual conveying lines allow for total redundancy to continue operation in the event of an unforeseen downtime event. This also provides the ability to switch to a second conveying process line during maintenance and cleaning.

Critical elements to look for in battery minerals machinery

- High levels of availability
- High levels of reliability
- Total batch transfers
- Equipment durability and longevity, including low maintenance requirements
- Process line technology to complement conveyor machinery, for example to control lumps and surge feeding
- Ability to integrate easily into new or existing process lines
- High levels of cleanability using dry clean methods like inert gas purging, to avoid contamination
- Longevity in the marketplace.

Bulk material delivery methods

$LiOH.H_20$ can be provided to battery cell manufacturers in multiple delivery methods. Look for a powder handling partner who provides process line technology that integrates easily with these needs.

Packages include:

- $LiOH.H_20$ is packed and shipped in large, flexible bulk bags (FIBCs) that run between 400 and 1200 kg. The bags are double or triple sealed, with a maximum shelf life of six months.
- Smaller bags of 22.7 kg can be supplied, with 40 bags on a pallet.
- $LiOH.H_20$ is also available in 100 kg polyethylene-lined fibre drums.

Plant operation considerations for lithium hydroxide powders

Maintenance and support

One major benefit of AMC conveyors is the minimal number of moving parts. The only part that needs replacing is the assembly rope, and they can last for thousands of hours of operation when properly maintained.

Operability

Look for machinery and equipment that is easily accessible by operators for maintenance and cleaning.

- Ability to rapidly bring back online after maintenance tasks or unplanned downtime
- Rapid component changeover with minimal downtime
- Ability for in-house maintenance teams to carry out all servicing activities
- Clean-in-place (CIP) capability.

07 Floveyor with FloDisc for battery minerals processing

Floveyor's proprietary FloDisc technology results in the lowest possible friction between the material and the inner pipe surface. It mitigates risk of contamination better than any other materials handling solution for hazardous or environmentally sensitive materials. No other AMC manufacturer offers this benefit. Watch a short video about FloDisc technology.

Continually evolving the AMC method

Floveyor was the first company to engineer and patent the aero-mechanical conveying method. Since 1958, our engineers have continually improved our method to outperform every other powder handling technology.

Floveyor has decades of experience managing powder handling in industries who have mastered hygienic materials handling with high throughputs. An ongoing culture of research and development provides guidance on how the battery minerals industry can safely and efficiently handle materials with rigorous hygiene requirements.

Advancements for battery minerals conveying

Floveyors used for battery minerals processing can be built using stainless steel with tungsten and carbon-coated housing, which is the hardest coating available. The housings are completely sealed and can be fitted with nozzles for inert gas purging. In addition, the rope assembly is available with a polymer coating to limit metal-on-metal contact, which reduces ferrous contamination.

Experienced with hygienic powder handling

More than 6,000 Floveyor machines have been installed worldwide with a focus on industries like food and beverage and pharmaceutical and chemical processing. These industries benefit from the unique features of Floveyor's AMC method of conveying for safe, hygienic, and dust- and contamination-free powder handling.

Floveyor process line technology for battery minerals

In addition, Floveyor manufactures process line technology for complete conveying systems. This ensures a seamless fit which helps reduce contamination. Floveyor offers complementary hygienic process line technology for battery minerals processing, including FIBC unloading, lump breakers, and screw feeders.

FloDisc® Technology

FloDisc technology is engineered to manage the strict requirements to eliminate ferrous, moisture, plastic, and CO_2 contamination during battery minerals processing.

"Only Floveyors convey powders and granules so efficiently and safely."

Not limited to lithium hydroxide monohydrate

While this white paper focuses on the highly valuable LiOH.H2O, the information applies to many other critical powders in the battery minerals value chain.

For example, Floveyor applies as much benefit and experience to sodium sulphate (Na_2O_4S) handling, a traditional by-product of the $LiOH.H_2O$ production process which can be problematic to convey.

08 Why partner with Floveyor for battery minerals processing?

Estimated maximum throughput of $LiOH.H_2O$ conveying with a Floveyor

3" (76.2 mm) tube: throughput capacity range 12 tph – 15 tph with a 2.2 kW Drive

4" (101.6 mm) tube: throughput capacity range 24 tph – 30 tph with a 5.5 kW Drive

5" (127.0 mm) tube: throughput capacity range 42 tph – 53 tph with a 7.5 kW Drive

Typical equipment noise levels

AMC - dry operation
~70dB

AMC - operating
~83dB

Typical particle degradation

0.3 - 0.76%
particle degradation per pass

Hallmarks of a Floveyor include:

- Little or no materials contamination
- Conveys almost any powder or granule, including by-products of battery mineral processing like lithium aluminosilicate, sodium sulphate and gyplime
- Protects product integrity and structure
- Meets ATEX 2014/34/EU safety standards, suited for potentially explosive applications
- Easily transfers fragile and friable materials
- Full batch transfers, leaving little or no residue
- Fully enclosed, dust-free operations
- Adapts seamlessly to any location or process
- Flanged, modular design for self-managed installation
- Small footprint with no need for dust extraction or filters
- Enhanced cleanability options, including inert gas purging to avoid materials contamination
- Faster, safer access for cleaning and maintenance
- Highly energy efficient
- Quiet, clean operation.

09 Conclusion

A new focus on midstream processing presents opportunities and challenges to the mining industry.

With vast quantities of raw materials like lithium and nickel, developing battery minerals processing capabilities is essential to promoting downstream battery manufacturing. Localised midstream processing operations also solves supply chain issues for battery manufacturers all over the world.

Processing battery minerals comes with stringent requirements not previously experienced in the mining industry and traditional conveying systems are not well suited to the challenges. However, hygienic conveyors and process line technology are already available in other industries and meet the demands of battery minerals handling for highly sensitive powders like $LiOH.H_20$.

Process engineers who are tasked with plant design or optimising plant operations should be aware of hygienic conveying advances developed for food and beverage, pharmaceutical, and chemical applications, namely the aero-mechanical, or AMC, method of conveying.

Floveyor is the pioneer in AMC technology and has evolved the technology since 1958 with continual investment in R&D.

Floveyors with FloDisc technology are engineered to mitigate the risk of ferrous and CO_2 contamination and provide an excellent foundation for high-yield midstream battery minerals processing. Floveyor conveying systems require little maintenance and can be trusted to reliably provide high throughputs without damaging the crystalline structure of $LiOH.H_20$.

If you would like to know more about powder handling for battery minerals processing, visit the Floveyor website at www.floveyor.com or review our resources for battery minerals conveyors, including fact sheets.

For more information about Floveyor, request our battery minerals capability statement.

FLOVEYOR.COM