Introduction

FEECO International was founded in 1951 as an engineering and equipment manufacturer for the fertilizer industry. 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.

Despite this growth, we’ve continued to maintain our position as a leader in fertilizer production technology and remain on the cusp of this ever-changing industry. As experts in the field of fertilizer and soil amendment production, we have been solving problems through feasibility testing and custom processing equipment and systems since the 1950s.

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

For further information on our specialty fertilizer and soil amendment production capabilities, contact a FEECO expert today.

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The Move Toward
SPECIALTY PRODUCTS

Manure-based fertilizer created in the FEECO Innovation Center
FACTORS PUSHING DEMAND FOR BETTER NUTRIENT MANAGEMENT

The agriculture industry is in the throws of a revolution; feeding the world’s estimated 2050 population of more than 9 billion people on less arable land proves to be the challenge that defines our generation. According to the Food and Agriculture Organization (FAO), this population jump will require a 60% increase in crop production compared to 2005/2007 levels.¹

Unfortunately, environmental challenges, nutrient deficiencies, and other critical mounting issues are adding to the urgency of resolution, pushing a surge in demand for better crop nutrient management, and in turn, better fertilizers and soil amendments.

The primary factors driving demand for better nutrient management are outlined here.

NUTRIENT RUNOFF

Nutrient runoff and its associated issues have been an escalating issue around the world in recent years; sources of drinking water are being polluted and “dead zones” (eutrophic, or low-oxygen areas in waterways) are resulting in die offs of aquatic life and other ecological consequences.

While nutrient runoff comes from a variety of sources, one of the primary sources of blame is attributed to the agriculture industry, prompting a call for better management of nutrients on farms.

At the same time, farmers are continually looking to prevail over a tough economy, necessitating greater efficiency of the fertilizers they apply in order to avoid waste in the form of runoff and achieve the highest yield rates and ROI possible.
SOIL NUTRIENT DEFICIENCIES

Scientists around the world are recognizing that soils are becoming increasingly deficient in the nutrients required for healthy and fruitful plants.

Generations of continued harvesting and replanting, combined with a focus on the primary macronutrients, has broken the natural nutrient cycle, leaving soils depleted of the nutrients and organic matter necessary for soil (and crops) to thrive—a major threat to increasing food production.

This degradation of soils can be seen in humans as well; science has proven in many cases that the crops we eat today offer less nutrient value than crops grown in prior generations.

In addition, nutrient deficiency can have devastating consequences to human health and wellbeing. Zinc, for example, is an essential micronutrient and has become the most common nutrient deficiency in soils around the globe, resulting in subsequent zinc deficiency in humans that rely on cereal crops from these regions for sustenance. Zinc deficiency in people is associated with a variety of health problems and often results in stunted growth and even death. This has caused a scramble for growers to improve the nutrition of crops through better nutrient management.

THE IMPORTANCE OF EVERY SINGLE NUTRIENT

As scientists look at how to maximize crop yields to feed the growing population, the importance of each and every single nutrient is becoming more apparent. No longer is it acceptable to simply apply the primary macronutrients and hope for the best; growers now know that a deficiency in any one nutrient—no matter how small the amount required by the plant—can cause growth and production issues, potentially limiting yield.

Similarly, applying the proper amount of each nutrient is also critical in feeding the plant and avoiding runoff issues. Growers are beginning to understand that maximum yield lies in providing optimal nutrition for the given crop and its surroundings.

SUSTAINABILITY

Many of the resources we rely on to produce fertilizers are not renewable and growing demand means we must ensure that no potential resource goes to waste.

The ability to recover nutrients from waste sources that could otherwise potentially cause environmental harm has become an increasing focus, particularly around sources of phosphorus, such as manure and biosolids.

THE NUTRIENT MANAGEMENT MOVEMENT

The many factors described here are culminating to drive major changes in nutrient management, particularly when it comes to what we apply to our soils. Two movements have been especially paramount in this effort: 4R Nutrient Stewardship and Precision Agriculture.

4R NUTRIENT STEWARDSHIP

A greater understanding of how nutrient runoff can be mitigated while still maximizing the potential of the applied nutrients has ushered in a new movement.
in agriculture: 4R Nutrient Stewardship—a concept that combines best practices to maximize nutrient availability and effectiveness.

Through four key principles, 4R Nutrient Stewardship focuses on maximizing nutrient use and minimizing nutrient loss in an effort to promote efficient and sustainable nutrient management. These principles are outlined here.²

**Applying the Right Source of Nutrients**
Take all factors into account to ensure that a balance of the essential nutrients is provided.

**Applying the Right Rate of Nutrients**
Consider plant-specific needs combined with what the soil can provide to apply fertilizer at the ideal rate.

**Applying Nutrients at the Right Time**
Ensure proper timing of application by considering factors such as nutrient loss risks, logistics, crop uptake, and more.

**Applying Nutrients in the Right Place**
Meet site-specific needs and limit nutrient losses by taking factors such as root-soil dynamics and nutrient movement into account.

The voice of the global fertilizer industry, The Fertilizer Institute (TFI), is aiming to ultimately reach a 100% adoption rate of 4R Nutrient Stewardship (i.e., all fertilizer will be applied according to 4R principles).³

**PRECISION AGRICULTURE**
Precision agriculture, or 'precision farming,' is the practice of using modern technology and agronomic principles to provide site-specific field management based on the identification and analysis of in-field variability, a concept that goes hand-in-hand with the principles of 4R Nutrient Stewardship.

The driving force behind precision agriculture is the basic principle that variability naturally occurs within fields. Therefore, applying the proper inputs in the right place, at the right time, in the appropriate amounts will achieve optimal yield for the entire field.
Key aspects of precision agriculture are summarized in the following paragraphs.

**Data Collection**
Mapping technology such as Geographic Information Systems (GIS) or Global Position Systems (GPS) is used to define a field’s physical coordinates. This sets up the ability to overlay field information gathered from analysis.

**Interpretation**
Information such as climate conditions, cropping practices, soils, etc. is processed to determine the best management practices for different areas within the field.

**Application of Inputs**
Variable-rate technology (VRT) options are incorporated into agricultural equipment, allowing nutrients to be applied accurately and specifically based on the individual needs of different areas in the field. VRT, combined with granular fertilizer inputs, is an optimal practice in precision agriculture.

Precision agriculture has become an important tool in reaching the objectives of 4R Nutrient Stewardship. According to the International Plant Nutrition Institute, the implementation of precision agriculture technologies significantly increases the ability of growers to follow the 4R Nutrient Stewardship concepts.⁴

Improved fertilizer products will be critical to all of these endeavors.
A New Era in
FERTILIZERS &
SOIL CONDITIONERS
GROWING INPUTS | NUTRIENT RECYCLING | IMPROVING PERFORMANCE & HANDLING

Ammonium Sulfate produced in the FEECO Innovation Center
Widespread use of commercially available fertilizer in the 20th century fundamentally changed agriculture forever; farmers could cultivate crops on the same land every year and had a more reliable way of promoting increased yields.

This change fed the growing population and became the basis of modern agriculture. But now, for the reasons previously discussed, fertilizers are again changing to meet the needs of the evolving industry.

If widespread use of commercially available fertilizers was the hallmark of the 20th century, it looks like the 21st century could be marked by sweeping changes in traditional fertilizer products and practices; a wave of new and improved soil conditioners and fertilizers, combined with other nutrient management best practices, is changing the way we feed our crops, and ultimately, ourselves.

**GROWING INPUTS**

While traditional fertilizers are still (and will continue to remain) a critical tool in crop production, a portion of this market has given way to more specialized products and additives. Producers are rising to the challenge, providing a myriad of specialty fertilizers and soil amendments that promise to deliver optimal nutrition for a given application, along with other benefits that will help to maximize the effectiveness of the product. Mordor Intelligence estimates the specialty fertilizer market will see a CAGR of 7.5% from 2018 to 2023.5

Specialty fertilizers and soil amendments encompass a wide array of products, but the overarching theme is customization for the intended application or use. Crop type, regional considerations, soil type, climate, and more, will all influence how (and what) a given application should be optimized for.

Here are some of the key trends arising in specialty products:

**SECONDARY NUTRIENTS**

The inclusion of secondary macronutrients in fertilizers and soil amendments is a prevailing movement, as growers increasingly see the importance that each nutrient contributes to crop yield and overall resilience. Secondary macronutrients, referring to their place in required quantity next to primary macronutrients (Nitrogen – N, Phosphorus – P, and Potassium – K), are Magnesium (Mg), Sulfur (S), and Calcium (Ca).

While these secondary nutrients were long supplied (and still are) through supplemental applications of the individual nutrient, they are increasingly being incorporated into primary nutrient fertilizers and other soil conditioners to provide improved nutrition.

**SULFUR**

The use of sulfur has particularly been on the rise in recent years, as the Acid Rain Act inadvertently reduced the amount of sulfur plants were receiving. Sulfur can be applied on its own, or as part of another compound fertilizer or soil amendment. Common sources of sulfur include:

- Elemental Sulfur
- NPKS
- Ammonium Sulfate
• Potassium Sulfate ($K_2SO_4$)
• Potassium Magnesium Sulfate (often supplied through application of langbeinite—$K_2Mg_2(SO_4)_3$)
• Organic matter
• Gypsum (Calcium sulfate dihydrate)

MAGNESIUM
Magnesium may also be supplemented in a variety of ways, whether it be used alone or added to a compound fertilizer formulation. Sources of magnesium often include:

• Potassium Magnesium Sulfate (often supplied through application of langbeinite—$K_2Mg_2(SO_4)_3$)
• Limestone (Dolomite)

CALCIUM
Similarly, calcium can also be supplemented through a variety of products, or included as part of a compound fertilizer formulation. Common sources of calcium include:

• Calcium nitrate
• Calcium phosphate
• Calcium silicate
• Limestone
• Bone Meal
• Gypsum (Calcium sulfate dihydrate)

MICRONUTRIENTS
Micronutrients, which plants require to an even lesser degree than secondary macronutrients, are also being increasingly employed in the effort to improve crop nutrition and yield. Micronutrients include:

• Boron (B)
• Chlorine (Cl)
• Manganese (Mn)
• Iron (Fe)
• Nickel (Ni)
• Copper (Cu)
• Zinc (Zn)
• Molybdenum (Mo)

Micronutrients can be applied through the use of organic matter, which is often rich in micronutrients, or as part of a fertilizer or soil amendment product.
are also a variety of fertilizer and soil amendment products on the market dedicated to providing these essential constituents.

**ORGANIC MATTER**

While not a nutrient, organic matter is a critical component in soil health and its ability to produce fruitful and nutritious crops. Organic matter provides a number of benefits, including enhanced soil structure, greater resistance to erosion, improved ability to retain water and nutrients, and enhanced nutrient uptake by plants. Organic matter can also be used as a source of microbes, as well as an ideal microbial environment. Ultimately, it helps to create a productive and thriving growing environment.

Organic matter can be incorporated into fertilizer and soil amendment products through a variety of materials. This may include:

- Humate
- Manure
- Chicken Litter
- Biochar
- Compost
- Agricultural residues
- Food residues
- Biosolids
- Worm castings
- Microbes
- And more...

**BIOCHAR**

The use of biochar, a charcoal-like, carbon-based material with roots in ancient civilizations, has been rapidly on the rise in recent years; biochar has scientists excited over the potential it holds for restoring depleted soils, improving food security, and aiding in climate change efforts when used as a soil amendment.

Biochar is created through the thermal treatment of biomass in a high temperature, indirect-fired rotary kiln, a process referred to as pyrolysis. Biochar can be created from any form of biomass—animal by-products, agricultural waste, forest product residuals, and more. The source material, as well as the parameters of the pyrolysis process, will impact the characteristics of the end product.

**BENEFITS OF BIOCHAR AS A SOIL AMENDMENT**

Biochar boasts a porous surface structure and chemical properties that allow it to capture and hold minute particles. This ability lends itself to attracting and holding nutrients, moisture, and agrochemicals, as well as providing a place for micro-organisms and fungi to reside.

Additionally, biochar is not as susceptible to degradation and breakdown, lasting longer in soil than other types of organic matter (terra preta soils have persisted for thousands of years), so its effects are long lasting.6

According to the International Biochar Initiative, biochar can offer the following benefits to soil:7

- Reduced nitrogen runoff
- Possible nitrous oxide emissions reduction
- Improved soil fertility through increased cation-
exchange capacity
- Moderation of soil acidity
- Better water retention
- Increased number of beneficial soil microbes

Although biochars can differ and soils respond differently, biochar has shown to result in more fertile soil, increased crop yields, and improved crop nutrition, even in challenging areas with depleted soils, insufficient water, or limited access to organic resources or fertilizers.⁶

THE IMPACT OF BIOCHAR ON DROUGHT RESISTANCE
Biochar could also be critical in conserving water in soils—another major concern in agriculture, given dwindling water resources and increasing aridity.

According to one biochar producer, biochar not only improves water retention, but also works with a plant’s root system in order to use water (and nutrients) more efficiently. The company claims that biochar can reduce water needs by nearly half.⁸

One study conducted on sandy loam soils found biochar to increase water retention in both organic and conventionally managed soils.⁹ Not surprisingly, the study attributes the increased water retention to biochar’s porous surface structure.

Another study showed biochar to increase soil water holding capacity by 11%, though the authors note that more research on whether or not this will be able to help balance fluctuations in water availability in a climate with increased periods of drought is needed.¹⁰

Biochar can also impact the microbial populations in soil and may even cause the promotion of beneficial microorganisms that foster growth and resistance to biotic stresses according to one study.¹¹ Another study that looked at biochar in relation to tropical soils found biochar to significantly increase the ability of both fungal and bacterial populations in soil to resist drought.¹²

R&D around utilizing biochar as a soil amendment, as well as incorporating it into other products, has been on the rise; the FEECO Innovation Center has seen a sharp increase in the number of companies working with biochar.
ROCK DUST FERTILIZERS AND REMINERALIZATION

Another emerging trend in nutrient management and soil treatment is the practice of remineralization, or the application of rock dust to soil in an effort to mimic nature’s fertilizing process. Remineralization is an age-old concept that the Earth has been carrying out on its own since the beginning of time.

Rocks of different types are made up of varying minerals and combinations thereof. These minerals are liberated from rocks through weathering, naturally increasing the surrounding soil fertility over time.

The concept of speeding up the remineralization process through the application of rock dust to soils has long been understood. In 1894, a book by agricultural chemist Julius Hensel, entitled Bread from Stones: A New and Rational System of Land Fertilization and Physical Regeneration, was published. The publication detailed the concept of remineralization and although not well received at the time, has become a cornerstone of modern remineralization efforts.

Today, after generations of pulling minerals from soil without replacing them, soils around the world have become depleted and increasingly unable to meet the demands required by the growing population, spurring greater interest around the practice of remineralization.

ROCK DUST SOIL AMENDMENT PRODUCTION R&D

As a developing industry, the use of rock dust as a soil amendment is not yet well established. While progress has been made, there is still a lot of research to be done. Many variables remain unknown and the widespread variation in rock dust sources poses a particular need for testing with every project.

Rock dust typically cannot be used readily out of the ground; it will require crushing and sometimes drying to create a suitable rock dust soil amendment powder. However, while a powder promotes faster delivery, it poses significant challenges in terms of dust, complicating transportation, handling, and application.

For this reason, many producers are looking to agglomerate rock dust into larger, dust-free particles that are easier to handle and spread. It may seem counterintuitive to crush rock dust only to agglomerate it, but when tumble growth (non-pressure) agglomeration techniques are used, a premium soil amendment product is created. Granules created via tumble growth agglomeration can be tailored to specific crush strengths and other characteristics to help control the release rate of the minerals, among other factors.

“Each source of rock dust is unique—unique in its geology, its physical characteristics, in how it will perform as a soil amendment, and even in how it will respond to agglomeration,” states Chris Kozicki, FEECO Process Sales Engineer. “We are seeing a lot of producers looking to develop an agglomeration process optimized around their particular source of rock dust to create a product with the specific characteristics their customers are looking for.”
BENEFITS OF REMINERALIZATION

Soil remineralization is increasingly being recognized as holding the potential to solve an array of issues. Numerous studies around the use of rock dust for improving soil fertility have been carried out with successful results. Some of the many benefits of remineralization are summarized below.

Improved Plant Health
According to a presentation given at a recent conference in Copenhagen, Denmark, remineralization can promote disease and pest resistance, increase nutritional value (and taste) of crops, and even increase yields. When carried out properly, remineralization can also be used to increase soil carbon levels.¹³

A Slow-Release Fertilizer
Since minerals are released into soil through the weathering process, the use of rock dust serves as a natural, slow-release fertilizer. This provides long-term results and is especially valuable in areas of high leaching activity, because the minerals are much less soluble compared to a traditional fertilizer product.

Reduced Acidification
Soil remineralization also looks to be a promising means of reducing the global soil acidification problem as well; upon weathering, silicate rocks produce an alkaline leachate, helping to neutralize acidic soil, which is a critical factor in nutrient uptake and other growth factors in plants.¹⁴

Enhanced Nutrition
Furthermore, unlike most traditional fertilizer products that focus on the primary macronutrients, rock dust is often host to a wide range of both macro and micronutrients, providing a more well-rounded approach to nutrition. It can also provide silica, which is important in strengthening plant structures and aiding in pest resistance.

In addition to remineralization’s many benefits to soils and plants, there are some other potential benefits to the practice as well:

Reduced Reliance on Chemical Fertilizers
As a natural, readily available material, rock dust can also serve as an alternative to chemical fertilizers. While chemical fertilizers will still play a crucial role in feeding the global population, rock dust could be especially valuable in areas that rely heavily on nutrient imports.

This is perhaps most exemplified by Brazil—a key contributor to global agriculture and food supply; while Brazil only contributes 2% of global fertilizer production, the country is the fourth largest consumer.¹⁵

A low-cost, locally available source of nutrients could be a big boost to the industry’s agriculture sector by reducing the need for more costly nutrient imports.

An Outlet for Industry Waste
The use of rock dust could also be a valuable outlet for the aggregate industry’s waste. Rock dust is often a by-product of the aggregate industry (called quarry fines or quarry dust), typically without large-scale beneficial reuse opportunities. This results in stockpiles
of unsalable dust. While research around reuse applications has been on the rise, this quarry dust could be used by the agriculture industry to reduce fertilizer costs and improve soil conditions (depending on the geology).

A similar situation exists in Michigan’s upper peninsula, where “stamp sands”—historic mine tailings—are being sought for use as a fertilizer.

Carbon Capture
Remineralization is also being explored as a method of carbon capture.14

ABOUT ROCK DUST FOR REMINERALIZATION
It’s important to recognize that not all rocks have an appropriate geology for use as a tool in soil restoration; some rock types offer greater performance over others.

Igneous, or magmatic rock formations, are especially favorable for remineralization applications. For this reason, the soil around young or active volcanoes is known to be particularly fertile; volcanoes pull minerals from deep underground and deposit them as part of the lava upon eruption. The lava then hardens into igneous rock, ultimately weathering and depositing the nutrients back into the soil over time.

Rock dust may also be generally referred to as rock flour, stonemeal, mineral fines, or quarry fines (or quarry dust).

Rock dust combined with biochar has also been recently examined with promising results.

NUTRIENT RECYCLING
More than ever, producers are looking at how “wastes” can be processed to recover any valuable material that could serve as a nutrient source. From agricultural wastes to industrial by-products (rock dust included), nutrients can be recovered for use in agriculture applications, reducing the amount of material going to landfill, while creating a more sustainable approach to crop nutrients in general.

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.16

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).17

SYNTHETIC GYPSUM
Synthetic gypsum, often referred to as FGD gypsum, is a by-product of the flue gas desulfurization process. This incredible material mimics the effects that natural gypsum has on soil, but does not require mining, and when used, is subsequently diverted from landfill. Synthetic gypsum can be processed into a soil amendment and has replaced the use of natural gypsum in many cases, even outside of agriculture.
The challenge with synthetic gypsum is that it can vary from source to source and often requires testing in order to produce a premium soil amendment product.

**MANURE**

Although manure has long been used as a fertilizer on farms, increasing regulation, coupled with the advent of large-scale industrial farming operations has created a pressing need for better manure management practices. This has farmers between a rock and a hard place; they often do not have enough land to accommodate spreading all of the manure, and hauling it more than a few miles from the farm is very costly. At the same time, it is a valuable resource rich in nutrients.

Fortunately, technology is advancing to meet the changing industry; on-farm nutrient recovery and manure granulation facilities are transforming manure into a premium fertilizer product. This alleviates the challenges that come along with raw manure, and in many cases, can even create a profit where waste management costs were once incurred.

**FLY ASH**

Fly ash, a coal combustion residual (CCR), is a powdery substance produced in significant quantities at coal-generated power plants. Often stored in containment ponds, a breach can be devastating to the surrounding area, as was seen in the 2008 Kingston Tennessee spill that thrust the industrial by-product into the nation’s spotlight.

As one of the largest industrial waste streams, alternatives to storing and landfiling fly ash have been widely researched. Fly ash has been explored extensively for use as a soil amendment in particular, as it has shown to improve soil pH and potentially holds value as a source of nutrients for plants. For this reason, the agglomeration of fly ash into a granular soil amendment product is being studied on a global scale.

**BIOSOLIDS**

Much like manure, biosolids, or treated sewage sludge from wastewater treatment facilities, has seen increased attention in recent years as well.
Municipalities are struggling to effectively and sustainably manage an ever-growing and increasingly regulated material. And while alternative disposal methods do exist, they are often costly and not sustainable.

Through drying and granulation, however, biosolids can be processed to meet Class A Biosolid standards, the stringent requirements for land application set forth by the United States EPA.

Milwaukee Metropolitan Sewerage District has been producing a fertilizer product from biosolids since 1926, having diverted 9.8 billion pounds of waste from landfills since the product’s inception. The product, a nitrogen source, is known as Milorganite.

ROCK DUST
As mentioned, rock dust or quarry fines can also be used as a value-added product when employed as a soil amendment.

IMPROVED PERFORMANCE, APPLICATION, AND HANDLING
Outside of nutrient formulation and source, a number of ways to improve how fertilizers and soil amendments handle and perform have been developed as well...

GRANULES OVER POWDERS
The application of nutrients in powder form has been phasing out due to the many benefits of granules over powders, including:

- Reduced product lost as dust
- More predictable and accurate results
- Easier handling and application
- Reduced windblown product
- Mitigation of powder being carried away by rainfall (granules provide a more controlled approach to delivery and won’t wash away with rain)

PERFORMANCE ADDITIVES
A number of additives to improve handling and performance are also being incorporated into fertilizer and soil amendment products to create a better-
performing product. This includes:

**Coating agents**
- To maintain product integrity throughout its lifecycle
- To control nutrient release over time (i.e. controlled release, or slow release)
- To reduce attrition (the breakdown of granules into dust)
- To inhibit moisture penetration
- To promote moisture penetration

**Anti-caking agents**
- To maintain product integrity and prevent caking during storage or transport

**COMPLEX FERTILIZERS VS BLENDS**

Another area that has seen significant change is in the use of complex fertilizers over blends.

Fertilizer blends, in which primary components are separately manufactured and blended together to create a mixture that meets an overall nutrient grade, are still widely employed. However, instead of simply mixing these separate nutrient granules, many producers are moving toward manufacturing granules with the entire formulation in every pellet. This approach prevents issues associated with segregation of the nutrients, making results more predictable and effective.

While fertilizer blends have long been the industry standard simply because they were the only multi-nutrient option available, complex fertilizers have become the preferred choice in many cases—a fact exhibited in a recent forecast by Markets and Markets. According to the firm, a solid 6.5% CAGR is expected from 2017 to 2022, settling on a 54.32 Billion USD market value (up from 44.03 Billion in 2016). The growth can likely be attributed to the many advantages complex fertilizers can offer over blends, most notably when it comes to promoting uniform nutrient distribution on fields.

**COMPLEX VS. BLEND: WHAT’S THE DIFFERENCE?**

In some ways complex fertilizers and blends are similar; they both provide a multi-nutrient solution; both can incorporate additional micronutrients or other components into the formulation; and they can both be applied with standard spreaders.

Combined with their similarities, confusion around terminology often results in many perceiving no difference between these two fertilizer types. In actuality, however, they are very different. Here, we’ll use the following definitions:

**Fertilizer Blend** - A multi-nutrient fertilizer that has been produced via bulk blending.

**Complex Fertilizer** - A multi-nutrient fertilizer where the entire formulation is singularly contained within each and every granule. May also be referred to as a Complex Compound Fertilizer, or CCF.

**Compound Fertilizer** - Any solid, multi-nutrient fertilizer. Can be a blend or a complex fertilizer.

**FERTILIZER BLEND**

A fertilizer blend is a multi-nutrient product in which
the various components are separately manufactured and then “blended” or mixed together in specific quantities to create the desired formulation.

Because the various nutrient components are manufactured separately, they often vary in particle size and density.

**COMPLEX FERTILIZER**

Conversely, complex fertilizers are manufactured so that each and every granule contains the desired formulation instead of the nutrients being brought together as separate components. Raw materials are combined and homogeneous granules are produced —each containing the entire nutrient formulation, as illustrated above.

**ACHIEVING UNIFORM NUTRIENT DISTRIBUTION**

Uniform nutrient delivery is a key aspect not only in providing optimal crop nutrition and maximizing yields, but also in realizing the full value of the applied nutrients, as well as protecting the environment. When nutrients are unintentionally applied in excess, or in concentrated areas throughout a field, the potential for nutrient runoff to occur can be increased, though it’s important to note that this is dependent on many variables.

In order to maximize the ROI of applied fertilizers, provide complete nutrition, and reduce the potential for runoff to occur, it is necessary to achieve as much uniformity in nutrient delivery as possible.

While it might seem a slight difference, the all-in-one granule approach of complex fertilizers can make a big difference in performance when it comes to the uniform dispersion of nutrients on fields.

There are many factors that can influence the uniformity in which nutrients are distributed. Two primary considerations that can be controlled through the fertilizer itself are segregation of particles and the dispersal of particles from the spreader - both of which are significantly affected by product uniformity.

**PARTICLE SEGREGATION**

Particle segregation occurs as a result of the differences in size and density of the varying nutrient granules in a fertilizer blend. When exposed to the natural jostling of handling throughout the fertilizer lifecycle, this difference in particles results in larger particles being pushed upward—a phenomenon often referred to as the brazilian nut effect—in reference to a can of mixed nuts where brazil nuts make their way to the top of the tin as a result of handling.
When applied to granular fertilizer blends, this effect can cause nutrients to become concentrated to some areas, instead of homogeneously mixed as they once were. This can occur during shipping or storage, or even in the spreader feed hopper. And while not the only factor influencing the uniformity of spreading, it has the potential to significantly affect the distribution of nutrients. As such, product uniformity is the key to the success of complex fertilizers; because all granules were manufactured in the same setting, the granules are much more uniform in size, shape, and density, eliminating the opportunity for segregation during handling.

**NUTRIENT DISPERSION IN SPREADING**

The difference in particle size, shape, and density can also be problematic during spreading. Depending on the characteristics of the granules, they may be more or less able to fly long distances when expelled from the spreader, resulting in uneven dispersion.

Again, this uneven distribution of nutrients can result in unpredictable results, an increased potential for runoff, and wasted nutrients.
PRODUCTION
EQUIPMENT | PELLETIZING | COMPACTION GRANULATION | DRYING | COOLING | ROTARY VS. FLUID BED | HANDLING

Hog manure granulation facility engineered and built by FEECO
Just as there is significant diversity among granular fertilizer and soil amendment products, there are many ways in which these products can be produced. Whether producing a single nutrient product, a multi-nutrient complex fertilizer, organic-based fertilizer, or soil amendment, the process configuration for a given application is often based on a highly flexible approach to granulation centered around several key pieces of equipment. This approach is designed to respond to the unique characteristics of the feedstock in order to produce a product with the desired specifications in the most efficient way possible.

For this reason, an overview of each piece of key process equipment is provided below. A look at how these pieces of equipment are combined into systems follows the equipment summaries.

**FERTILIZER & SOIL AMENDMENT PRODUCTION: KEY EQUIPMENT**

Several pieces of equipment prevail in the commercial production of granular products for use in agriculture, whether they are considered more traditional, or specialty. The equipment listed here is highly customizable and adaptable, and as mentioned, can be combined into various configurations in order to produce a product to exacting specifications.

**GRANULATION DRUMS**

Granulation drums, also called granulators, are a type of non-pressure (tumble growth) agglomeration device. Incredibly versatile and with a high throughput, they are the centerpiece of many granulation operations—especially when working with a chemical reaction, high throughput, or long retention time.

Granulation drums are used to produce a wide range of products, both organic and inorganic.

**HOW GRANULATION DRUMS WORK**

Granulation drums work by tumbling material in a rotating drum set at a slight angle. Particles are tumbled on a bed of fines (recycle), while a binder spray system continuously sprays the particles so they become tacky and pick up more fines—a layering effect known as accretion.

When a chemical reaction is involved, material inputs are pre-reacted and fed into the drum as a slurry. As the material cools and solidifies, the tumbling action rounds it into granules. A bed of recycle and binder spray system may or may not be used.

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.
COATING DRUMS
Coating drums are similar to granulation drums, but instead of granulating, they serve to coat granules with an additive. This might include an anti-caking agent, anti-dusting agent, or other performance- or handling-enhancing coating.

HOW COATING DRUMS WORK
Coating drums work much like granulation drums; the rotating drum imparts a tumbling action on the bed of granules. As the drum rotates, a spray system affixed to the interior of the drum sprays the tumbling bed with the desired coating. The tumbling bed helps to evenly distribute the coating throughout the granules.

PIPE REACTORS
Pipe reactors are an optional component in some settings employing a granulation drum with a chemical reaction. Pipe reactors are integrated into the granulation drum and serve to react the materials, as opposed to reacting them in pre-neutralizing tanks prior to the drum. The benefit to pipe reactors is that they allow the heat of the reaction to be captured and used to flash off moisture from the granules in the drum, significantly reducing the energy requirements of the downstream dryer.

HOW PIPE REACTORS WORK
Pipe Reactors are simply an acid-base reaction vessel into which the reactionary constituents are fed. The produced hot melt is then sprayed into the granulation drum, again, cooling and solidifying into granules as it tumbles.

DISC PELLETIZERS
Disc pelletizers, or pan pelletizers, or pelletizing discs, are another non-pressure agglomeration device. Granules (or “pellets”) produced in this manner are often referred to as having been “pelletized.” Disc pelletizers promote a tighter window of particle size distribution and can be used to create a very refined spherical product.

HOW DISC PELLETIZERS WORK
Disc pelletizers work by tumbling material on a rotating disc in the presence of a liquid binder. As in the granulation drum, the continuous addition of fines and
binder causes the particles to become tacky and pick up additional fines as they tumble. This allows the pellets to “grow” to the desired size, at which point they exit the pelletizer.

**FEECO DISC PELLETIZERS AT A GLANCE**

<table>
<thead>
<tr>
<th>SIZE</th>
<th>24&quot; - 25' (0.6 - 7.5m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPACITY</td>
<td>100 lb/hr - 100 TPH</td>
</tr>
<tr>
<td>CUSTOMIZABLE?</td>
<td>Yes</td>
</tr>
</tbody>
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**PIN MIXERS**

Pin mixers are a type of medium-shear industrial mixer. In the agriculture industry, they are ideal for processing finely divided solids such as chicken litter and are especially adept at combining finely divided solids with a liquid binder. They may also be used to create “micro pellets” of minerals or nutrient combinations.

Pin mixers can be used as a stand-alone agglomeration device, or as the preconditioning step in a disc pelletizing or granulation drum setup.

**HOW PIN MIXERS WORK**

Pin mixers are comprised of a rotating cylinder affixed with rods (or “pins”) inside a stationary shell casing through which feedstock and binder are continuously fed. This type of mixer employs an intense spinning action to form agglomerates (often called seed pellets when preceding a disc pelletizer or agglomeration drum). This motion also densifies the material.

**FEECO PIN MIXERS AT A GLANCE**

<table>
<thead>
<tr>
<th>SIZE</th>
<th>10&quot; - 50&quot; (254 - 1,270mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPACITY</td>
<td>200 lb/hr - 70 TPH</td>
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<tr>
<td>CUSTOMIZABLE?</td>
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**PUG MILLS**

Pug mills, also commonly called paddle mixers, are another type of medium-shear industrial mixer frequently used in the production of fertilizers and soil amendments. Similar to pin mixers, they can be used as a stand-alone agglomeration device, or as the preconditioning step in a disc pelletizer or rotary drum configuration.

**HOW PUG MILLS WORK**

Pug mills utilize a gentle, kneading and folding over motion to thoroughly mix feedstock materials into a homogeneous mixture. Because of this type of motion, pug mills are ideal for combining solid and liquid feeds in heavy-duty processing applications where the feedstock is more of a sludge or slurry. They are frequently utilized when working with digested dairy manure.
HAMMER MILLS

Hammer mills are used for grinding down over-size pellets so they can be reintroduced into the process as recycle—a critical component in many fertilizer and soil amendment production operations.

HOW HAMMER MILLS WORK

Hammer mills use a spinning shaft affixed with hammers and/or chains to break down over-size product. Unlike many other types of hammer mills, which use a grinding or pulverizing action to break down material, FEECO hammer mills utilize a cracking action.

ROTARY DRYERS

Rotary dryers are an industrial drying system prized for their high capacity, heavy-duty build, and reliability. Rotary dryers are a forgiving piece of equipment, known to tolerate variance in feedstock moisture and particle size distribution, which is often a given in many fertilizer or soil amendment applications. Rotary dryers reduce the moisture content of the product to the desired level.

HOW ROTARY DRYERS WORK

Rotary dryers work by tumbling pellets in a rotating drum as a drying air moves through the drum. Flights, or material lifters, pick up the material, carrying it over, and dropping it through the air stream as the drum rotates to maximize heat transfer efficiency. The tumbling action imparted by the rotating drum offers the added benefit of “polishing” the pellets—further rounding them as they dry.

ROTARY COOLERS

Rotary coolers are an industrial cooling system used to reduce the temperature of material exiting the dryer. Cooling helps to prevent caking issues during storage and also mitigates the potential for damage to downstream equipment resulting from a hot material. A cooling step may or may not be used depending on the subsequent processing or handling required.

HOW ROTARY COOLERS WORK

Rotary coolers work very similarly to rotary dryers; material is tumbled in a rotating drum, while flights pick up the material and cascade it through the air stream. Instead of heated air, chilled or ambient air is used.

FEECO PUG MILLS AT A GLANCE

<table>
<thead>
<tr>
<th>SIZE</th>
<th>14” - 78” (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>

FEECO ROTARY DRYERS AT A GLANCE

<table>
<thead>
<tr>
<th>DIAMETER</th>
<th>3’ - 15’ (1 - 4.6m)</th>
</tr>
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<tbody>
<tr>
<td>CAPACITY</td>
<td>1 TPH - 200 TPH+ (1 MTPH - 181 MTPH)</td>
</tr>
<tr>
<td>CUSTOMIZABLE?</td>
<td>Yes</td>
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</table>
One often-overlooked aspect to fertilizer production facilities is the handling system. The right handling system often means the difference between seamless production and unnecessary downtime and headaches.

A variety of material handling components can be used to streamline the production process from raw material to end product. The most commonly employed types are listed here.

### BUCKET ELEVATORS

Bucket elevators transfer fertilizer 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 fertilizer bucket elevators is often 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 fertilizer 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 in a facility, 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.

SYSTEMS
The aforementioned equipment serves as the basis of most granular fertilizer and soil amendment production operations.

Here, we’ll overview some of the most common ways in which these pieces of equipment are combined to create the systems used for producing both traditional and specialty granular fertilizer and soil amendment products. It’s important to recognize that these processes are highly flexible and are often customized to serve the specific needs of the task at hand.

All of the following processes can also accommodate additives, allowing them to create single nutrient products, as well as complex, customized formulations of organic or inorganic origin. They may be used to produce a number of different products, including:

- Ammonium Nitrate
- Ammonium Sulfate
- Blood Meal
- Bone Meal
- Compost
- Feather Meal
- Gypsum
- Iron
- Limestone
- Manure-based Fertilizers
- Potassium Chloride
- Potassium Sulfate
- NPK
- And more...

TRADITIONAL GRANULATION
In the traditional (and still widely used) approach to fertilizer production, the feedstock components (for example, gaseous ammonia and phosphoric acid in the case of MAP or DAP) are reacted together to form a pre-neutralized, or partially ammoniated slurry. The
Slurry is then tumbled in a granulation drum where the reaction completes and the tumbling action rolls the material into pellets as it solidifies.

As can be seen in the diagram, material exiting the granulator moves on to drying in a rotary dryer. A screen classifies the particles, allowing on-size product to move on to cooling, while directing over-size product to a hammer mill for crushing.

Cooling is carried out in a rotary cooler and helps to bring down the temperature of the material, which helps to prevent caking, and creates a more stable product.

A coating drum may be used to apply coatings to improve product performance or to control release properties.

The crushed over-size material is combined with the under-size material from the screen and reintroduced to the process as recycle.

This approach is well established and offers straightforward, reliable and consistent production.

**GRANULATION WITH A PIPE REACTOR**

In some settings, a pipe reactor can be integrated into the granulation drum for a modified approach to the traditional method of granulation. This technique
is very similar to the previously described process, but in this case, feed materials are reacted within the pipe reactor instead of in pre-neutralizing tanks.

The hot melt produced from the reaction is sprayed into the granulator and the heat resulting from the reaction helps to flash off moisture from the granules. Product then moves on to drying, screening, and cooling, as shown in the diagram above.

This approach to granulation is very advantageous, because it allows the heat of the reaction to be captured and utilized, significantly reducing the energy requirements of the downstream dryer.
GRANULATION
(W/OUT A CHEMICAL REACTION)

When a chemical reaction is not required, raw material is typically first fed into an industrial mixer—either a pin mixer or pug mill—in order to create a homogeneous mixture of the feed components and binder. The mixture of newly formed seed pellets is then fed into the rotating drum, where additional binder is sprayed onto the tumbling bed of material, causing the particles to become tacky and pick up more fines. Drying and if necessary, cooling, follows, as shown in the diagram above.

MIXER TO DRYER GRANULATION

In the mixer-dryer approach, the pug mill serves as the sole agglomeration device. As shown in the process flow diagram on the next page, an industrial mixer is continuously fed with raw feedstock and binder.

The mixer works to promote a homogeneous mixture of feedstock components and binder, and also agglomerates the material. The particles exit the mixer and are fed into a rotary dryer. Here again, drying may be followed by cooling.

This approach is used with high moisture materials such as animal manures.
The mixer to dryer approach is advantageous because it is a simple, closed system; control is easy, and it does not require a lot of special knowledge or skill if the feedstock is properly preconditioned. Things like speed and paddle arrangement can be adjusted to vary the size of the desired pellet. It can also accommodate many different feedstock components for a highly customized product.

**MICRO PELLETIZING**

When using a pin mixer to produce small agglomerates in the mixer-dryer setup, this technique may be considered micro pelletizing.

“Micro pellets” are a popular choice in commercial landscaping and turf applications, as the small particles sink between grass blades so as not to detract from the appearance of the turf. They also offer faster product breakdown.

**DISC PELLETIZING**

In an approach similar to the mixer to dryer method, a disc pelletizer is incorporated into the process after the mixer, and before the dryer. Implementing a disc pelletizer in the process adds an element of fine-tuning and control over the end product. Variables such as spray locations, scrapers, incline, and speed, are all methods of optimization with a pan pelletizer, and help to offer enhanced control.
In this approach, the mixer preceding the disc pelletizer serves as a preconditioning step, homogeneously mixing the binder and feedstock. Preconditioning ensures a uniform mixture of the feed components is produced, so the end product is uniform in quality. This step is also used to form “seed pellets.” Seed pellets are the beginning agglomerates that, when fed onto the disc pelletizer, continue to pick up fines and “grow” via a layering effect known as accretion.

In general, adding a pelletizer to the process improves efficiency and quality of the end product; not only does a pelletizer create more on-size product, but the product is a little more dense, and has a more refined shape, as opposed to when solely a mixer is used, where the end product can be slightly rougher. Discs are also flexible with the addition of binders.

This method of granulation, often called pelletizing, is especially popular, because it creates a premium product. The produced granules are not dusty, allowing for easy handling and application, but are still capable of breaking down under standard field conditions. This method is frequently used to produce limestone and gypsum soil amendments.
Disc pelletizers can also be used as a stand-alone device (without the mixer), but this is not as common, because it is a more time-consuming approach to granulation, because densification is created gradually through the addition of binder, rather than through the medium-shear action employed by the mixer.

The various methods of production available to fertilizer and soil amendment producers are rich in opportunity for creating everything from traditional NPK grades to highly customized specialty products. The choice between the different systems is dependent on a variety of factors, some of which are listed below:

- Characteristics of feedstock
- Desired characteristics of end product
- Whether or not a chemical reaction is needed
- Capital and operating expenses

Testing in a facility such as the FEECO Innovation Center can also be an invaluable tool in working out process variables and developing a recipe for scale-up around your unique material.

**SIZE REDUCTION**

Granulation processes often rely on the ability to break down over-size material in order to reach ideal particle size distribution for feedstock, or to put over-size product back into the process as recycle. In order to break down over-size product, size reduction equipment is employed. And while there are a variety of size reduction equipment types available, one option—the hammer mill—offers a reliable size reduction tool for many applications.

Sometimes referred to as crushers, hammer mills provide an efficient solution for breaking down over-size granular materials at a high rate of production, without the use of a grinding action. They are particularly robust and adept at processing demanding materials.

**PARTICLE SIZE REDUCTION: WHY IT’S IMPORTANT**

Particle size reduction is most often desirable for one of two reasons: to provide recycle for the process, or to provide the necessary particle size distribution to create a product with the desired characteristics.

**RECYCLE**

After pellets have gone through the process loop, they are typically screened by size, where on-size product is separated out to move on to packaging or shipping, and under- and over-size pellets go back into the process, so they can be processed into on-size pellets, a process referred to as “recycle.” Here, under-size pellets typically go right back to the start of the process loop, while over-size pellets must be broken down prior to re-entering the process.

Employing a recycle loop aids in minimizing product lost because it was not on-size, making sure as much product is produced as possible.

Some processes require a certain amount of recycle in order to provide a process buffer, should any upsets in the process occur. Having recycle on-hand to put into the process can mean the difference between reliable, continued production of the desired product, or downtime and product lost. In these cases, hammer mills are a key component to operational success, helping to continuously reduce particle size and
provide a reliable source of recycle.

**PARTICLE SIZE DISTRIBUTION**

Oftentimes, in order to achieve the desired end product characteristics, a range in particle size distribution is desirable. This range in particle sizes helps to create a more cohesive pellet or granule, because smaller particles will fill in the spaces between larger ones. A feedstock with too large a particle size would result in a weak pellet, due to the increased amount of void space between particles in the final pellet. In this case, particle size reduction provides the feedstock with the smaller particle size needed to create a pellet of optimum strength.

**HOW HAMMER MILLS WORK**

FEECO hammer mills utilize a central rotating shaft, fitted with several “hammers” affixed to pivots on the shaft. As the shaft spins, the hammers are swung via rotational energy, causing them to collide with the material, breaking it up into smaller particles.

Hammer mills are flexible and can be used in a variety of applications. Because of their heavy-duty construction and high-capacity processing capabilities, hammer mills are most commonly utilized in mineral agglomeration and fertilizer production applications.

In a typical pelletizing process where the hammer mill is used in the breakdown of over-size pellets, the hammer mill is placed after screening in the process flow. In certain low-energy impact situations where the hammer mill is intended to break down raw material to reach ideal particle size distribution, the hammer mill would simply be placed at the beginning of the process.

**CHOICES IN EQUIPMENT**

While the flexibility available in granulation allows for a myriad of options in processing configurations to suit just about any need, it can also cause confusion over what equipment might serve the process best.

Below are a few comparisons that are often faced when developing a granulation process for fertilizer or soil amendment products.

**PIN MIXER OR PUG MILL**

Both pin mixers and pug mills are considered suitable industrial mixers in the granulation process. However, they each offer distinct benefits and capabilities. Typically, the material itself, along with processing considerations, will help in determining which mixer will best fit the needs of the process and material.

The following information outlines the basics on each mixer’s capabilities.

**THE PUG MILL**

**How It Works**

Material undergoes tumbling, kneading, and medium-shear action, resulting in an intimate mixture of materials.

**Typical Use**

Mixing, conditioning, or agglomerating.

**Processing with a Pug mill**

FEECO’s pug mill is a U-shaped, horizontal trough. Inside the trough, a series of pitched paddles are mounted on dual counter-rotating shafts that run the length of the device. The paddles move material from the bottom of the trough, up the middle, and back down the sides, creating a kneading and folding ef-
fect that intimately mixes the material.

The pug mill is also used for conditioning or agglomerating materials. In these instances, a liquid spray system is added to dispense a binder that assists with the conditioning or agglomerating process.

**Pug mill Applications**

The kneading motion of a pug mill makes this type of industrial mixer best suited for heavy-duty materials and applications. Typical pug mill material applications include:

- **Mixing**: FGD scrubber sludge, fly ash and lime for $\text{SO}_2$ neutralization, municipal sludge for composting facilities, and other processes combining moist and dry feed materials.

- **Conditioning**: Fly ash, cement or lime kiln dust, foundry dust, iron oxide, friction material waste, lead fume, iron ore dust, and zinc oxide.

- **Granulation of a variety of materials**: agricultural chemicals, fertilizers, pesticides, coke fines, chemical consumer products, carbon powders, cement kiln dust, flue dust from dust collectors, pigments, and dyes.

**THE PIN MIXER**

**How It Works**

Material undergoes an intense spinning action, resulting in densification.

**Typical Use**

Micro pelletizing, solids mixing, densification, de-dusting, preconditioning, conditioning, and granulation.

**Processing with a Pin Mixer**

The pin mixer is comprised of a stationary cylindrical shell that houses a high-velocity central rotor shaft. The rotor shaft extends the full length of the mixer, with numerous rods (or pins) that extend outward. A constant speed motor spins the rotor shaft at several hundred RPMs in order to impart agitation forces on the material. The motion and high rotational speeds produced by the pin mixer minimize air and reduce water volume between particles in the material. This results in densification many times that of a disc pelletizer. A fluid binder material is added in order to aid in the agglomeration process.

**Pin Mixer Applications**

Pin mixers are ideal for processing fine materials such as powders. Typical applications include:
• Calcium chloride
• Carbon black
• Coal dust
• Gypsum
• Limestone
• Mine fines (such as zinc sulfate)
• Pigments
• Sodium aluminum chloride
• Other fine particle materials

Pin mixers work well as a stand-alone agglomeration unit, or as a preconditioner in a two-stage agglomeration process involving a disc pelletizer. Pin mixers are also ideal components in an automated system, offering precise quality control and accurate production rates.

CHOOSING BETWEEN A PUG MILL AND A PIN MIXER
Pug mills and pin mixers both provide a wide array of benefits and processing capabilities. When choosing which industrial mixer to use, the material may help in determining which equipment should be selected. Processing system requirements and facility considerations are also used to determine the best equipment solution. However, the best way to choose between a pug mill and a pin mixer is to evaluate the raw material and decide what type of outcome is preferred; the equipment’s capabilities will lead to choosing one device over the other.

For example, a pug mill tends to handle sticky and/or abrasive materials a little better, because of its slower speed. It also offers a significantly higher throughput over a pin mixer, making it an attractive option for high-capacity operations. Pin mixers would likely get “bogged down” when trying to process a sticky material, and would not stand up as well to severely abrasive materials, due to its high rotational speed.

A pug mill is also more forgiving than a pin mixer, an ideal characteristic when working with tougher materials, or where tramp material could possibly enter the mixer; a stray rock or tramp bolt may cause a few pins to break off in a pin mixer, while the pug mill would likely not see any damage. This is also true when working with large particle sizes. Similarly, large particles could lodge between the pin tips and the interior wall of the pin mixer. In a pug mill, however, the clearance between the trough and paddles is greater, decreasing opportunity for this. There is also typically enough torque in a pug mill to dislodge particles as well, in the event that any do get stuck.

When looking to densify a material, the high-speed spinning action that occurs in a pin mixer can offer much better results than a pug mill. Pin mixers also excel in working with ultra-fine materials, such as pigments and dyes. The pin mixer’s ability to effectively micro pelletize a fine powder is tough to beat.

DRUM OR DISC?
Another commonly faced choice occurs in comparing a disc pelletizer with an agglomeration/granulation drum. There are many things to take into account that can help to make the right decision for the project at hand when looking at these two types of equipment.

Many times, the choice between a rotary drum and a disc pelletizer is dependent upon historical prefer-
ence; throughout various industries, one or the other has been used for generations, and there is no need for change. However, each device offers its own advantages in terms of product and performance, so it’s important to consider all of the factors.

RECYCLE

There are many differences between a drum and a disc, but whether the differences are an advantage or a disadvantage is often dependent upon the goals of the specific project. This is clear when looking at the amount of recycle in a process.

Overall, a pelletizer results in far less recycle than a rotary drum does. This is ideal in situations where the material goes from a pelletizer to a dryer, because the less recycle that has to be dried, the more efficient the process will be (i.e., the less recycle that needs to be dried, the less energy spent on drying).

However, while rotary drums may result in a higher amount of recycle, this recycle can also be beneficial to a process. For example, when utilizing a rotary drum agglomerator, the higher amount of recycle can act as a buffer in the process. If there is any upset in conditions, there is enough recycle in the process to help “even things out.” With a pelletizer, however, there is such little recycle, that when there is an upset in conditions, the output is almost immediately affected. Additionally, some material processes require a certain amount of recycle to function efficiently, and whether using a drum or disc, extra recycle is advantageous. Such is often the case when a pin mixer is introduced into the process. Some materials require a certain amount of recycle to be mixed in with the feedstock going into the pin mixer in order for the feedstock to mix efficiently before going onto the pelletizer. For this reason, it is often a requirement to have a little more recycle on hand.

SYSTEM CONSIDERATIONS

Another aspect to consider when choosing between a rotary drum and a disc pelletizer, is the throughput. When it comes to running a very high capacity, rotary drums are often the equipment of choice. Typically, a rotary drum can handle a much higher throughput than a pelletizer can. What might take a few pelletizers may only take a single drum.

While rotary drums allow for a higher throughput,
pelletizers are the equipment of choice when a tight window of size range is desired for the output product.

Creating pellets on a pelletizer has been likened to a form of art, allowing for customization and fine-tuning of the end product. Pan speed, pan angle, feed location, and binder location, are all things that can be adjusted to zero-in on the size range (among other qualities) of the pellets. However, this also means a pelletizer requires a much more watchful eye than a rotary drum. Where one operator would be capable of watching several drums, one operator should only watch a few pelletizers. Rotary drums are far more “limited” in terms of customization, offering fewer variables for adjusting end product, but subsequently requiring less monitoring.

Another side to consider in the choice between a rotary drum and disc pelletizer, is whether or not a closed system is desired. Rotary drums are considered a “closed system,” because the agglomeration happens within the drum, meaning the vessel can be sealed to help control dust and odor. The disc pelletizer is considered an open system, meaning the operation happens in a less sealed atmosphere than a drum.

MAINTENANCE
In terms of maintenance, pelletizers typically require less maintenance than a rotary drum. Though pelletizers do need to be properly maintained in order to function efficiently, there are fewer parts to be replaced—usually only scrapers and spray nozzles. With rotary drums, there are many parts that not only require regular maintenance, but that also need replacing now and then. It is important to note that the performance of either piece of equipment is severely hindered if not properly maintained.

ROTARY DRYER OR FLUID BED DRYER?
Perhaps the most notorious equipment comparison is that between rotary dryers and fluid bed dryers. Historically, rotary dryers have been used for more industrial applications, such as minerals, fertilizers, and aggregates, while fluid bed dryers have been used in the pharmaceutical, specialty chemical, and food industries.

Despite some industry preferences, the drying capabilities of these two industrial dryers have allowed for a significant amount of overlap in applications, and subsequently, confusion for which dryer is ultimately the best choice for a given application.

Though the choice between a rotary and fluid bed dryer can be material or industry specific, ultimately, each dryer has its own advantages and disadvantages. With comparable capital costs, the decision often comes down to customer preference and what will best suit the processing conditions, with a few considerations to keep in mind....
MATERIAL CONSIDERATIONS
Rotary dryers have been called the “workhorse” of the industrial drying industry, due to their heavy-duty construction, their high capacity capabilities, and most of all, their ability to tolerate variance in feedstock. Because of this, rotary dryers are better suited for heavy-duty materials where a lot of variety in feedstock is a given, such as with various minerals. Rotary dryers are known for their ability to take what is given and produce a quality product.

Conversely, fluid bed dryers have a very tight window when it comes to variability in feedstock, requiring as much uniformity in particle size distribution and moisture content as possible. Where a rotary dryer will just keep running with little to no process upset, variability in feedstock with a fluid bed dryer has the potential to leave an operation at a standstill; feedstock with lumps or inconsistencies in moisture content can cause serious problems when processed in a fluid bed dryer.

Additionally, rotary dryers are better suited for heavy processing loads; because it takes significant energy to fluidize large or heavy materials, it is not practical to process these types of materials in a fluid bed dryer. Fluid bed dryers are best reserved for applications processing lighter-duty materials.

Materials that must not suffer degradation are better served in a fluid bed dryer. Rotary dryers often result in some, albeit little, degradation to material, because of the fact that the material is being picked up and dropped. This is not an issue with all materials, but can be an issue with some.

Rotary dryers do offer the advantage of “polishing” granules; because of the rolling action on the bed of material, loose edges are knocked off and granules are further rounded, or “polished.”

SPATIAL FOOTPRINT
Rotary dryers are typically larger than fluid bed dryers, and therefore require a larger spatial footprint in the processing plant. Fluid bed dryers are smaller, and have the advantage of being modular, allowing them to be added on to, and making them ideal for situations where there is a likelihood for operational growth.

OPERATIONAL CONSIDERATIONS
Rotary dryers require significantly less supervision than their fluid bed counterparts. Rotary dryers are largely unaffected by fluctuations in feedstock and other processing conditions. They offer a consistently reliable solution in settings where inconsistencies in feedstock and instabilities in processing are to be expected.

Fluid bed dryers are much less suited for these types of situations, requiring a consistent processing environment. Variations in feedstock can cause major problems when working with a fluid bed dryer.

ENERGY CONSUMPTION
The choice between a rotary dryer or fluid bed dryer is also a matter of energy. Fluid bed dryers work by fluidizing the material, which requires a high magnitude of air. Additionally, because it takes a certain amount of energy to fluidize a material, energy is not reduced when running at lower capacities. As mentioned, because material is fluidized, it is not always practical to run high-volume, heavy materials through a fluid bed dryer, because of the extra energy required to fluidize the material.
Rotary dryers require less energy to dry material, and unlike fluid bed dryers, energy consumption is reduced when running at decreased capacities. In terms of thermal efficiency, the two dryers are comparable.

**MAINTENANCE & LIFESPAN**

In terms of maintenance and lifespan, rotary dryers and fluid bed dryers are comparable.

**PHYSICAL SPECS FOR GRANULAR FERTILIZERS & SOIL AMENDMENTS**

Fertilizer and soil amendment products have had a long evolution in terms of quality. At the start of modern agriculture, growers had few options—most of them not ideal. But advanced manufacturing methods, coupled with a greater understanding of nutrient and particle performance, has allowed producers to zero-in on precise product specifications to create a product that performs exactly as desired.

A product that is not produced to spec can cause a number of issues. This might include:

- Breaking down too quickly
- Breaking down too slowly
- Becoming segregated during shipping or handling
- Producing excessive dust, yielding lost product and a hazardous work environment
- Caking during storage or transport, and subsequent difficulty of spreading and handling
- Inconsistent product on the consumer end
- Inconsistent flow properties
- Increased potential for nutrient runoff

As modern technology allows, however, the above issues are largely circumvented by using production techniques to reach precise particle characteristics. While these characteristics (and the combination thereof) often vary depending on the product, some of the most commonly targeted physical specifications are listed here, along with the production techniques used to influence them.

**PARTICLE SIZE**

Particle size is a critical factor in the performance of fertilizer and soil amendment products and in most cases, is the first characteristic producers are looking to target. The particle size of a product influences two key parameters in performance:

**Rate of nutrient/active ingredient delivery:** In general, the larger the particle size, the longer the product will take to break down, with powders offering the fastest nutrient delivery (though they also often become windblown). It’s important to note that particle size is not singularly responsible for the rate of breakdown; many other factors come into play as well. Particle size can also influence the rate at which a fertilizer dissolves.

**Segregation of particles:** Segregation occurs when a mixture of particles of varying sizes naturally group together according to size, forming a heterogeneous mixture, instead of remaining homogeneous. This often results in uneven application and unpredictable results.

**PARTICLE SIZE DISTRIBUTION (PSD)**

Particle size distribution is a measurement of the amount of material that falls into each of the various size ranges within a given sample.
In addition to PSD, there are a number of other indicators used to define a sample’s size qualities in more detail.

**SGN (SIZE GUIDE NUMBER)**
The size guide number of a material is a commonly used specification to describe particle size characteristics. SGN is the mean, or average, of the particle sizes that make up the product.

This number is calculated by multiplying the average particle size (in mm) by 100.

**UI (UNIFORMITY INDEX)**
The uniformity index of a product is a measurement of the relative difference in size between particles. A UI between 40 - 60 is ideal for fertilizer (the larger the number, the greater the uniformity), as this will help to ensure that particles are uniform (mitigating potential segregation issues), but different enough within that uniformity that they will spread efficiently and maximize storage or packing space.

The UI of a product is calculated through the following equation:

\[
\left( \frac{d_{95}}{d_{10}} \right) \times 100
\]

- \(d_{95}\) - size of sieve opening that retains 95% of sample (smaller granule diameter), i.e., the amount of particles at or above this specific diameter
- \(d_{10}\) - size of sieve opening that retains 10% of sample (larger granule diameter) i.e., the amount of particles at or above this specific diameter

Example:
If \(d_{95} = 3.0\text{mm}\) and \(d_{10} = 6.0\text{mm}\), then the equation is as follows:

\[
\frac{3}{6} = 0.5
\]

\[0.5 \times 100 = 50\]
Since 50 falls within the ideal 40-60 UI range, this is an acceptable UI.

**GSI (GRANULOMETRIC SPREAD INDEX)**
Granulometric spread index is another size parameter producers are looking to control. This number quantifies how much variance exists between particles in a given sample. The lower the number, the more uniform the sample. GSI is calculated using the following equation:

\[
\frac{(d_{84} - d_{16})}{2 \times d_{50}} \times 100
\]

\(d_{84}\) and \(d_{16}\) = the diameter of mass fraction at the 84% and 16% percentile level, respectively
\(d_{50}\) = median diameter of the sample

**SURFACE AREA TO VOLUME**
Also important in particle size is the surface-area-to-volume, or surface-to-volume ratio. This may be given as:

\[\text{SA:V}\]

This ratio illustrates the relationship between the total volume of the granule compared to its total amount of surface area. SA:V is important when working with fertilizers and soil amendments, because it influences the rate of active ingredient delivery.

Particles with a high surface-area-to-volume ratio allow increased contact with the soil, which promotes faster product delivery.

Conversely, particles with a low surface-area-to-volume ratio will inherently take longer to break down and deliver the active ingredient. While in most cases producers are looking to promote faster delivery, the SA:V of a product can be used to control or delay delivery of the active ingredient when desired, such as when producing controlled-release or slow-release fertilizers.

As can be seen in the illustration above, smaller particles have comparatively more surface area to volume than a larger particle.

Note how as the granule breaks down, there is an increasing amount of surface area exposed and the surface area to volume ratio increases.

**FACTORS THAT INFLUENCE PARTICLE SIZE**
Particle size is generally influenced by the method of production and the process parameters used in the production setting - most notably retention time in the granulation unit.

In granulation (or “tumble growth agglomeration”)
processes, various equipment configurations can be employed to obtain a product within a desired size range. If a pin mixer or pug mill was used as the sole granulation device, the resulting granules would generally be smaller than those produced using the combination of a mixer and an additional device, such as an agglomeration drum or disc pelletizer.

In general, the longer the retention time, the larger the granules (up to the maximum size that the material characteristics would allow for).

Moisture content also plays a role in the size of the granules, as up to a certain point, the more moisture that is added to a seed pellet or particle, the more tacky it will become and the more fines it is likely to pick up during processing.

**CRUSH STRENGTH**

Crush strength, or hardness, is another key specification in soil product performance. As the name suggests, this metric indicates how much pressure is required to break a granule. Crush strength is often used as a predictor for the amount of degradation due to handling that will occur with a product.

For example, a low crush strength can cause granules to break down too easily (for this reason, granules with a low crush strength may break down at the bottom of a super sac under the weight of the product).

Achieving the optimum crush strength for the product will help to ensure that it is capable of withstanding handling, bagging, storage, etc., but will still break down as needed under standard field conditions. Crush strength is measured in the amount of pressure (lb. or kg.) it takes to crush a single granule. Crush strength for fertilizer and soil amendment products generally falls around 4-6 pound-force (LBF).

**FACTORS THAT INFLUENCE CRUSH STRENGTH**

The crush strength of a product can be influenced by several factors - most notably, the binding agent.

During the granulation process, the liquid binding agent causes the particles to become tacky, allowing them to pick up additional fines as they tumble. The binder affects crush strength in two important ways:

**Green Strength:** The crush strength of the pellets in their wet state is referred to as “green strength.” Reaching a suitable green strength is critical to maintaining pellet integrity throughout the process, as pellets must be able to withstand the various drop and transfer points that occur during processing. If an appropriate green strength is not achieved, pellets will break up during processing.

**End Product Crush Strength:** Upon drying, the binder enhances the bond between the particles to influence the end product’s crush strength. The amount of binder, as well as the type of binder, will impact this value. Binders are available by the hundreds, with some being better than others in the context of fertilizer.

Achieving a uniform distribution of the binder is also important. If binder and raw material feedstock are not properly combined into a homogeneous mixture, the finished product can vary in crush strength as a result of the uneven distribution.
Other factors that can be used to control crush strength include chemical makeup, agglomeration equipment/process used to manufacture the granule, material preconditioning, and moisture content. The different components within a product can also sometimes react, producing a stronger bond.

Particle shape can also impact granule strength. Since the sphere is the strongest shape, spherical particles will generally hold their shape and be less prone to premature breakdown than jagged or irregular granules, which are more easily influenced by external pressures.

**BULK DENSITY**
Bulk density is also a critical characteristic when working with fertilizers and soil amendments. Bulk density is the relationship between weight and volume of a given bulk solid material.

The bulk density of a material has a substantial impact on end product performance and handling, with implications in packing, shipping, metering, and spreading.

Bulk density is measured as the weight of a material at a given volume. For this reason, if the bulk density of a material is known, along with one other variable, the missing variable (weight or volume) can be calculated.

There are several variations of the bulk density measurement. The two most common are loose bulk density and packed bulk density:

**LOOSE BULK DENSITY**
The “bulk density” of a material generally refers to the material’s loose bulk density. This measurement is simply the material’s resting density after having been poured into a container, where void spaces exist between particles.

**PACKED BULK DENSITY**
Conversely, packed bulk density, or “tapped density” is a measurement of the material’s bulk density after the container of material has been tapped until no further change occurs. Tapping causes the void spaces to become filled in by smaller particles (if applicable). The difference between loose and packed bulk density is important to measure, because it can have several ramifications....

A material with a greater packed bulk density means that more material can fit in a smaller space. In some cases, this may be an advantage, such as when looking to maximize the allotted volume of a container. In other cases, it can be a disadvantage: material with a much greater packed bulk density may be packaged at loose density, but after transportation, appears significantly lower in volume. This can be especially troubling with consumer products: if a bag of product leaves the production facility full, but once on the shelf appears only half full, consumers may perceive the product as a lesser value.

**FACTORS THAT INFLUENCE BULK DENSITY**
A myriad of factors can influence the bulk density of a material, making it a complex specification to control in production. The most influential parameters are:
Moisture Content
In general, as the moisture content of a material increases, so too does the bulk density. This is because moisture adds weight. However, this is not the case with all materials; some materials, such as bentonite clay, will swell with added moisture, meaning that both weight and size of the particle are increasing.

Density of Each Individual Particle
Two particles of the same material and same size can have differing bulk densities. This is because a greater volume of material can be packed into the same size particle.

Production methods can greatly influence the density of particles. A pin mixer, for example, employs an intense spinning motion to create a homogeneous mixture of solid and liquid feed. This intense spinning action causes the particles to be more dense than if they were created in a disc pelletizer or granulation drum alone.

Particle Shape
Particle shape is another significant factor in the bulk density of a material, as it has a direct effect on the volume of void spaces between particles.

Particle shape has a number of influences on the performance of a soil product:
- Packing ability
- Flowability
- Amount of dust produced

ATTRITION
Attrition is the breakdown of particles into dust as a result of granule-to-granule or granule-to-equipment contact. Minimizing attrition is desirable in most cases to reduce product lost as dust, to avoid a hazardous work environment, and to mitigate other dust-related issues.

FACTORS THAT INFLUENCE ATTRITION
Particle shape has a direct effect on the amount of attrition that occurs; angular granules are more likely to result in attrition than round granules, as a result of the jagged edges being knocked off. For this reason, round granules are typically considered to be a more premium product.

HYGROSCOPICITY
Hygroscopic materials are capable of exchanging moisture with the surrounding atmosphere. This can result in off-spec product that does not handle or perform as intended. Similarly, it can also foster the creation of crystal bridges between particles, causing caking to occur.

Hygroscopicity is generally controlled through the chemical composition of a product, as well as through surface treatments or coatings to inhibit moisture absorption.
**SOLUBILITY**

Similar to hygroscopicity, targeting a specific solubility, or rate of dissolving, contributes to the overall rate of breakdown as well. One way this can be controlled is through surface treatments and coatings.

**PROCESS & PRODUCT DEVELOPMENT**

Despite the fertilizer industry being relatively well developed, defining the process parameters that will work together to produce precise product specifications is often a process that requires thorough R&D. Variation in raw materials, changes in production settings, and more, hold the potential to significantly "throw off" a process, or make it challenging to define on a consistent, commercial-scale basis.

Combined with the rising interest in producing specialty fertilizers and soil amendment products, a surge in process and product development around fertilizers is being seen. Testing in a facility such as the FEECO Innovation Center has become increasingly critical to the success of granulation processes. Some companies are even investing in their own granulation pilot plants to serve their ever-expanding product development needs.

Process engineers in the Innovation Center work with producers to test various equipment configurations, binders, and a myriad of other process parameters to develop a process that can consistently produce the intended end product on a commercial scale.

**COATING**

With producers and buyers becoming more discerning, the need to produce high-quality granular fertilizer products has never been more important; producing a product exactly to the desired specification has become a necessity in today’s ultra-competitive market, particularly when it comes to specialty fertilizer and soil amendment products.

This evolution of products has prompted an increased demand for better particle coating. The performance of a coating, however, hinges on its proper application to the product. And while conveyors have long provided a seemingly low-cost option, when a premium product is the goal, the use of a coating drum creates a uniform coating distribution, increases production, reduces downtime, and can even lower production costs.

**THE ESSENTIAL ROLE OF COATING**

The need to coat a material is pervasive throughout many industries. A sophisticated finishing process, coating allows the handling, storage, and performance properties of a granular fertilizer product to be more tightly controlled. The primary ways in which coating is used in this effort are summarized here.

**DUST CONTROL/DE-DUSTING**

Coating is an essential method of controlling dust when working with granular products. Dust results in product lost as waste and often creates a hazardous work area, both in terms of an inhalant and in some cases, even as a combustion risk. Furthermore, fugitive dust at industrial sites is becoming increasingly regulated.

De-dusting agents are used to create a protective coating around each granule to prevent the genera-
tion of dust. This is especially useful with granules that have angular edges, which are more likely to degrade into fines and dust (often referred to as attrition).

Products that are frequently coated to mitigate dust issues include MAP, DAP, sulfur, and potash.

ANTI-CAKING
Caking prevention is another way in which coating improves fertilizer products (and a variety of industrial materials as well). Caking can occur as a result of many factors, including chemical reaction, moisture absorption, and inadequate cooling. Caking is highly undesirable as it creates handling and storage issues, and often, yields spoiled product.

Like de-dusting agents, anti-caking agents are used to create a protective barrier around each granule. This coating prevents the exchange of moisture between the granule and the external atmosphere, allowing product integrity to be maintained throughout its lifecycle.

As a hygroscopic material, urea is frequently coated to prevent moisture absorption and subsequent caking. Hygroscopic materials may also be coated to prevent absorbed moisture from activating ingredients in the granule.

CREATING A PREMIUM PRODUCT
Coatings can also be used to modify how a material looks and performs as an end product. This is frequently seen with slow-release or controlled-release fertilizers, where coatings are used to control the rate at which the nutrients or active ingredients are delivered. Similarly, coatings also frequently serve to incorporate beneficial additives into a product, such as a microbial blend.

Coatings can also be used to improve the appearance of granules, be it through color or surface quality. It can also help to enhance flowability. Ultimately, coating allows producers to create a premium product in performance and appearance.

HOW COATING DRUMS WORK
The coating drum consists of a sealed rotary drum
which rotates at a defined speed while material is continuously fed into the inlet end.

Set on a slight angle, gravity helps to move material through the drum according to a predetermined retention time. As material moves through the drum, a spray system sprays the coating agent onto the material bed. In some cases, tumbling flights may be used to promote greater bed turning for improved coating-to-granule exposure. Spray systems must be designed for optimal distribution of the coating agent, taking into account factors such as spray locations, nozzle type, bed depth, rotational speed, and more.

Coating drums are typically smaller than a traditional granulation drum, but can range in size from 36” to 15’ in diameter (1 - 4.6m) and can handle capacities between 500 lb/hr - 3500 TPH.

COATING CAPABILITIES
Coating drums are highly diverse and can accommodate a wide array of both liquid and solid coating types, and are beneficial in any coating application. This might include powders, oils, waxes, polymers, or other coating types.

ADVANTAGES OF A COATING DRUM
Producers can spend years developing the perfect coating formulation for their product, but that does not mean it will work; the coating needs to be expertly applied to achieve optimal performance. This is where coating drums offer significant advantages over conveyors:

UNIFORM COATING DISTRIBUTION
When coating with a conveyor, material moves under the coating spray, but is stationary on the belt. This results in a liberal application to the topmost surface area of the material on the belt, while the granules underneath remain untouched. Similarly, if the feed rate of the coating is increased in an effort to improve coating distribution, the top layer will simply become more saturated with only a minimal improvement in distribution.

Conversely, coating drums tumble granules in a material “bed” as the drum rotates. This motion promotes greater granule-to-granule contact, which thoroughly distributes the coating throughout the bed. The result is a uniform distribution of coating on the entire surface area of each granule.
A uniform coating on the entirety of each granule’s surface is especially critical when blocking moisture absorption, such as with urea, as any uncoated spot can allow moisture in.

It’s important to recognize that with any coating equipment, the product feed rate must be consistent to achieve uniform results. For example, if the feed rate of solids to a coating drum was reduced while the amount of coating agent remained the same, the end product would have a higher quantity of coating than desired and could potentially change the final analysis, depending on the product.

**INCREASED PRODUCTION & REDUCED MAINTENANCE**

When using a conveyor to coat material, overspray is a common problem; since material typically lies in the center of the belt, coating may be inadvertently sprayed onto the adjacent belt surface as well. Overspray may also occur as a result of the coating agent spraying through the material, due to a high spray rate, or because material feed rate has been reduced, as shown below.

This not only wastes coating agent, but depending on the coating, could cause a number of issues, from pooling to build up. In severe cases, it can require that the operation be stopped for cleaning on a frequent basis.

Conversely, coating carried out in a drum contains the coating process to the drum’s interior and when properly designed, prevents regular disruptions due to buildup and mitigates the need for frequent cleaning to maintain operational uptime.

**REDUCED COATING AGENT REQUIREMENT**

As mentioned, uncontrolled overspray can result in a significant amount of wasted coating agent.

This problem is alleviated when using a coating drum, as the coating agent is used much more efficiently. This means that the same amount of coating agent...
provides better results, and in some cases, allows for a reduction in the amount of coating agent required.

**TESTING THE COATING PROCESS**

Achieving the perfect coating distribution often requires testing in a facility such as the FEECO Innovation Center.

Testing allows a number of variables to be tested and fine-tuned to reach optimal product coating. Data points may include:

- Rotational speed
- Coating feed rate
- Material feed rate
- Spray locations
- Tumbling flight design

The FEECO Innovation Center is capable of testing all of the variables above and more in order to gather the data necessary for the design of a commercial-scale coating drum.
CONSIDERATIONS

FACTORS THAT INFLUENCE GRANULATION | PROCESS & PRODUCT DEVELOPMENT

Potash granules created in the FEECO Innovation Center
FACTORS THAT INFLUENCE GRANULATION

Be it for a fertilizer or soil amendment product, the granulation process (and the many configurations thereof) requires a delicate balance of variables in order to economically produce a product that meets the desired qualities.

Depending on the feedstock, the end product, and the process used, these factors can vary significantly. For this reason, testing is often an essential step in the development of a process for producing a granular soil amendment or fertilizer product.

However, there are a few overarching themes that play into the success of any granulation operation no matter what the product. These are outlined here.

MEASURING GRANULATION SUCCESS

It’s important to recognize that the “success” of a granulation operation can mean many things. There are two primary ways in which a granulation process will need to be successful in order to make sense pursuing on a commercial scale:

END PRODUCT SPECS ARE ACHIEVABLE

Not all materials are capable of granulation. Similarly, some materials may agglomerate to an extent, but result in an inferior product. This is often the first explored avenue in assessing a granulation process: is the process/product physically possible?

ECONOMIC FEASIBILITY

Once the process has been deemed physically possible, the next question is whether or not the process required to produce the desired product is economically feasible. Just because a process can be carried out, does not mean that it is economically viable to do so.

Many factors that may not be obvious at first can throw off the economies of a granulation process. For example, perhaps in order for the process to work, an increased amount of one of the components is needed. The required increase means the product would be too costly to produce compared to its market value.

Or, perhaps a more costly binder is required to make the process work; or the most effective binder is not available in the project’s locale, requiring substantial transportation costs to get it there. Many potential factors exist. Similarly, if a significant amount of energy (natural gas, fuel oil, etc.) is required during the production process, costs may become too high.

KEY FACTORS INFLUENCING THE GRANULATION PROCESS

Whether or not the granulation process is physically possible is influenced by several parameters. The balance of these parameters, culminating in a product with the desired characteristics, is often determined through extensive testing in a facility such as the FEECO Innovation Center, or in an in-house pilot plant. The factors that have the most influence on whether or not the process is capable of being carried out are the characteristics of the feedstock, the desired end product characteristics, and the binder.
FEEDSTOCK MATERIAL CHARACTERISTICS

The starting point in any granulation operation is the material feedstock. Feedstock must meet several parameters in order for granulation to be possible, let alone effective. Important feedstock characteristics typically include:

**Particle Size Distribution**
The particle size distribution (PSD) of feedstock is a key contributor to the success of a granulation process. PSD should be generally uniform, with variation in desirable ranges differing depending on the unique project. In all cases, large particles will need to be removed or broken down, as they will inhibit granulation. This is commonly seen with manure feedstocks that may contain bedding fibers.

**Moisture Content**
The wet granulation process relies on capillary forces to be effective. This requires the addition of moisture throughout the granulation process, typically through the inclusion of a liquid binding agent (even in the form of water). As a result, the feedstock must be within a moisture range that can accept additional moisture without overwetting. This may necessitate a drying step prior to granulation, or back mixing—a technique in which dried material is mixed into the wet feedstock to reduce the overall moisture content of the inlet material.

**Material Composition**
The chemical and physical properties of each individual component in a product—and how they will interact—will need to be considered to avoid unintended consequences. For example, some components may chemically react to increase the bond strength between particles, resulting in a much higher crush strength than may be desired, ultimately causing delayed nutrient delivery. Similarly, components may be difficult to uniformly combine as a result of their physical or chemical properties. Some others may tend to become soft and/or plastic-like on wetting, requiring an adjustment in the process to work around this characteristic. Exothermic and endothermic reactions can also be problematic.

The amount of preconditioning required to bring a material within the range of specifications can sometimes push CAPEX and OPEX past the point of economic feasibility.

Furthermore, the desired components for a product may require that the ratio of these components be adjusted in order for granulation to be successful. These are only a few examples of how material composition can impact the physical and economic viability of a project.
DESIRED END PRODUCT CHARACTERISTICS
In addition to the material’s properties as a feedstock, the desired end product characteristics can also influence whether or not the granulation process can be successful, particularly in relation to particle size.

In some cases, it may be challenging to go beyond a certain pellet size, simply due to the material characteristics. The coarseness of particles, as well as their shape, can cause limitations in producing larger agglomerates.

Similarly, some materials can be difficult to produce as very small agglomerates due to yield concerns.

BINDER
The binder also contributes substantially to the overall success of a granulation operation. Binder contributes to process success in three key ways:

Fostering particle growth (coalescence or accretion)
The binding agent is what allows seed pellets, or nuclei, to become tacky and pick up additional fines. Without a binding agent, particles would simply tumble in the granulation device, without growth.

Ensuring proper green strength
Green strength is the strength of the pellet in its wet state, prior to drying. Achieving and maintaining an adequate green strength is what allows the pellet or granule to stay intact throughout processing. Various transfer and drop points often exist between the granulation device and the end product; particle integrity must be able to be maintained throughout this process to ensure that pellets don’t break down during processing.

Achieving desired crush strength
The binder also contributes to the crush strength of the end product, allowing it to withstand handling, transportation, storage, and application. Dry crush strength essentially ensures that a product arrives at its destination as intended and can be utilized exactly as designed, without prematurely breaking down.
Binders are available by the hundreds, each offering own unique properties in performance and composition. Depending on the material feedstock and the desired end product characteristics, some binders will be better than others. Furthermore, as mentioned, several economic considerations will need to be evaluated during the binder selection process.

PROCESS AND PRODUCT DEVELOPMENT

The interplay between factors influencing the overall success of a granulation process is complex and with some exception, generally cannot be determined through theory alone. Testing remains a critical aspect of being able to reach the answers sought, particularly in the field of new and advancing specialty products.

The importance of testing is further emphasized in the often-varying physical and chemical composition of source materials and minerals.

The Innovation Center can accommodate a broad range of fertilizer or soil amendment testing needs, with many equipment configurations and customizations available—all backed by decades of industry experience. Process Engineers in the Innovation Center can work to overcome the many challenges that can be faced during the development of a granulation process and/or product.

As a result of the comprehensive granulation expertise and process data collection capabilities, the FEECO Innovation Center has become an epicenter for such test work.

WHAT TYPES OF TESTING ARE AVAILABLE?

For fertilizer and soil amendment products, the following types of processes are typically tested:

GRANULATION & AGGLOMERATION

Granulation and agglomeration techniques are frequently tested in the Innovation Center for traditional and specialty products. The facility can accommodate organic materials, as well as 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.

As mentioned, the coating process can also be tested.

THERMAL TESTING

Testing for drying and high-temperature thermal processes is also available. Thermal testing is often conducted to determine the time and temperature profiles necessary for the material and to collect emissions data for the process. 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. Various types of equipment and configurations are available.

Testing typically centers around the creation of these desired specifications. Throughout testing, process engineers work with a number of variables in order to produce these results. Depending on the setup, variables may include:

- Material Feed Rate
- Amount of Recycle
- Binder Feed Rate
- Type of Binder
- Mixer Speed
- Type of Mixer
- Mixer Pin/Paddle Arrangement
- Disc Speed
- Disc Angle
- Dryer Temperature
- Dryer Air Flow
- Dryer Flight Design and/or Pattern

**THE PHASES OF TESTING**
The testing process in the FEEO Innovation Center generally happens in four phases:

**FEASIBILITY/PROOF OF CONCEPT**
Process engineers run batch-scale tests to determine if the specific source of material will agglomerate. Small sample sizes can be produced for use in lab or grow room trials to determine if the product will perform as needed.

**PROOF OF PRODUCT**
In this more in-depth batch testing phase, more time is spent determining if the specific manure sample can be made to exact specifications. Additional formulations and binders can also be tested.

**PROOF OF PROCESS**
Building off of step two, this phase utilizes a continuous setup to determine if the process is viable on a continuous scale, and what process variables will need to be for continuous production of the specific manure sample.

**PROCESS/PRODUCT OPTIMIZATION**
This phase works on fine-tuning the end product, as well as the process itself, providing a recipe for process scale-up. Samples produced can be used in field trials.

**AUTOMATION**
Throughout testing, FEEO process engineers utilize our state-of-the-art automation system from Rockwell Automation to gather, trend, and report on data, even adjusting process variables in real time.

While FEEO offers control systems as part of a system purchase, the capabilities afforded through automation in the Innovation Center are especially valuable during the testing phases, providing customers with complete process transparency through data visualization.

This provides for unparalleled data analysis during the process development stages.
The Innovation Center is also equipped with an on-line, continuous moisture analyzer, as well as an on-line particle analyzer for real-time analysis and adjustment—streamlining process and product development.

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 fertilizer and soil amendment products and raw materials. The unique capabilities of our testing facility allow us to test nearly any granulation 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.

“Our long-standing relationship with the fertilizer industry has made us the go-to place for testing new and modified granulation processes and products,” states Shane Le Capitaine, FEECO Process Sales Engineer. “Our experience has really put us on the cusp of developing new ideas into commercial-scale facilities.”

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.
ADDITIONAL RESOURCES

For further information or reading on specialty fertilizers and soil amendments, 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

The Fertilizer Institute (TFI)
www.tfi.org

International Plant Nutrition Institute
www.ipni.net

International Fertilizer Development Center (IFDC)
www.ifdc.org

International Fertilizer Association (IFA)
www.fertilizer.org

FAO
www.fao.org/home/en

World Fertilizer Magazine
www.worldfertilizer.com/

Argus Media
www.argusmedia.com/en/fertilizer

Remineralize the Earth
https://remineralize.org/

4R Nutrient Stewardship
www.nutrientstewardship.com/
REFERENCES

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 fertilizers and soil amendments, material testing, or custom equipment, contact FEECO International today!

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