THE PHOSPHATES PROCESSING HANDBOOK

FROM THE FEECO
MATERIAL PROCESSING SERIES

TOMORROW'S PROCESSES, TODAY.
FEECO.com
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Introduction

FEECO International was founded in 1951 as an engineering and equipment manufacturer. We quickly became known as the material experts, able to solve all sorts of material processing and handling problems, and now serve nearly every industry, from energy and agriculture, to mining and minerals.

As experts in the field of granulation, FEECO has been providing feasibility testing, process and product design, and custom processing equipment for phosphate materials since the 1950s. From initial phosphate rock drying, to animal feed and fertilizer granulation, we offer unparalleled capabilities in phosphate processing.

Many of the world’s top companies have come to rely on FEECO for the best in custom process equipment and solutions. These companies include:

For further information on our custom phosphate processing equipment and systems, or our many other phosphate processing capabilities, contact a FEECO expert today.

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Intro to
PHOSPHATES

Phosphate granules created in the FEECO Innovation Center
AN INTRO TO PHOSPHATES

Phosphorus is an irreplaceable nutrient, utilized for its life-giving capabilities to all life on Earth. Phosphorus is critical to carrying out a variety of cellular and biological processes that help plants, animals, and even humans to grow strong and healthy. As such, phosphorus is a key ingredient in fertilizers and animal feeds.

Phosphorus is mined all over the world in the form of phosphate rock and processed into all the products that keep our world running. A key component in crop production, livestock feed, and even in consumer products, in 2014 alone, world phosphate rock production was at a staggering 225 MT and projected to increase in the coming years.¹

According to the USGS, 95% of the phosphate rock mined in the United States is used in the production of fertilizer products,¹ with the rest going toward animal feed, and food or chemical products.

PROCESSING

FERTILIZER GRANULATION | ANIMAL FEED GRANULATION
No matter what product phosphate rock is destined for, it must first be mined and beneficiated.

Mined phosphate rock beneficiation differs greatly from one deposit to the next, with any combination of crushing, screening, flotation, filtration, classification, and more carrying out the job.

The ore resulting from the beneficiation process must be dried before it can move on to subsequent processing. This is typically carried out in a rotary dryer, an industrial drying system ideal for processing phosphate ore, because of its heavy-duty build and high capacity capabilities.

The dried phosphate ore is then most commonly processed into phosphoric acid through reaction with sulfuric acid. Phosphoric acid is a versatile material and is the base of phosphatic fertilizers and animal feeds.

**PROCESSING PHOSPHATES FOR USE IN FERTILIZER PRODUCTS**

Phosphates have been used in the fertilizer industry for generations. Phosphorus assists in many biological processes that help to create strong stems and roots, aid in resistance to disease, and create a more productive plant overall.

While ground phosphate rock can be applied directly to soil, it is most beneficial to first process the phosphate rock into a form that allows the phosphorus to be more readily absorbed by plants.

Phosphate rock can be processed into a variety of phosphatic fertilizers. Most commonly, it is processed into Monoammonium Phosphate and Diammonium Phosphate fertilizers, more commonly known as MAP and DAP.

**MAP & DAP FERTILIZER PRODUCTION**

MAP and DAP fertilizers are produced by reacting phosphoric acid with ammonia and then granulating the resulting material. This process is described here in detail and illustrated on the next page.

The phosphoric acid and ammonia are pre-neutralized (reacted) in tanks to form a slurry. This slurry
is then fed into a rotary granulator, where it forms granules as it tumbles through the drum and solidifies.

These granules are then carried by a conveyor or bucket elevator to a rotary dryer where they are dried into their final form. The tumbling action of the dryer further rounds and polishes the granules. Granules exit the dryer and go through a screening process to separate over- and under-size granules.

Over-size granules are crushed via a hammer mill and fed with the under-size granules back into the process as recycle. On-size product moves on to cooling, which is carried out using a rotary cooler. Cooling helps to prevent caking during storage, and is necessary when material exiting the dryer is too hot for subsequent material handling equipment.

AN ALTERNATIVE APPROACH TO MAP GRANULATION

While this is the primary processing method for MAP production, an alternate process, which includes the addition of a pipe reactor, is sometimes used for the energy savings it can offer. This method is illustrated on the following page.

Instead of being reacted in tanks, phosphoric acid and ammonia are reacted in the pipe reactor.
The hot melt formed from this reaction is sparged into the rotary granulator and the resulting heat from the reaction flashes off moisture from the granular material.

While a rotary dryer is still needed, energy requirements are significantly reduced, because the heat of the reaction can supplement much of the drying energy required. Again, material is then screened and recycle is separated out, while on-size product moves on to cooling.

The addition of a pipe reactor can be a popular option for retrofits, because it is easily installed and the pre-neutralizing tanks can serve as feeding tanks to the operation. And while no operation requires the use of a pipe reactor, in the right setting, it can offer significant value in energy savings.

**ADDITIONAL PHOSPHATIC FERTILIZERS**

While phosphate rock is most commonly made into MAP and DAP, it can also be made into a variety of other fertilizer products as well:

- Single Super Phosphate (SSP)
- Triple Super Phosphate (TSP)
- NPK (Although phosphate is not the base of this product, it is included with potassium and nitrogen to create a variety of NPK blends.)
These materials may be comprised of varying components, but all are produced using the traditional granulation approach.

**PROCESSING PHOSPHATES FOR USE IN ANIMAL FEED**

Phosphorus is critical to the nutrition of animals, aiding in a variety of cell functions to build strong bones and teeth, and contributing to a variety of other essential processes in the body as well. As such, phosphorus is a key ingredient in animal feeds, namely Monocalcium Phosphate (MCP) and Dicalcium Phosphate (DCP).

While only about 5% of global phosphate consumption goes toward animal feed production,\(^2\) the production of phosphate animal feed plays a critical role in maintaining livestock health and overall food security.

**PREPARING PHOSPHATE ORE FOR ANIMAL FEED PRODUCTION**

Much like for fertilizer, phosphate rock is first mined, the ore beneficiated, and then processed into phosphoric acid. In some cases, processing in a kiln may also be required if the phosphate is contaminated, or found in the presence of organic materials that will necessitate removal.

MCP and DCP are created by reacting the phosphoric acid with calcium carbonate and granulating the resulting material. It is worth noting that animal feed was not always (and sometimes still isn’t) granulated, but granulation has proven to add significant value to the end product; a granular feed is much more easily handled, provides a more uniform product, and offers significantly less dust.

**MCP AND DCP PRODUCTION**

Traditionally, phosphoric animal feeds have been produced utilizing a Spinden reactor—a horizontal mixer/reactor similar to a pug mill. While this approach yields effective results and is widely used throughout the animal feed industry, FEECO has improved upon the process through the addition of a high-speed mixer.

**HOW FEED GRANULATION WITH A HIGH-SPEED MIXER WORKS**

Phosphoric acid and limestone (calcium carbonate) are fed into the high-speed mixer. The mixer is comprised of a vertical chamber with a paddle shaft running through the middle, which rotates at 300-400 RPMs to create an intense mixing action.

This intense mixing step serves to create a more homogeneous mixture, and subsequently, a better reaction of the materials. The high-speed mixer thoroughly mixes the materials, and then drops the mixture via gravity into the pug mill on which it is mounted.

The pug mill completes the reaction, and granulates the mixture as it moves down the length of the mixer. Once the mixture has been granulated, it exits the pug mill and is carried by conveyor to a rotary dryer. The dryer removes the desired amount of moisture from the product and further polishes and rounds the granules. After drying, under-size and over-size material are screened out and fed back into the process as recycle, with over-size pellets first going through a grinding step in a hammer mill. On-size product can move on to packaging, shipping, or

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storage. The FEECO granulation process described here is illustrated above.

**BENEFITS OF THE HIGH-SPEED MIXER APPROACH**

The FEECO animal feed granulation process utilizing a high-speed mixer offers significant value over the traditional approach to animal feed granulation.

The mixing step in a granulation process sets the stage for the quality of the end product. The addition of a high-speed mixer offers a more intimate mixing of the materials. This not only improves the uniformity of the pellet, but it also results in a better reaction of the materials, yielding a higher quality pellet.

The FEECO approach to producing Monocalcium Phosphate and Dicalcium Phosphate is an improvement on the traditional approach, offering increased product quality.
FEECO Pug mill used in the production of animal feed.
PHOSPHATE PROCESSING EQUIPMENT OVERVIEW

The phosphate industry continues to gain attention as of late, as the world begins to approach peak phosphorus. With that, companies will increasingly be looking to improve upon their phosphate products and processing methods, further necessitating high quality equipment.

What follows is a basic overview of the equipment used in the aforementioned processes. Some equipment features may be specific to FEECO International.

GRANULATION DRUMS

Granulation drums are the centerpiece of most phosphatic fertilizer operations. This is where material is granulated after reaction.

Granulation drums are incredibly versatile and can therefore be used to process a wide array of materials. They are used frequently throughout the agriculture industry to create a variety of fertilizer products.

HOW GRANULATION DRUMS WORK

In phosphatic fertilizer production, granulation drums work by tumbling reacted material in a rotating drum. As the material cools and solidifies, the tumbling action rounds it into granules. Tumbler flights can be added to increase material agitation and create the desired product characteristics.

Flexible and corrosion-resistant drum liners can be implemented to reduce or eliminate material buildup on drum walls and decrease the potential for damage due to a corrosive material.

FEECO GRANULATION DRUMS AT A GLANCE

<table>
<thead>
<tr>
<th>SIZE</th>
<th>Drum diameters from 36” - 15’ (1 - 4.6m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPACITY</td>
<td>500 lb/hr - 3500+ TPH</td>
</tr>
<tr>
<td>CUSTOMIZABLE?</td>
<td>Yes</td>
</tr>
</tbody>
</table>

PUG MILLS

In the phosphates industry, pug mills, also commonly known as paddle mixers, are used in granular fertilizer production to mix the recycle with the new raw materials, and in animal feed production to thoroughly mix, react, and granulate feed ingredients.

HOW PUG MILLS WORK

Pug mills use a folding and kneading action to thoroughly mix materials. In granular fertilizer
production, they make a homogeneous blend prior to entering the granulator. In animal feed production, they facilitate the reaction between components. The thorough mixing helps to ensure a uniform product.

**FEEO PUG MILLS AT A GLANCE**

<table>
<thead>
<tr>
<th>SIZE</th>
<th>14&quot; - 78&quot; (356 - 1,981mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPACITY</td>
<td>500 lb/hr - 250 TPH</td>
</tr>
<tr>
<td>CUSTOMIZABLE?</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**ROTARY DRYERS**

Rotary dryers are used prolifically throughout the phosphates industry—for drying phosphate rock, as well as for drying granular animal feeds and fertilizer products.

**HOW ROTARY DRYERS WORK**

Rotary dryers work by cascading material in a rotating drum in the presence of a drying air/hot gas. Material lifters, or flights, lift the material, carry it over, and drop it through the drying air stream in order to maximize heat transfer efficiency.

**FEEO ROTARY DRYERS AT A GLANCE**

<table>
<thead>
<tr>
<th>DIAMETER</th>
<th>3’ - 15’ (1 - 4.6m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPACITY</td>
<td>1 TPH - 200 TPH+ (1 MTPH - 181 MTPH)</td>
</tr>
<tr>
<td>CUSTOMIZABLE?</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**ROTARY COOLERS**

Rotary coolers are typically used in fertilizer granulation. A cooler is commonly used after the drying step to cool material exiting the dryer. Cooling helps to bring down material temperature so it is not too hot for subsequent handling. It also helps to prevent caking issues during storage.
HOW ROTARY COOLERS WORK
Much like rotary dryers, rotary coolers cascade material in a rotating drum. Instead of heated air, however, they utilize chilled or ambient air to cool material. Here again, flights are used to increase efficiency.

FEECO ROTARY COOLERS AT A GLANCE

<table>
<thead>
<tr>
<th>DIAMETER</th>
<th>3’ - 15’ (1 - 4.6m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPACITY</td>
<td>1 TPH - 200 TPH+ (1 MTPH - 181 MTPH)</td>
</tr>
<tr>
<td>CUSTOMIZABLE?</td>
<td>Yes</td>
</tr>
</tbody>
</table>

HAMMER MILLS
Hammer mills are used for both fertilizer and animal feed granulation applications. Hammer mills are used for crushing over-size granules so they can be worked back into the process as recycle.

HOW HAMMER MILLS WORK
Hammer mills use a spinning shaft affixed with hammers and/or chains to break down over-size product. FEECO hammer mills avoid the use of a grinding/pulverizing action.

HIGH-SPEED MIXERS
The high-speed mixer is unique to the FEECO approach to animal feed granulation and is the most efficient type of reactor/mixer on the market today. The addition of a high-speed mixer to the pug mill provides an improved reaction and a more uniform product.

HOW HIGH-SPEED MIXERS WORK
High-speed mixers are comprised of a vertical chamber, through which a shaft extends. The shaft is affixed with several paddles, and operates at 300-400 RPMs to provide thorough mixing and initiate the reaction before material moves on to processing in the pug mill.

COATING DRUMS
Coating drums are sometimes used in the production of MAP and DAP fertilizers. Coating drums coat granules with a material that improves the end product in some way, typically by reducing dusting issues, or employing an anti-caking agent.

HOW COATING DRUMS WORK
Similar to rotary granulators, coating drums consist of a rotating drum through which material is fed. The material tumbles through the drum, and a spray system releases the coating agent onto the material. Tumbler flights help to increase agitation, ensuring uniform results.

ROTARY KILNS
Rotary kilns are similar to rotary dryers, but operate at much higher temperatures in order to cause a
chemical reaction or physical change in the material. In the phosphates industry, kilns are typically used to purify or upgrade low-grade or contaminated phosphate ore.

HOW ROTARY KILNS WORK
Rotary kilns work by heating material to the temperature at which the desired reaction will take place, and holding it there for a specified amount of time (referred to as the retention time).

FEECO ROTARY KILNS AT A GLANCE

<table>
<thead>
<tr>
<th>SIZE</th>
<th>Up to 15’ (4.6m) diameter x 100’+ (30.5m+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPACITY</td>
<td>1 TPH - 200 TPH+ (1 MTPH - 181 MTPH)</td>
</tr>
<tr>
<td>CUSTOMIZABLE?</td>
<td>Yes</td>
</tr>
</tbody>
</table>

PIPE REACTORS
Pipe reactors are an acid-base reaction vessel sometimes used in the production of MAP fertilizers. Although they are not required in any system, in the right setting, they can provide significant energy savings, because they allow for the heat of the reaction to be captured, supplementing some of the energy required for drying.

HOW PIPE REACTORS WORK
Phosphoric acid is fed into one side of the reactor, and gaseous or liquid ammonia is fed into the reaction chamber. A hot “melt” is produced, which is sprayed onto a bed of recycle material in the rotary granulator. The captured reaction heat helps to dry the material as it tumbles through the granulator and solidifies.

ROTARY DRYERS: THE IDEAL CHOICE IN PROCESSING PHOSPHATES
Despite such variation in end use, one industrial tool helps to make all of the phosphate products we need possible: the rotary dryer.

From the initial beneficiation, all the way through to the end product, rotary dryers remain a key tool in producing the many phosphate products our growing world requires.

DRYING PHOSPHATE ROCK
As mentioned, the beneficiation of phosphate rock differs greatly from one deposit to the next. In general, however, phosphate rock is processed via a wet process, resulting in a wet phosphate rock, which must be dried before it can move on to subsequent processing.
BENEFITS OF DRYING PHOSPHATE ROCK
The drying of phosphate rock is an essential step in transforming phosphate rock into usable products, offering significant benefits to the process as a whole, and to any subsequent processing that will need to occur. This includes:

- **Improved Product Handling**: Drying phosphate rock reduces moisture content, so handling issues associated with wet or sticky phosphate rock are avoided.

- **Reduced Potential for Buildup**: Dried phosphate rock offers reduced opportunity for buildup in equipment. This decreases the potential for equipment to clog, ultimately improving process flow and efficiency.

DRYING PHOSPHATIC FERTILIZERS
Drying plays a critical role in the success of fertilizer products. Since many fertilizer products will move on to bagging, storage, or shipping, the moisture content must be reduced to help prevent caking issues and to maintain product integrity.

DRYING ANIMAL FEEDS
Similar to fertilizer production, phosphate rock that is processed into animal feed also requires a drying step. Here again, phosphate materials are granulated into agglomerates that must then be dried.

BENEFITS TO DRYING GRANULAR PHOSPHATE PRODUCTS

- **Enhanced Product Quality**: For both phosphatic animal feeds and fertilizer products, drying can offer an added benefit when dried in a rotary dryer; granule characteristics are improved, because the tumbling action imparted by the dryer wears down rough edges, reducing the opportunity for attrition later, and essentially polishing the granules to create a premium granular product.

- **Hardened Granule Surface**: Drying cures granular phosphate products into their final form, yielding a hardened product that is capable of withstanding handling, transportation, and even application. As mentioned, this hardened surface also reduces the potential for caking issues during storage.

HOW PHOSPHATE DRYERS WORK
Rotary dryers are the ideal choice in processing any type of phosphate product. Rotary dryers are robust in design and construction, allowing them to withstand the rigors of drying phosphate products. Additionally, their high throughput is ideal for the often high capacity requirements of phosphate processing.

These industrial drying systems are also valued for their ability to accept variance in feedstock, which is often a given in processing phosphates, particularly at phosphate mining and beneficiation sites where ore can vary in makeup and moisture content.

Phosphate rotary dryers work by tumbling the material to be dried in a rotating drum in the presence of a drying air. These dryers are typically of the co-current airflow configuration, meaning that the material and drying air flow in the same direction. When drying an animal feed or fertilizer product that has been...
granulated by reaction, this helps prevent the most dry material from becoming too hot, which would result in the creation of fines and attrition. When drying phosphate rock, the co-current configuration helps to “flash off” initial surface moisture, and allow the rock to be dried through to the core as it moves down the length of the drum. Flights, or material lifters, pick up the material and drop it through the stream of drying air as the drum rotates in order to maximize heat transfer efficiency.

MATERIAL CONSIDERATIONS IN PHOSPHATE DRYING
Phosphate can be a challenging material to work with, presenting a number of characteristics that affect the drying process. Some of the most common characteristics to take into consideration during design and development stages include:

BUILDUP
Because phosphate can tend to clump, knocking systems are typically required on rotary dryers, with the ball and tube type knocker being the most common choice. A knocking system serves to dislodge potential buildup inside the drum by “knocking” the exterior of the drum as it rotates.

A screw conveyor may also be an option in combating buildup; screw conveyors “fling” material into the dryer, helping to break up potential clumps as they enter the dryer.

In addition, various materials of construction such as stainless steel with a 2B finish can aid in the prevention of buildup.

ABRASION
Phosphates can be abrasive. Because of this, materials of construction must be carefully chosen. Additional modifications may be required for high-wear areas, such as the material inlet of the dryer.

DUSTING
Phosphate can also be a dusty material to work with. This is particularly problematic when drying phosphate rock. Here, particulate matter in the form of phosphate rock dust is collected in a baghouse as part of the emissions control system.

Rotary dryers continue to provide an ideal drying medium for all types of phosphate processing operations. From animal feed and fertilizers, to phosphate rock, rotary dryers play a critical role in helping phosphoric products get to market while offering many benefits along the way. And although phosphates can present challenges in processing, custom rotary dryers can be designed to work around these difficult characteristics, producing an end product of quality, while prolonging equipment life.

MATERIAL HANDLING IN THE PHOSPHATES INDUSTRY
No matter what material is being produced, all phosphate operations have one thing in common: they rely on heavy-duty material handling equipment to keep operations running seamlessly.

Material handling equipment is used frequently throughout animal feed granulation, fertilizer granulation, and phosphate mining and beneficiation operations in order to bring automation and flexibility to a process.
COMMON PHOSPHATE HANDLING EQUIPMENT

BUCKET ELEVATORS
Bucket elevators transfer phosphate materials vertically and are often chosen because they are ideal for high capacity handling applications. While single chain bucket elevators are an option, the most popular choice for phosphate bucket elevators is the double chain continuous style, due to the increased capacity and height capabilities they can offer. Bucket elevators are highly customizable, allowing for an optimal handling solution to be met for nearly any application.

BELT CONVEYORS
Belt conveyors are also commonly used in phosphate processing operations. Belt conveyors allow material to be carried horizontally and are commonly used to transport material from one process stop to the next, or from one building to another. They are also extremely customizable, with common modifications including the addition of loading skirtboards, belt cleaning systems, and more.

A variety of additional conveyor types exist to further optimize the handling of a phosphate operation, with two of the most popular being:

Reversing Shuttle Conveyors: A belt conveyor that is mounted to a rail or track system, in order to allow for more than one discharge point and conveying in both directions.

Steep Incline Conveyors: Steep incline conveyors carry material vertically, or at an angle that is too steep for horizontal transport.
BELT TRIPPERS & PLOWS
Belt trippers and plows allow for increased flexibility of a material handling system. Trippers travel along the length of the conveyor and can discharge material at any point along the travel range, providing for a continuous, long storage pile of material, as compared to a single pile of material discharged from the end of a conveyor. Trippers essentially “trip” material off the conveyor at either fixed or movable points, while belt plows are fixed, but allow for discharge from the conveyor on one or both sides.

BELT FEEDERS
Belt feeders ensure controlled feed rate from a bin or hopper onto a conveyor or other piece of process equipment. They are highly versatile and can be used in a variety of applications.

CONSIDERATIONS IN HANDLING PHOSPHATES
Whether the material is animal feed, fertilizer, or phosphate rock, phosphate products present a few challenges that will require ingenuity on the part of the equipment manufacturer...

ABRASION & CORROSION
Phosphates can be abrasive and sometimes corrosive. Much like the industrial drying system, material handling equipment will likely require customizations to guard against abrasion and corrosion in order to maintain process efficiency and prolong equipment life. This might include reinforcing high-wear areas such as transfer chutes, or using various alloys such as stainless steel to construct the handling equipment.

Additionally, material should not be allowed to build up in equipment, as this can promote excessive wear. No matter what type of phosphate operation is at hand, material handling equipment plays a critical role in automating the process and allowing for flexible, seamless operation.
Phosphate granules created in the FEECO Innovation Center
PHOSPHATE PROCESSING CHALLENGES

As we’ve already discussed, phosphates can present challenges during processing. However, careful planning and preparation of both the process and the equipment can help to achieve desired results, while prolonging equipment life at the same time. Below are some of the common issues processors face when working with phosphates.

**ABRASIVE**

Depending on the form they’re in and what they’re being processed into, phosphates can be anywhere from mildly to extremely abrasive. Whether produced to be a fertilizer such as MAP, DAP, or NPK, or an animal feed such as MCP or DCP, abrasiveness can pose problems to unprotected equipment, and therefore, equipment will need to be designed with this in mind.

**DUST ISSUES**

Phosphate products can also be dusty, depending on what form they’re in. Dust issues are especially problematic at phosphate beneficiation plants, where mined phosphate rock is dried after processing. The phosphate rock becomes dusty upon drying, and fines are commonly collected in a baghouse.

While these collected fines are dusty and difficult to handle, opportunity exists in agglomerating the fines so they are more easily handled and processed down the line. The agglomeration of fines significantly reduces issues associated with dust, and also allows the product to be more easily reintroduced to the process.

**CORROSIVE**

In processing phosphate products, many corrosive solutions are often added. The base of many phosphate products is phosphoric acid, which is a highly corrosive material. Specialty alloys and linings are often required on equipment to protect against corrosion.

**CLUMPING**

Clumping can also be an issue when processing phosphate products. Wet phosphates are prone to sticking and clumping, causing issues in processing equipment and impacting overall process efficiency.

While drying the phosphates, sticking and clumping can occur on the belt conveyors and chutes going to the dryer, as well as on the walls and flights of the dryer. For this reason, phosphate rotary dryers are commonly fitted with knocking systems in order to reduce clumping during drying.

**VARIABILITY**

Phosphate deposits are incredibly diverse. Phosphate ore differs greatly from one deposit to the next, and even within the same deposit. This can be a challenge, because each deposit will likely require modifications to processing methods in order to produce a quality product with the desired properties.

**CONTAMINATION**

Similar to variation, phosphate rock is sometimes considered contaminated, meaning it is found in the presence of organics. This causes the phosphate rock to be low in value or even unusable as-is. In these cases, the phosphate rock will typically require
purification via calcination in a rotary kiln, a process commonly referred to as the upgrading of phosphate ore.

**COMBATING PHOSPHATE CHALLENGES**

**FEASIBILITY AND PILOT TESTING**

It is often both necessary and desirable to conduct testing, whether it be to troubleshoot and improve an existing process, collect data for a new process, or to take a concept from idea to product. Testing of phosphates at batch and pilot scale helps to work out process variables and provide the information necessary for successful process scale-up and equipment design. These early testing stages allow for a familiarity with the unique sample to be gained, helping to minimize surprises later.

Testing is also especially critical when looking to purify contaminated phosphate ore. Because the makeup of phosphate ore deposits vary considerably, the time and temperature required to remove organic components will also vary. Testing in a batch rotary kiln is frequently used to develop the time and temperature profiles necessary to remove the organic components and produce desired results. Testing of phosphates is covered more in-depth in the next section.

**HIGH QUALITY EQUIPMENT**

When it comes to processing phosphates, high quality equipment is essential. Equipment will need to be robust and designed around the characteristics of the sample at hand, as well as any additives that may be included in the process. Choosing an equipment manufacturer that is familiar with the potential challenges that phosphate products can present will go a long way in prolonging equipment life and ensuring process efficiency.

For example, critical wear points such as paddles and plows on agglomeration equipment will likely require modifications to protect against abrasion and corrosion. This might include constructing high wear areas with abrasion-resistant materials, or reinforcing them with specialty linings.

**PHOSPHATE PROCESS & PRODUCT DEVELOPMENT**

While phosphate production is a well-established industry, testing remains a critical component in the success of many phosphate operations.

**WHY TESTING IS IMPORTANT**

As is shown here, there are many reasons why testing is both necessary and desirable. The most common reasons for testing phosphate materials include:

**TO CREATE A NEW PRODUCT/PROCESS**

New phosphate products are constantly being developed in all sectors. When working with fertilizers, it is common to try new blends for custom applications. Similarly with animal feed, new products aimed at better nutrition are tested. With consumer products, testing is used to develop new detergents, cleaners, and other products for consumer use.

**TO IMPROVE AN EXISTING PRODUCT**

Improvement of an existing product is perhaps the most common reason for testing. When new market opportunities open up, or a product isn’t performing
as intended (or could perform better), a variety of characteristics can be modified to improve performance or enhance the product in some way.

This might include adjusting the blend or formulation of the product, or altering physical characteristics such as granule size, crush strength, or bulk density to make the product easier to handle or apply.

**TO IMPROVE AN EXISTING PROCESS**
Testing is also frequently conducted to improve on an existing process. This could be to troubleshoot an inefficient process, work out the incorporation of a new addition to the process, or even test out an improved way of carrying out the process.

**WHAT TYPES OF TESTING ARE AVAILABLE?**
Various types of testing can be conducted. In the FEECO Innovation Center, the following types of processes can be tested:

**AGGLOMERATION**
Agglomeration of phosphates is frequently tested for a variety of reasons. This may be to test a new product for process knowledge or to introduce a product to a new or existing market. It may also include testing feasibility of granulating ground ore fines, recycle or baghouse fines into a usable product, or the blending of phosphates with other materials.

**GRANULATION**
Granulation of phosphate products is frequently tested in the Innovation Center for both fertilizer and animal feed applications. The FEECO Innovation Center can accommodate the use of phosphoric acid, sulfuric acid, or ammonia, allowing various reactions in the granulation process to be tested; all pumps, spray systems, heat tanks, and agglomeration equipment are designed to handle both heated and non-heated phosphoric acids and gases.

**THERMAL TESTING**
Phosphate rock can be processed in a rotary kiln to accomplish a variety of goals. It can also be processed in a rotary dryer to remove moisture. Phosphate rock varies considerably in chemical composition and the materials that it is found with from one deposit to the next, and even within the same deposit. This presents challenges when looking to process the phosphate rock, because few samples are alike.

For this reason, thermal testing in a kiln or dryer, depending on the goal, is often conducted to determine the time and temperature profiles required, and collect emissions data for the unique deposit at hand. This not only aids in designing a process that most efficiently processes the material, but it also helps in the design of a commercial size unit.

For all types of testing, depending on what information the customer already knows and is looking to gather, testing commonly starts at batch scale, with small samples of material being tested to gather initial data and determine feasibility of the intended goal. Once batch testing has been successful, continuous pilot-scale testing can be conducted. This is a much larger scale test, where a continuous process loop is tested.
ADVANTAGES TO TESTING WITH FEECO

Testing in the FEECO Innovation Center offers unparalleled advantages to customers. FEECO has a long history in the fertilizer and agriculture industry; customers come to us because of our familiarity and expertise in the process of producing the various types of phosphate products and fertilizer blends. The unique capabilities of our testing facility allow us to test nearly any phosphate-based process, be it a common process or a novel one. We can work with you to take your project from idea to full-scale production, and even produce the equipment required to do the job.

We have also partnered with Rockwell Automation to bring our customers the best in automation control and reporting capabilities, both as a service in the Innovation Center, and as part of a system purchase. Our automation system can collect and trend numerous points of data, giving customers complete transparency with their process, and allowing for unmatched reporting capabilities.
Phosphate materials are frequently tested in the FEECO Innovation Center for a variety of reasons. This might include to enhance the characteristics or performance of an existing product, improve upon or troubleshoot a process currently in use, or even to test the feasibility or develop a process around a new product or idea.

Depending on where the customer is in their process, and what they are looking to achieve, testing is generally carried out in four stages:

1. Feasibility/Proof of Concept - An initial, non-witnessed batch testing phase in which the possibility of creating a product is explored.

2. Proof of Product - A more in-depth batch testing phase in which more time is spent determining whether a product can be made to desired specifications.

3. Proof of Process - A continuous testing phase that aims to establish the equipment setup and parameters required for continuous production of your specific material.

4. Process/Product Optimization - An in-depth study to optimize your specific material’s characteristics and/or production parameters in an industrial setting.

Equipment Commonly Tested:
- Granulation Drum
- Paddle Mixer
- Rotary Dryer
- Chain Mill
- Pipe Reactor
- Coating Drum
- Rotary Kiln

* All equipment in the Innovation Center is equipped to handle phosphoric acid, allowing a variety of phosphate products and processes to be tested, including fertilizer granulation, animal feed granulation, and more.

Commonly Tested Phosphate Materials:
- Phosphate Rock
- MAP/DAP
- MCP/DCP
- SSP/TSP

Processes Commonly Tested:
- Animal Feed Granulation
- Fertilizer Granulation
- Phosphate Ore Upgrading
Testing in the FEECO Innovation Center provides an invaluable opportunity to test in a controlled environment, allowing you to gain a familiarity with your material, while reducing the chance for unforeseen problems after process scale-up. Some of the many advantages to testing in the FEECO Innovation Center include:

**Material Experience:**
FEECO has been a pioneer in material processing since the 1950s, and has extensive knowledge around hundreds of materials and processing methods.

Customers gain a valuable familiarity with their material and its unique characteristics through testing in the Innovation Center.

**Complete Process Knowledge:**
FEECO is familiar with each aspect of a process, from agglomeration and kiln processing, to drying and cooling, allowing us to look at how the process will function as a whole, instead of each individual portion.

**Process Scale-up:**
Once the process configuration has been defined, FEECO can aid in process scale-up, as well as manufacturing the equipment needed to get the job done.

**Automation & Data Collection:**
FEECO is a Rockwell Automation partner, providing integrated process control solutions for our customers, both as a service in the Innovation Center, and as part of a system purchase. This provides customers with state-of-the-art data collection and reporting capabilities.

A variety of data points can be monitored, trended, and adjusted in real time, all from a single interface or mobile device.

Historical data is also available for returning customers, allowing you to pick up exactly where you left off.

**Virtual Lab:**
FEECO offers a unique Virtual Lab where customers can view their material being tested in real time, without having to come to the FEECO facility.

**Commonly Targeted Material Characteristics:**
- Crush Strength/Hardness
- Abrasion/Attrition
- Material Composition
- Bulk Density
- Flowability
- Moisture Content
- Green/Wet Strength
- Sieve Analysis
- Solubility

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**SCHEDULE A TEST**
To discuss your testing needs with one of our process engineers and schedule a test, contact us today at: [FEECO.com/contact](http://FEECO.com/contact)
OUTLOOK ON
PHOSPHATES
OPPORTUNITIES IN RECYCLING
OPPORTUNITIES IN RECYCLING PHOSPHORUS

WHY RECYCLE PHOSPHORUS?
Mineralogical phosphate reserves are a finite and irreplaceable resource. As economically accessible reserves begin to diminish, scientists worldwide are concerned about food security and the survival of a world without this crucial mineral. This worry is compounded by the fact that demand for phosphate is constantly on the rise, as the world tries to feed a growing population.

In 2008, a brief 800% spike in phosphate prices was enough to cause riots and suicides in areas where access to fertilizer became unavailable.3

Simultaneously, the inefficient use of phosphorus is causing it to end up in waterways, threatening the environment and the surrounding ecology.

However, many are beginning to recognize that existing sources of phosphorus waste streams, particularly in the form of manure and wastewater, may hold the key to ensuring an environmentally and economically sustainable source of phosphorus for the world over.

PHOSPHORUS RECYCLING HOLDS PROMISE
Studies around the world are looking at the opportunity to recycle phosphorus from wastewater treatment plants (biosolids), and from manure sources.

One recent study looked at three primary phosphorus waste streams (human food waste, human excreta, and animal manure), and how they could be applied to corn production, one of the primary crops produced in the United States.

The study found that just 37% of the phosphorus available in existing waste streams could support the annual phosphorus requirements of the U.S. corn crop.4

Another study found that the phosphorus available in organic waste sources may even be more readily available for plant uptake than that found in traditional fertilizer products, depending on the hygienization treatment, as well as the chemicals used in the capture of phosphorus from waste sources.5

The recovery and reuse of phosphorus from waste streams is a fairly new endeavor, and much research is needed to work out the feasibility and logistics of such a concept. Currently, various technologies for recovering phosphorus from such waste sources are being developed with success, some that may even be more cost-effective than the processing of phosphate rock.6

And while more research is needed in both the recovery and the reuse of phosphorus from waste streams, one technology is likely to lend a hand: granulation.

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Granulation is a process that can transform sludge and other organic materials into a dry, granular product. This technology is fairly established in the agriculture industry already; granulation mitigates many of the issues associated with raw manure, such as difficult handling, high transportation costs, and challenges in managing nutrients. Granulation produces a marketable product and offers ample opportunity for product customization, offering a premium product where once waste management costs were incurred. Furthermore, a granular product helps to reduce opportunity for nutrient runoff, because no additional moisture is being added.

In the case of manure, granulation works by taking the nutrient-rich cake left over from the anaerobic digestion process, and using tumble growth agglomeration to process it into a granular product, which is then dried and cooled. The resulting product is nearly odor-free, and goes beyond EPA qualifications for a Class A Biosolid, quelling many of the worries associated with the issues surrounding the traditional method of land-applying raw material. Considering that phosphorus waste streams are an inevitable part of human life on Earth, and subsequently, a completely renewable resource, the recovery and reuse of phosphorus from existing waste streams looks to be a promising solution to our disappearing phosphate rock reserves.

FEECO has been working with companies to reuse nutrients recovered from manure and wastewater sources through the practice of granulation for years. We are currently working on a project that looks to make on-farm granulation a scalable option in the agriculture industry.

This new approach to the recovery and reuse of phosphorus from waste streams is still in its infancy stages. Much research and development must be done. As an expert in the reuse of nutrients recovered from manure, FEECO intends to be on the front lines of this endeavor.
ADDITIONAL RESOURCES
For further information or reading on phosphates, we have provided some additional resources below. Please note that the inclusion of any resource or company is not an endorsement and the views of that resource do not reflect those of FEECO International.

ASSOCIATIONS & PUBLICATIONS
Florida Industrial and Phosphate Research Institute
www.fipr.state.fl.us/

American Institute of Chemical Engineers
www.aiche.org/

BOOKS
Phosphates and Phosphoric Acid: Raw Materials: Technology, and Economics of the Wet Process: 2nd Edition (Fertilizer Science and Technology)
by Pierre Becker

Beneficiation of Phosphates: Comprehensive Extraction, Technology Innovations, Advanced Reagents
by Patrick Zhang (Editor), Jan Miller (Editor), Ewan Wingate (Editor), Laurindo Leal Filho (Editor)
THE FEECO COMMITMENT TO QUALITY

FEECO International, Inc. was founded in 1951 as an engineering and equipment manufacturer. FEECO is recognized globally as an expert in providing industry-leading process design, a range of engineering capabilities, including everything from process development and sample generation, feasibility studies, to detailed plant engineering, as well as manufacturing to a variety of industries, including: fertilizer and agriculture, mining and minerals, power/utility, paper, chemical processing, forest products and more. As the leading manufacturer of processing and handling equipment in North America, no company in the world can move or enhance a concept from process development to production like FEECO International, Inc.

The choice to work with FEECO means a well-rounded commitment to quality. From initial feasibility testing, to engineering, manufacturing, and aftermarket services, we bring our passion for quality into everything we do. FEECO International follows ISO 9001:2015 standards and procedures.
For more information on processing phosphates, material testing, or custom equipment, contact FEECO International today!

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