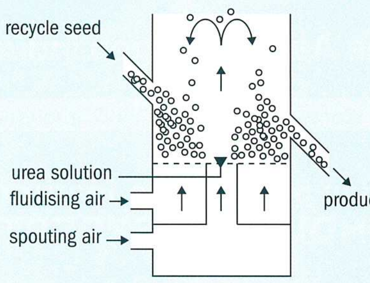
From prills to granules

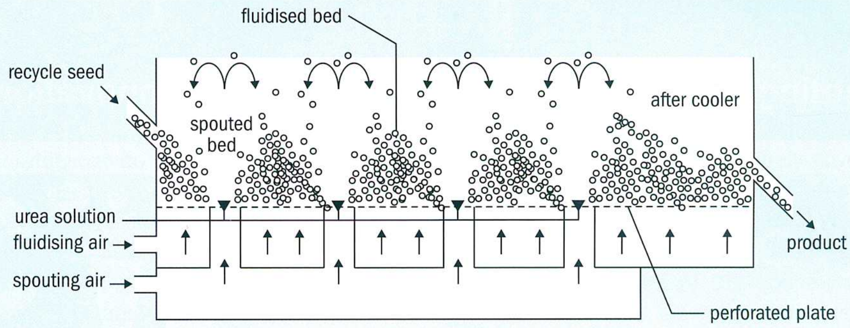
When a prilling tower limits urea unit capacity, granulation technology can be used to fatten prills, resulting in greater capacity and improved poduct quality, due to the increase in the average size of the prills and the improved prill strength. Toyo and NIIK report on their granulation technologies and how they can be applied for prill fattening.

Fig 1: **Spout-fluid bed granulation**



Source: Toyo

Fig 2: **Multi-stage spouted bed granulator**



Source: Toyo

Toyo's approach to prill fattening

Toyo's spout-fluid bed urea granulation process is mainly applied to produce granular urea from urea solution but can also use urea prills as seeds to produce granular urea in a prill fattening plant.

The Toyo spout-fluid bed granulation concept is shown in Fig. 1. The granulator consists of a spouted bed surrounded by a fluidising bed on a perforated plate, high performance spray nozzles, and spouting air pipes. Key features of the technology are reduced energy requirements and improved product quality.

In the granulator, a spouting bed is formed by an upward stream of air introduced to the spouting pipe of the granulator and a fluidised bed is formed around the spouting beds.

The air keeps the particles in suspension. Each spouted bed unit has one spray nozzle. The concentrated urea solution is sprayed using a proprietary spray nozzle into the spouted bed of urea seed particles in the granulator. The small droplets of urea solution are deposited on the circulating particles passing through the spray zone, which completely solidify before falling back onto the bed surface. The particles grow gradually by accretion of the sprayed urea droplets while this operation is repeated.

Since the air introduced for spouting and fluidising has effects on cooling and drying, the spout-fluid bed granulator functions as a cooler and drier. As a result of the drying function, 96% urea solution can be fed to the granulator to obtain a product with a moisture content of 0.3% or less.

Commercial scale urea granulator

Toyo's spout-fluid bed granulator is scaled up by proportionally increasing the number of spouting units while maintaining the capacity of the spray nozzle, flow rate of spouting air, and the geometry of the single spouting bed unit. An industrial scale granulator consists of a multi-stage spouted bed granulator as shown in Fig. 2.

According to pilot plant operation data, the higher recycle ratio gives the narrow particle size distribution of the granulator outlet granules as shown in Fig. 3. In the multi-stage spouted bed granulator, the recycle ratio of each spouted bed is inversely proportional to the number of spouted beds in series when the overall recycle ratio is constant (Fig. 4). The multistage arrangement produces very spherical granules with a sharp size distribution as shown in Fig. 5, even if the recycle ratio is low.

Seeds for granulation

Urea seeds required for the production of granular urea are generally supplied to the granulator by crushing the large sized urea. Prilled urea can also be utilised as seeds for granular urea production, in a urea fattening production scheme.

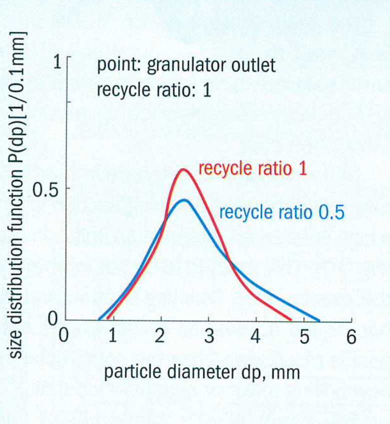
Typical urea fattening process scheme

The typical urea fattening process scheme is shown in Fig. 6, which is similar to the standard granulation process. The prilled urea is introduced to the granulator with recycle urea. The urea solution concentrated in the evaporator is fed to the spouted beds through proprietary spray nozzles to enlarge the recycle particles and prilled urea seeds in the granulator. The urea solution concentration fed to the granulator is 96-99.7% depending on the availability of the urea solution. The water in the feed urea solution is evaporated in the granulator.

The enlarged granules are cooled to a suitable temperature by fluidising air in the fuidised beds in the granulator.

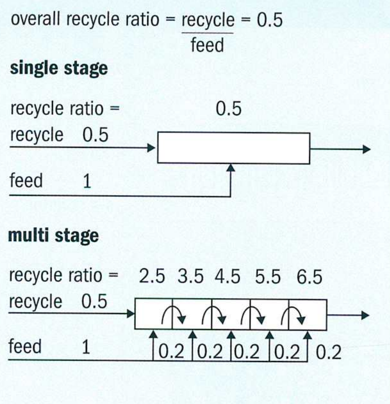
Coarse urea granules produced in the granulator are screened to separate

Fig 3: **Effect of recycle ratio**



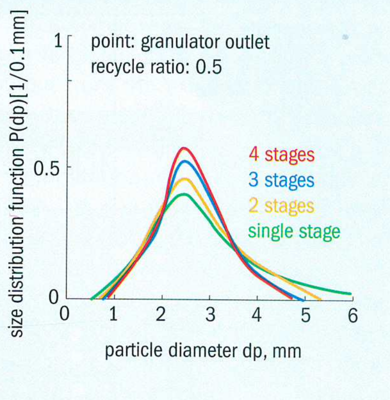
Source: Toyo

Fig 4: **No. of stages & recycle ratio**



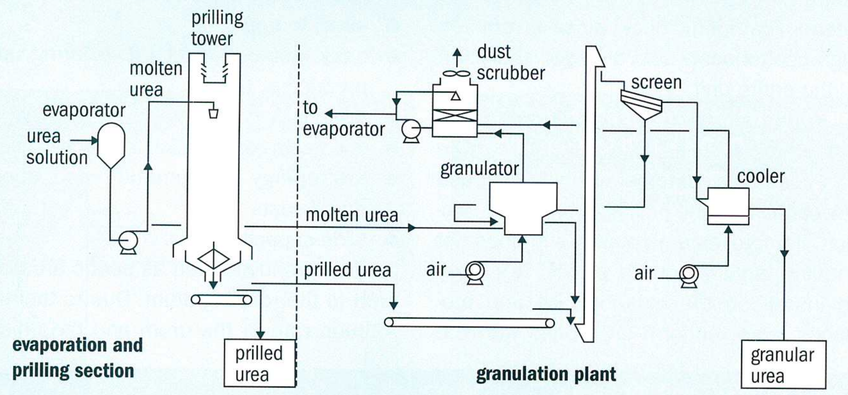
Source: Toyo

Fig 5: **No. of stages & size distribution**



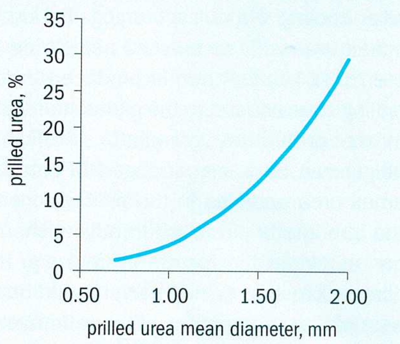
Source: Toyo

Fig 6: **Typical flow diagram of urea fattening plant**



Source: Toyo

Fig 7: **Required prill urea as seed for 3 mm granular urea production**



Source: Toyo

the product size granules from undersize granules. The undersize granules are recycled back to the granulator as seed. The product size granular urea is transfer to the urea storage house after being cooled down to the appropriate temperature for storage in the product cooler.

In the standard granulation plant, a crusher is provided to crush large sized granular urea to produce seeds for the granulation process. However, no crusher is required for the fattening plant since the seeds fed to the granulator are comparatively uniform in size. Dust generation is expected to be less with no crusher.

Prilled urea requirements for fattening plant

The prilled urea from the existing prilling tower has its own size distribution and mean diameter. In the fattening plant, the prilled urea requirement depends on the available size of the prilled urea as seeds. Fig. 7 shows the required prilled urea for a fattening plant. In the case, for example, where prilled urea of 1.4 mm is used as seed for the fattening plant to produce granular urea with 3 mm mean diameter, approximately 10% of the final production capacity is fed to the fattening plant for granular urea production. As the mean diameter of prilled urea is larger, the required amount of prilled urea is increased.

Reference plant

Mitsui Chemicals, Inc. constructed a urea granulation plant in its Osaka factory in 1983 to meet requirements in Japan. The plant produced 100 t/d of granular urea using molten urea and prilled urea as seed. This plant, stood adjacent to the existing prilling tower, and fully utilised the existing urea plant. Noteworthy features of the plant were:

- the molten urea feed pump is eliminated because the head of molten urea from the head tank on the top of the prilling tower was sufficient pressure for the spray nozzles
- no additional dust recovery system was required because the existing dust scrubber was utilised for the granulation plant.

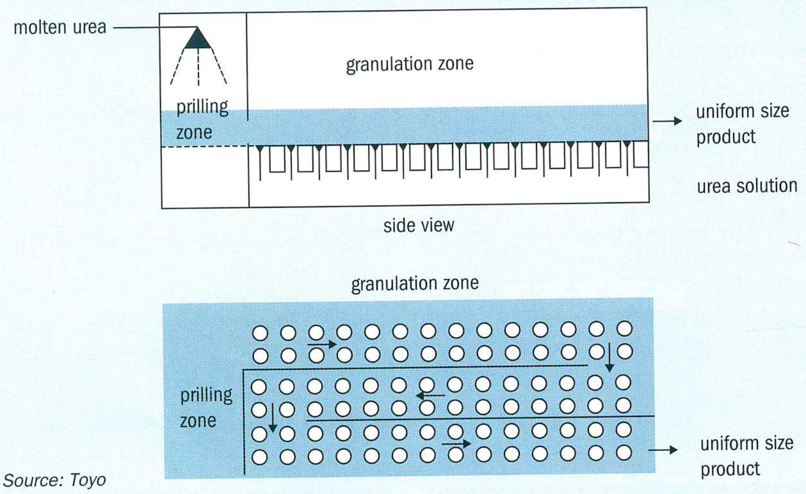
These features resulted in a more compact plant and less investment cost compared to the installation of an additional granulation plant to the existing urea plant with prilling tower.

Unfortunately, the granulation plant was closed in the 2000s due to market conditions which made imported granular urea more competitive.

Alternative granulator

The concept for an alternative Toyo granulation process is shown in Fig. 8, in which the number of stages in the granulator is increased to produce a product with uniform size distribution based on the multi-stage concept already described, so as to deliver

Fig 8: **Alternative granulator**



Source: Toyo

all granular urea to the urea storage house after cooling without screening. Spherical prilled urea with an average particle diameter of 0.4 to 0.8 mm is produced in the prilling zone and fed to the granulation zone in the proprietary granulator. Sufficient height can be easily arranged to produce small urea particles in the prilling zone of the granulator. This alternative scheme can eliminate the recycle system e.g. the screen, crusher, bucket elevator and other associated equipment. This alternative configuration has been patented in several countries including some process variations. The alternative configuration has several advantages such as lower equipment cost by eliminating the recycle system, simple operation, and small structure for granulation plant. When the prilled urea can be supplied from an existing prilling tower, the granulation zone only is provided. The alternative scheme is currently under proposal for a commercial plant.

NIIK experience in prill fattening

NIIK's high speed drum granulation (HSDG) is a universal technology that can be used for the production of urea-based fortified fertilizers such as urea with sulphur, urea with ammonium sulphate, urea with zinc and many others. Another application of HSDG technology is prill fattening (Fig. 9). For example, a urea unit can be upgraded in a small revamp to increase capacity by 15-20% with low investment cost. Larger capacity increases (>20%) of the urea finishing section (prilling, granulation) are often limited by the existing equipment and economical inefficiency, since it requires high capital costs and a longer shutdown of the entire unit.

In this situation, a space-saving drum granulator such as NIIK's HSDG can be very useful if a customer wants to increase the capacity of the prilling/granulation section. It improves urea quality and does not require large amounts of air. It's easy to install on the existing site and produces large, uniform urea prills with the properties of granulated product including their anti-caking properties.

The main feature of the HSDG unit as compared to other granulation units is a small external cycle which makes it smaller and cheaper and consequently reduces the production cost.

NIIK proposes an alternative method for revamping the urea finishing section in which a high speed drum granulation unit is installed (Fig. 10). This method does not interfere with the existing urea finishing section and does not require a urea unit shutdown. Its capital cost is much lower than the construction of a new prilling tower or a granulation unit.

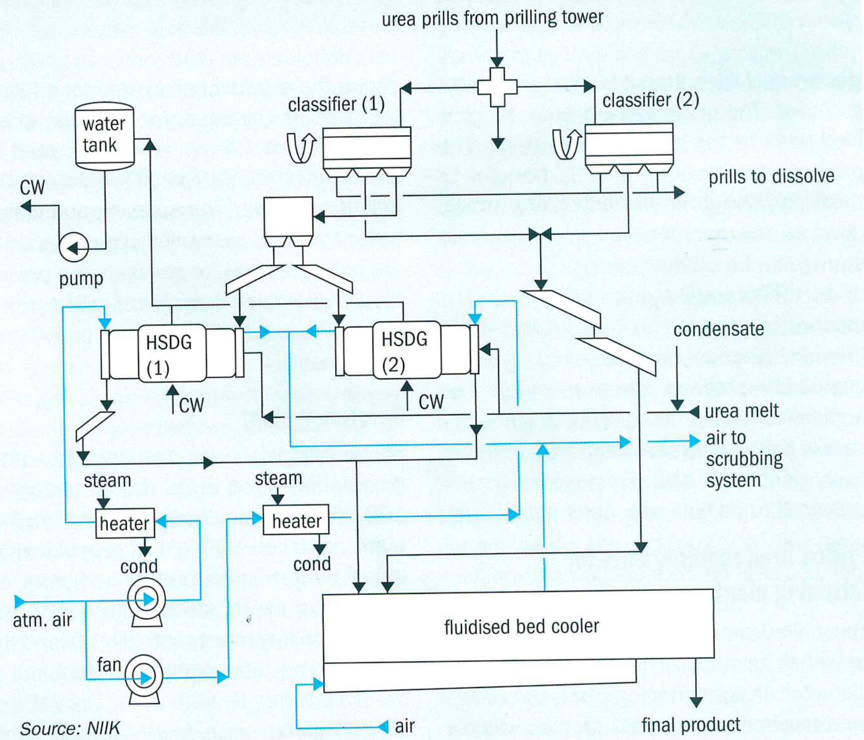
The capacity of a single HSDG varies from 120 to 240 t/d or 5-10 t/h. The total capacity of the HSDG unit can be increased by installation of several HSDGs.

The main advantages of the HSDG unit are:

- small footprint
- easy installation at the existing urea production site
- low consumption of air
- low steam consumption for process needs
- low energy consumption and operational costs
- wide capacity range.

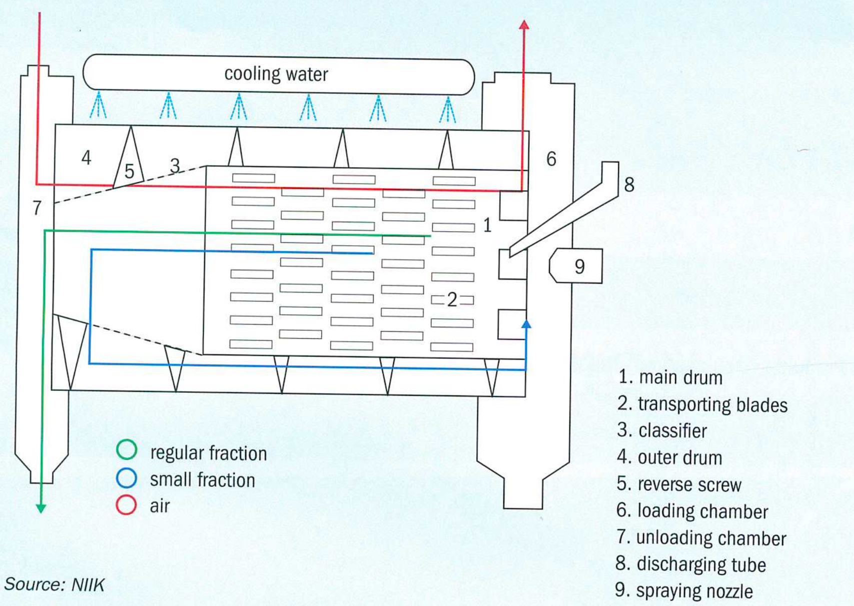
Prills or granules used as seeds are delivered to the rotating drum. Due to the high rotation rate of the drum and the unique

Fig 9: **HSDG unit for urea prills fattening**



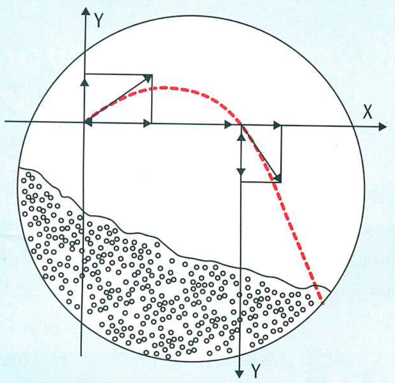
Source: NIIK

Fig 10: **High-speed drum granulator**



Source: NIIK

Fig 11: **Creation of curtain in the HSDG**



Source: NIIK

Table 1: **Properties of fattened urea prills produced in a HSDG**

Size distribution of fattened prills, %	
< 1 mm	1 max
1-4 mm	98 min
2-4 mm	92 min
screen residue 6 mm	n/a
Static strength of prills, kgf/prill	0.8 min.
Finished product temperature, °C	50 max.

Source: NIIK

design of the internal blades, the movement of the seeds follows a parabolic curve to form a dense and uniform curtain inside the drum (Fig. 11).

At the same time, a solution or melt is sprayed by spraying nozzles into the front part of the drum.

As a result, all the seeds are sprayed with the solution or melt many times thus being fattened.

After fattening with the solution or melt the product is supplied to the classifier where under-size granules are removed. The finished product is discharged from the classifier to the discharge chamber and transferred for cooling. The under-size product is delivered to the main drum via a screw conveyer.

The under-size product recycled to the main drum is again sprayed with the solution or melt. The spraying and classification cycles are repeated until the granules reach the required size.

Key features of the HSDG are:

- formation of a curtain inside the drum
- classification and internal recycle
- production process intensification due to increase of the drum rotation rate.

NIIK has a continuous mode HSDG pilot unit that is used to carry out granulation trials on different types of fertilizers, to optimise the operation process and to produce samples.

The HSDG was part of the revamping concept at Kemerovo Azot aimed at a capacity increase of up to 1,700 t/d (i.e. stable output of 1,700 t/d all year round) and improved urea quality. The revamping concept also included the modernisation of the MP condensation section and vacuum condensation of the evaporation section.

In summer when the ambient temperature is higher than 15-20°C the product output from the existing prilling tower is less than 1,700 t/d (output is reduced to 1,500-1,600 t/d).

Installation of the HSDG unit can offload the prilling tower to its design capacity 1,500 t/d and makes the operation stable reducing the number of defective prills and increasing the number of on spec prills with a size of 2-4 mm. The quantity of undersize prills (<1 mm) is reduced, the number of prills with a size of 2-4 mm is increased due to fattening of the small prills under 2 mm, consequently the strength of the prills is also improved.

After the evaporation section, urea melt is divided into two streams: the first stream goes to the prilling bucket in a prilling tower to produce 1,500 t/d of finished product and the second stream is pumped to the HSDG unit to produce 100 t/d of finished product per drum granulator.

Before supply to the HSDG the melt is diluted with hot condensate to a concentration of 96-98%.

After the prilling tower the prilled urea is conveyed to the classifier, where it is sorted according to the size of the prills: under 2 mm (small prills), 2-4 mm (commodity prills), over 4 mm (big prills). Big prills are delivered for dilution, commodity prills go to the fluidised-bed cooler and about 300 t/d of small prills are supplied to the feed chamber of the HSDG unit.

The small prills are fed from the feed chamber to the drum granulator, which produces the finished product.

To maintain the required temperature in the drum granulator, the external drum surface is cooled with water and ambient air is supplied to the drum granulator.

Exhaust air from the HSDG containing ammonia and urea dust is treated in the existing wet scrubber. The urea solution from the dilution section and the scrubber is delivered to the vacuum evaporation section.

In the event that the HSDG is stopped for any reason, the prilled urea from the prilling tower is delivered to classifier (2). Prills with a size of 1-4 mm are sent to the fluidised bed cooler and further conveyed for storage or handling. Undersize and oversize prills go for dilution.

The properties of the finished product quality following the revamp of the urea unit is shown in Table 1. ■