
Cover Story

# A Pipe Dream

**Gabriele Marcon, Casale, Switzerland,** highlights how single and dual pipe reactor technologies provide a safe, flexible and efficient way of producing solid nitrogen, phosphorus, and potassium fertilizer.

Around the world, growing populations are in greater need of food. Thus, farmers have to control and expand their yields through the use of organic or inorganic fertilizers.

From place to place, soil quality and crop requirements vastly differ. Over the last few decades, the industry has made serious progress by spending time focusing on these core foundations. Farmers are consequently now in a position where they can be sure they are using the proper quantity and quality of fertilizer at the proper time to get the best efficiency.

As a result, by knowing a crop's specific requirement and having access to an in-depth soil analysis (which also indicates the remaining nutrients from the previous period), a farmer can calculate the quantity and quality of fertilizer to be sprayed on the field and the number and timing of application.

A fertilizer can be characterised by the total nutrient content and the ratio between these nutrients. For example:

- Urea contains 46% of nutrients with a ratio of 1-0-0 (nitrogen [N], phosphorus [P – expressed as phosphorus pentoxide ($P_2O_5$)], and potassium [K – expressed as potassium oxide ($K_2O$)] elements).
- Pure ammonium nitrate contains 35% of nutrients with a ratio of 1-0-0.
- 15-15-15 contains 45% of nutrients with a ratio of 1-1-1.
- 10-5-5 contains 20% of nutrients with a ratio of 2-1-1.

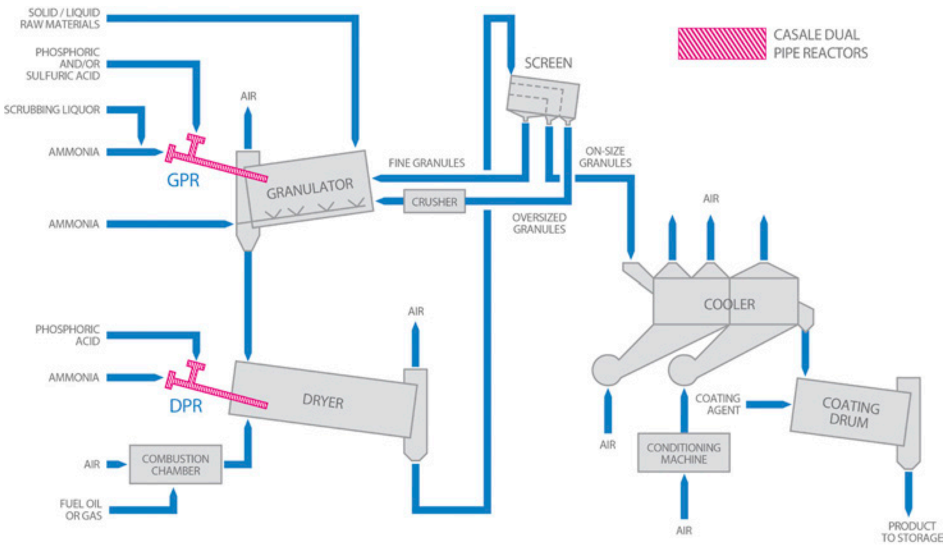


**Figure 1.** Dual pipe reactors process block diagram.

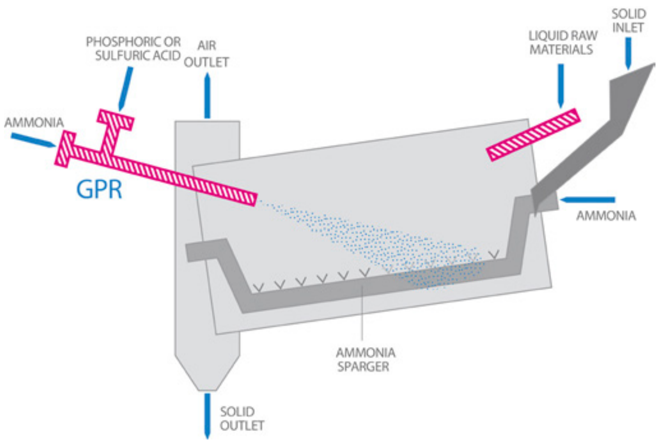


**Figure 2.** Drum granulator with granulator pipe reactor (GPR).

A plant's needs vary according to their type and the period of growth they are in.

A general basic fertilizer with a ratio 1-1-1 can always be applied, but may not have the desired effect the farmer may be looking for. To promote root growth, a fertilizer with higher P content, such as with a ratio 1-2-1, is a much better option. Meanwhile, to promote flowers and fruits, more K is required, such as in the fertilizers with a ratio of 1-1-2, 1-2-2 or 2-1-2. To promote leaf growth and, generally speaking, vegetation, a nitrogen-rich fertilizer is preferred, such as in fertilizers with a ratio of 2-1-1, 3-1-1 or straight nitrogen fertilizers, e.g. urea and ammonium nitrate.

Consequently, dependant on the desired growth patterns, a wide variety of fertilizers are produced, ranging from single nutrient to multi-nutrient fertilizers.

- Single nutrient fertilizers that only produce N include ammonium nitrate, calcium ammonium nitrate (CAN) and urea.
- At the same time, triple superphosphate (TSP) and single superphosphate (SSP) only provide P.
- Meanwhile, fertilizers such as mono-ammonium phosphate (MAP), di-ammonium phosphate (DAP) and urea superphosphate (USP) provide both N and P.
- Finally, NPK fertilizers are those that provide crops with all three nutrients: N, P and K.

There are two main categories of NPKs, depending on how their constituents are combined. They can be produced, for example, by physically mixing together separate granules of ammonium nitrate, MAP and muriate of potash (MOP) in a process known as bulk blending. On the other hand, compound fertilizers can also be produced using a granulation process to combine all three nutrients homogeneously within a single granule.

Compound NPKs are generally preferred over NPK blends as they do not segregate during storage and transportation, helping to ensure that nutrients are spread evenly during field application.

Furthermore, compound NPKs can be manufactured using a range of different raw materials.

The N source is usually a mix of ammonia, ammonium nitrate or urea. However, ammonium sulfate can also be used, either sourced as an external product or produced in-situ from sulfuric acid and ammonia.

The P can be sourced from phosphate rock or phosphoric acid (even if the phosphoric acid originated from phosphate rock). However, the disadvantage of using phosphate rock is the calcium content of the rock, which remains as a diluent in the fertilizer. As a result, it is not possible to produce some fertilizer grades, such as MAP and DAP, or the calcium must be treated separately, generating a side production of CAN. Although phosphoric acid costs slightly more than source phosphate rock, it is still a good alternative if the fertilizer plant is located far from a phosphate mine, as the shipping and storage requirement are typically less demanding.

The K source can be potassium chloride, or in very special cases depending on market value, potassium sulfate.

## General concepts

Casale's approach to the NPK process uses phosphoric acid. As previously suggested, the main advantages of this route are that:

- It can be operated on any site even at distance from any phosphate mine.
- It manufactures a better quality of products, particularly when compared to NPK bulk blends.
- It offers flexibility in terms of the different fertilizer grades which can be marketed.
- It generates high grade fertilizers (i.e. high quantity of nutrients in the fertilizer), avoiding the calcium associated with phosphate rock.

Some processes that use phosphoric acid are built with the inclusion of a pre-neutraliser. However, Casale bases the process on pipe reactors, a production technology that offers distinct advantages in terms of flexibility, safety and cost (both in CAPEX and OPEX). As a result:

- Less equipment is required.
- Neutralisation energy is not lost.
- The granulation loop capacity is lower than in the case of a pre-neutraliser.
- Less changeover time is required when a plant shifts production between different grades, enabling some operators to produce three different NPK grades in a single day.
- The different raw materials can be sourced from the international market.

Grassroot NPK plants can be designed with a single or dual pipe reactor, and existing plants that are already equipped with pre-neutralisers can be revamped with pipe reactor technology.

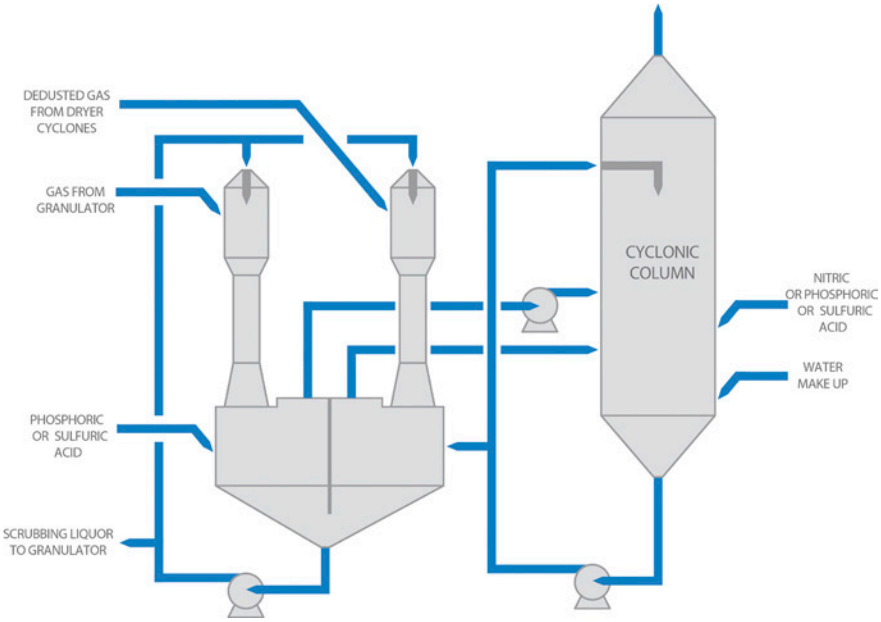


**Figure 3.** Scrubbing section.

**Figure 4.** Drums granulation plant overview.

## History

The granulator pipe reactor (GPR) and the dryer pipe reactor (DPR) processes were first introduced by Grande Paroisse in 1970 and 1974 respectively.

Since then, several NPK units were designed with capacities ranging from 110 tpd to more than 2800 tpd.

In 2014, Casale acquired from Borealis (which formerly acquired them from Grande Paroisse) the complete set of process technologies for the production of compound fertilizers (NPKs), superphosphates (SSP, TSP, USP), nitric acid, ammonium nitrate and urea ammonium nitrate (UAN) solution.

## Single pipe reactor process

A granulation plant using a single pipe reactor process comprises a drum granulator, a drum dryer, screens and crushers, cooling equipment and, if required, a coating drum. Equipment for transportation are also in place, as well as gas treatment devices in order to reduce the emissions of contaminants into the air.

The different solid raw materials are fed directly to the granulator along with the solids recycled from the previous process. Afterwards, the liquid raw materials are fed mainly to the pipe reactor, where the phosphoric acid is neutralised by the ammonia.

The molar ratio (MR) between the phosphoric acid and ammonia fed to the pipe reactor is an important parameter that needs to be considered when tuning the pipe reactor.

For the GPR, the MR is usually kept at 0.7 – 0.8 or 1.2 – 1.4 so that the fluidity of the slurry is at a maximum.

For NPKs containing a high quantity of sulfur trioxide ($SO_3$), sulfuric acid is fed also into the GPR. Sulfuric acid can cause serious corrosion issues within a pipe reactor, particularly due to the high temperature used to heat the slurry. Thus, it is essential to choose the correct material during construction to avoid costly damage.

Some ammonia is also fed into the granulator throughout an ammonia sparger, in order to help adjust the composition of the fertilizer and to assist the granulation process.

In order to allow the GPR to spray into the rolling bed without creating a build-up inside the granulator, Casale have developed an ammonia sparger which injects the ammonia directly inside the rolling bed of granules. It is equipped with a brace-shaped moving arm, enabling it to be lifted outside of the bed if necessary, such as during a plant shutdown. The movement provision of the arm also means it is possible to create a completely free space inside the granulator.

To enter the dryer, the granulated product exits the granulator through a chute. However, the chute can easily become choked, causing serious operational problems and impacting overall plant productivity. Consequently, the company designed a chute to limit this risk, which employs a special material for the area of the chute which remains in contact with the product. This material limits the adherence of the granules and remains flexible so that the automatic hammering system which is in place can achieve its full efficiency.

The granules are then fed to the dryer, which is a rotary drum with a co-current flow of hot air. The drum is fitted with optimised lifters to ensure maximum contact between the granules and the hot air during the residence time. The settings can be adjusted by a ring at the outlet whenever required.

A lump screen at the outlet of the dryer separates large agglomerates and directs these to the lump breaker. This device protects the elevator located at the outlet of the dryer from the risk of blockage and damage.

After being lifted up to the top of the plant, the granules are then fed through the screening devices.

Two deck screens move in a circular motion, having been fitted with an unbalanced shaft. These separate the granules into three parts:

- Undersized granules flow down directly to the recycling belt conveyor.
- Oversized granules flow down to the crushers, where their size is reduced before they join the undersized granules on the recycling belt conveyor.
- Granules of the desired size are then fed to the cooling system.

Granules on the recycling belt conveyor are recycled to the granulator, where their size is increased again by the feeding material.

The cooling system in place can vary depending on client preference as well as site and ambient conditions. Typical devices include a:

- Fluid bed cooler.
- Rotary drum cooler.
- Bulk flow cooler.

Selection is made on a case-by-case basis as a result of a weighing up the pros and cons of each system. Some examples of condition-based scenarios include:

- Fluid bed and rotary drum coolers both use air as a cooling media. Thus, in tropical conditions the humidity of the air, if not properly prepared, can affect the product quality.
- Bulk flow coolers are tall and thus an additional elevator is usually required. This can also affect the quality of the product.

Once the product is cooled down, it is usually coated before going to storage or the packaging unit.

A lot of air is used throughout the NPK production process, not only for drying and cooling but also for the dedusting of equipment.

Consequently, process air can be contaminated with chemicals (particularly ammonia, acids and fluorine) and dust and therefore needs to be treated before it is released back into the atmosphere.

Typical treatment of this air consists – when the air is dry enough – of cyclones to remove the dust that remained solid, which is then directly recycled to the granulator as solid material.

However, not all the contaminants can be collected as a solid, are therefore have to be collected in the subsequent wet part of the scrubbing system, consisting of a series of venturi and cyclonic columns.

Optimised gas treatment systems ensure that all the scrubbing liquors generated are recycled within the process. As a result, the process produces zero-liquid effluent under normal conditions.

## Dual pipe reactor process

Dual pipe reactor processes are designed to help optimise the granulation process by installing a second pipe reactor, the DPR, into the dryer.

The DPR works in almost the opposite way to the GPR, as it is designed to produce a solid rather than a slurry. In order to avoid clogging, the MR needs to be chosen and kept to around one, so that only solid MAP is produced. No sulfuric acid is used during this stage of the process.

Otherwise, all the other components of the NPK plant remain the same.

In order to increase the capacity of the plant using a single pipe reactor process, more raw materials are required, contributing to a larger quantity of liquid in the granulator. Therefore, to keep control of the granulation, more solids have to be recycled to the granulator, meaning the full loop capacity has to be increased across all equipment involved in the process, including the granulator, dryer, elevators, screens, crushers, etc.

Meanwhile, within plants using a dual pipe reactor process, a large percentage of the phosphoric acid and ammonia is fed directly to the DPR, where they react to form MAP, which is then recycled to the granulator. Essentially, the DPR supplies the granulation loop with extra MAP and by allowing additional N and P feed to be introduced directly as a solid, the overall output can be increased without having to add extra loop capacity.

In addition, because the neutralisation of phosphoric by ammonia is exothermic and takes place in the dryer, the heat produced helps contribute to the drying of material. In some plants, the heat of the reaction is the only heat used within the dryer, generating energy savings for the plant.

## Case study and revamp projects

Due to the flexibility the process provides a 2000 tpd plant has been able to successfully produce over 200 different grades of fertilizer within a single year.

However, licensed pipe reactors can not only be installed in grassroot plants, but in revamp operations as well. Typical revamp operations include:

- Replacement of pre-neutraliser by GPR or dual pipe reactors process.
- Addition of a DPR to a plant already equipped with a GPR.
- A DPR addition to a plant running with a pre-neutraliser.

Furthermore, the shutdown time need to implement revamp solutions is very short in comparison to a modification of the entire granulation loop.

## Conclusion

Single and dual pipe reactor technologies provide a safe, flexible and efficient way of producing solid compound NPK fertilizers, which provides the farmer and market needs with a competitive production unit. WF