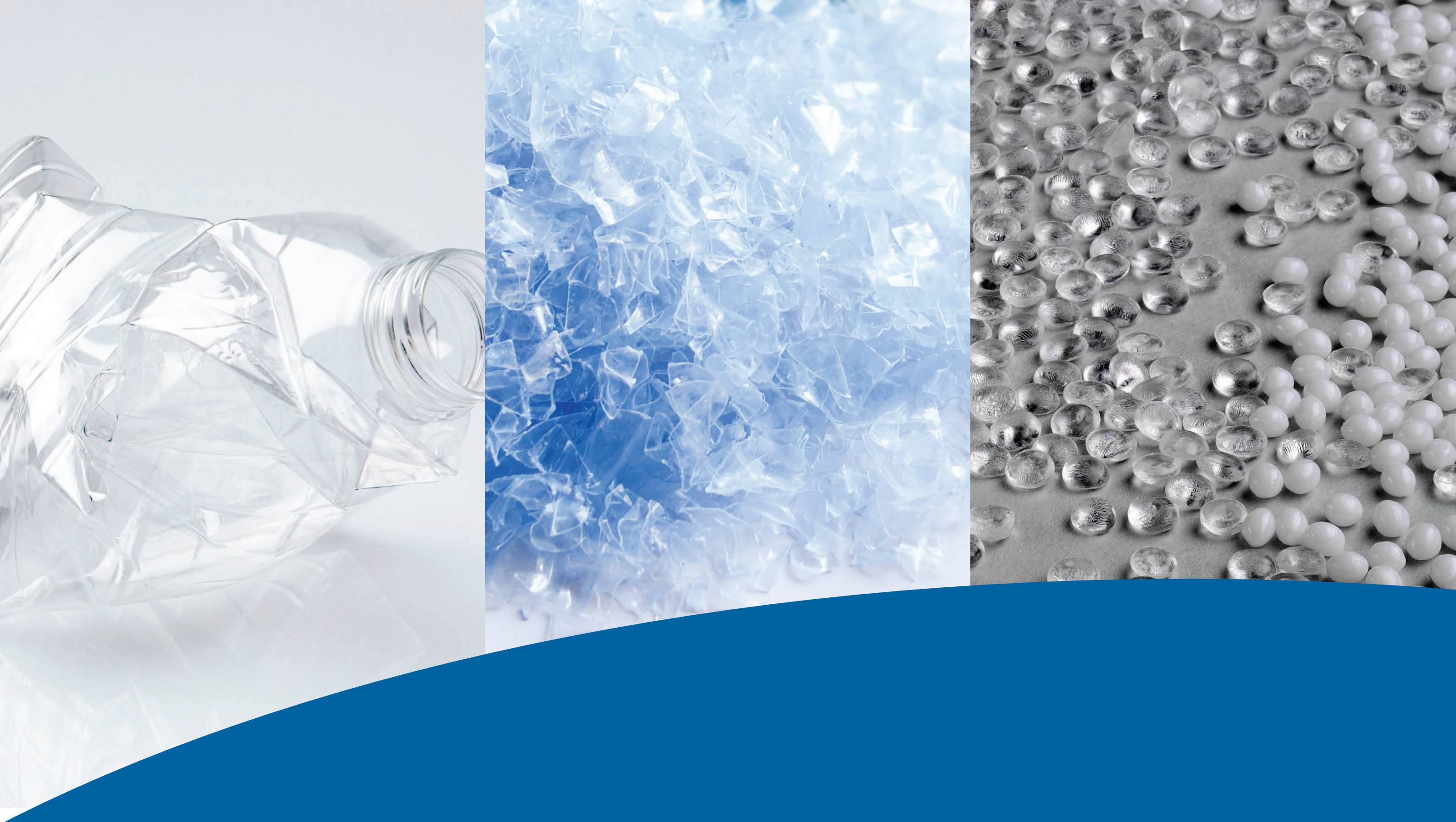


Melt Delivery and Pelletizing Systems For Producing Virgin-Like rPET

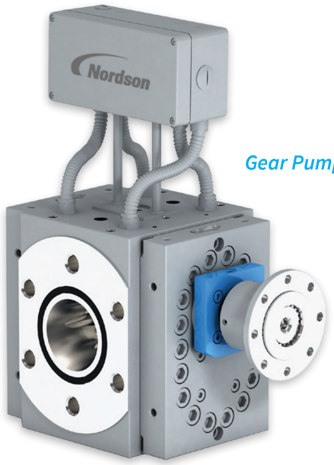
The worldwide boom in demand for recycled PET (rPET) has generated new challenges for polymer processing systems used to transform molten polymer from PET flake into high-quality material for reuse. By far the biggest challenge involves bottle-to-bottle recycling, where regulatory and marketing mandates now call for a dramatic increase in bottle collection and use of rPET in new packaging.

Downstream of the extruder, the key equipment in rPET production lines includes so-called "melt delivery" components - gear pumps and screen changers; pelletizing systems; and, as required, systems for crystallizing pelletized material. Among the major post-extrusion challenges faced by processors of PET flake are intensifying requirements for:

- *High levels of purity.* Bottle flake feedstock includes considerable amounts of contaminants such as labels, metals, paper, wood, and plastics other than PET. These substances must be filtered out by the screen changer.
- *Melt pressure stability.* A gear pump provides the uniform melt flow and pressure required for the process to operate efficiently and with uniformly high-quality product. The pressure requirements for each component downstream of the extruder must be calculated to determine the appropriate extruder drive rate and type of gear pump.
- *Fineness of melt filtration.* A fineness of 25 to 30 µm is essential for bottle-to-fibre applications in order to extend the working life of the screen packs on the spinning line. In bottle-to-bottle recycling, finenesses are now increased from a typical former level of 60µm or more up to 40µm or less. By comparison, a young, healthy human eye cannot distinguish particles finer than 50µm.
- *Minimal losses of polymer.* The widely used "backflush" screen changer ejects some of the polymer melt as part of the process of removing contaminants. Over time, the amount of material loss can be substantial. One goal of innovation in screen changers is to reduce such losses.
- *Energy efficiency.* In conventional underwater pelletizing systems, three phases where an energy input is required are **1)** maintenance of the tempered water system circulating through the pelletizer; **2)** drying of pellets; and **3)** crystallization. One goal of innovation is to reduce energy consumption in these stages.
- *High productivity.* The maximum throughput now considered the standard in producing rPET pellets for bottle applications is approaching 5 tons per hour. For post-extrusion components, achieving these rates depends on three factors: **1)** component designs that yield streamlined flow properties; **2)** enhanced control over melt pressure and temperature; and **3)** reduction in downtime for troubleshooting and maintenance.

Gear Pump

The gear pump shifts part of the job of building melt pressure from the extruder, thereby reducing stress on the extruder and on the processed material while delivering melt at the pressure level required by the screen changer and the following downstream equipment. In addition, the gear pump provides uniform flow, reducing surges and other process variations that can negatively affect the pelletizing process and pellet uniformity. With use of a gear pump, the degassing system of an extruder can be made more reliable, and the extruder length can be reduced.

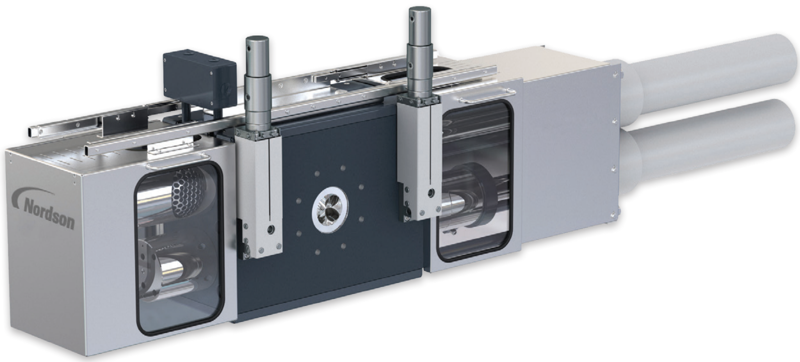


Gear Pump

Screen Changer

While typically deployed immediately downstream of the extruder and upstream of the screen changer, the gear pump may be preceded by an additional screen changer that provides “pre-filtration” at a fineness level down to 1,000 µm, removing large particles that can cause excessive wear to the gear pump. At this particle size, the contamination level is less than 0.1%, provided that there has been efficient washing and sorting prior to extrusion. Otherwise, the contamination level is higher.

Backflush screen changer



For the main filtration step in PET processing, a piston-actuated system with a self-cleaning feature based on a hydraulically powered process called backflushing is state-of-the-art. In a screen changer with four screen cavities, for example, melt flow is split into four streams. Backflushing starts automatically when the pressure differential caused by contaminant build-up increases to a pre-set level. Melt is then compressed and discharged in the reverse direction back through the screen, carrying away contaminant for removal from the system. The sequence is performed for each cavity, one after the other. In normal operation, polymer is flowing through all four cavities. While one of the cavities is cleaned, production continues through the other three.

There are two challenges to improving this type of screen changer: first, to reduce downtime by extending the working life of the screens and thus reducing the frequency of required screen changes; and second, to cut back on material loss by reducing both the amount of polymer expended per backflush cycle and the number of cycles needed in a given period of time. With a ton of PET bottle flake selling at € 920 Euros ($1,000 USD), material losses with a standard backflush screen changer, operating on a 24/7 basis, can amount to more than € 100,000 ($ 108,467 USD) per year.

To address these issues, Nordson has developed a filter stack composed of multiple so-called FlexDiscs™ which replaces the standard screen in each cavity, substantially enlarging filtration area while decreasing the melt loss caused by backflushing. Each filter stack consists of two to four cassettes, with two screen packs in each cassette.

In PET recycling, backflush screen changers combined with FlexDisc™ filter stacks have provided filtration as fine as 25 to 30 µm, increased screen lifetime, and exhibited more than 50% less material loss versus comparable screen changers. Comparative data from trials at one recycling company appear in **Table 1**.

FlexDisc™

Table 1

Reductions in Downtime and Material Loss
with BKG® FlexDisc™ Filter Stack for Screen Changers

Source: Nordson Corporation

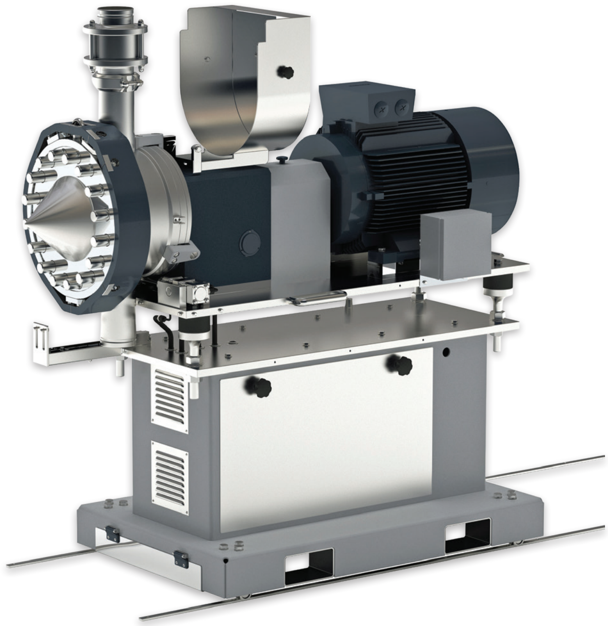
	Competitor (8 cavities)	BKG® HiCon™ V-Type-250-3G with BKG® FlexDisc™
Throughput	1,800 kg/hr | 3,968 lbs/hr	1,800 kg/hr | 3,968 lbs/hr
Filter fineness	30 micron	30 micron
Filter area	1,814 cm^2	4,000 cm^2
Screen changes per day	2 to 3	---
Screen changes per week	14 to 21	2
Screen working life (hours)	8 to 12	110
Maximum number of backflushes	20	120
Material loss per backflush cycle	11.33 kg | 25 lb	9.97 kg | 22 lb
Material loss per day	680 kg | 1,500 lb	239 kg | 528 lb
Material savings	---	65%

Pelletizing Systems

Two types of pelletizing system are used in PET recycling—strand pelletizers and underwater pelletizers (UWPs). A third type, water ring pelletizers, is not appropriate for lower-viscosity materials like PET.

Widely used for recycling, UWPs provide several advantages over strand pelletizers. The UWP can achieve by far the greatest throughput rates and is more capable of automation, making possible linkage with the upstream process. Unlike strand pelletizing, underwater production of pellets is a closed process, minimizing emissions as well as the generation of dust during production and in the final product. With constant melt flow (ideally ensured by a gear pump) and the flow uniformity provided by a round die plate, underwater pelletizing yields the most consistent pellet size distribution. The spherical shape of pellets produced under water results in 5 to 10% greater bulk density compared to cylindrical pellets, and it reduces their tendency to clog in subsequent post-pelletizing equipment as well as in hoppers and feed throats.

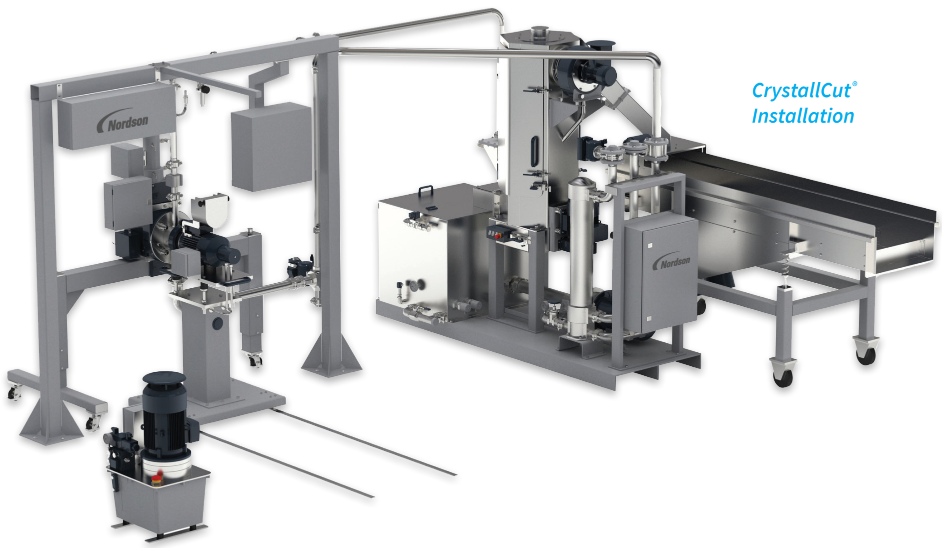
Downstream of the pelletizer are the pellet dryer and the tempered water system. After process water has been used in the pelletizer cutting chamber and for transporting pellets to the dryer, it needs to be cleaned of fines and cooled to within a strictly maintained temperature range for reuse in the pelletizing cycle. Fines-removal components in tempered water systems range from a woven wire mesh screen that periodically must be removed and cleaned manually, to systems that reduce downtime and operator intervention by providing continuous, automated filtration. Still more advanced is an automated, self-cleaning system that reduces overall pelletizer energy consumption by 10 to 17% by eliminating the need for a separate fines-removal system, which in standard systems requires a secondary, dedicated water pump.



Underwater Pelletizer

Energy-saving Inline Crystallization

For the bottle-to-bottle recycling process, systems have been developed that reduce energy costs by combining the pelletizing and crystallization step in a single integrated process. This technology uses the thermal energy of the molten polymer in PET pelletizing for subsequent crystallization, avoiding the need to cool PET after pelletizing and then reheat it for crystallization.



CrystallCut® Installation

The inline crystallization system developed and patented by Nordson, called CrystallCut®, is designed to work with the spherical pellets generated by UWPs and is an integrated network incorporating pelletizer, dryer, and crystallizing unit. rPET pellets achieve a crystallization level of up to 32% (in production of virgin polymer, by comparison, the figure is approximately 40%, depending on the initial quality of the material). Subsequently, a solid state polycondensation (SSP) reactor raises the intrinsic viscosity of the polymer and carries out a final decontamination step by removing trace substances like acetaldehyde, which have a deleterious effect on taste in food applications.

Pellet temperature in the CrystallCut® system is maintained at 140 to 180 °C. The system eliminates the intervening step of holding pellets in a silo at a maximum 60 °C (to avoid pellets sticking together) and a separate pre-crystallization step before the pellets are transferred to the SSP reactor. Alternatively, by adjusting process parameters, it is possible to bypass the CrystallCut® step or to produce amorphous polymer.

Compared with a traditional operation with UWP and SSP operating at 2.5 tons per hour, the CrystallCut® system provides thermal energy savings of 30 to 50 kWh per ton, electrical energy savings of 10 kWh per ton, a reduction in cooling water of up to 40%, and a reduction in fresh water for refill of up to 90%. As energy costs vary from region to region globally, plant operators need to calculate their cost savings individually, or Nordson can assist if the local cost structure is provided.

The system can be used to yield rPET with near-virgin properties. Because process heat is retained in the core of the pellets, crystallization takes place uniformly from the core to the outside surface. By means of process optimization, it is possible to achieve this crystallinity at small pellet sizes, making the rPET more compatible with virgin PET when blended. At the same time the higher bulk density of the rPET increases SSP capacity and reduces costs for transportation and packaging.

Complete Polymer Processing System

Polymer processing systems for PET recycling—from gear pumps through in-line crystallizing systems—are available individually, but there are benefits in sourcing them from a single company. Apart from the obvious one of reducing the number of interfaces during the engineering and purchasing phase, single-sourcing enables the supplier to design a system to maximize the efficiency with which the various equipment components interact. For example, the pressure demands of the screen changer and pelletizer affect the selection of the gear pump. Another important advantage of working with a single supplier is that of using a single control or software solution to integrate the entire post-extrusion system. With UWPs, the operator can use a single interface on the pelletizing system to access the extruder, feeding equipment, screen changer, and melt pump.

To meet the surge in demand anticipated for rPET, the recycling industry will have to achieve massive increases in new capacity. Along with the extensive equipment needed for producing high-quality flake from post-consumer PET bottles, recycling companies will have to invest in extrusion and post-extrusion systems capable of yielding rPET with properties as close as possible to those of virgin material. In helping these companies to supply a fast-growing market for rPET, new-generation post-extrusion systems will be key to increasing productivity and profitability.

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