# Drying and Crystallizing Systems for Reclaim Extrusion

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02/21/13

## Abstract

Many reclaim lines require moisture removal from the regrind material, and a PET reclaim extrusion line will not operate properly if the drying and crystallizing system cannot supply the material into the feed throat at the desired moisture content, temperature and intrinsic viscosity (I.V.). A proper drying and crystallizing system can be the difference between quality product and junk, so it is worthwhile to consider some features of the new equipment for your system:

- Correct sizing and proper operation
- New filter systems for increased performance
- High-efficiency motors
- New user-friendly PLC-based control systems
- Heat recovery systems
- Gas-fired options
- Integration with extruder control system

The following equipment is crucial to any reclaim extrusion line:

- Hot air dryer (material dependent)
- Crystallizer (material dependent)
- Dust collection system
- Dryer and hopper sized for the application
- Loading system
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## Introduction

A properly configured crystallizing and drying system will help produce your product with higher quality, improved efficiency and lower cost if they are reviewed and specified in advance.

## Auxiliary equipment sized to match downstream production needs

Many reclaim lines require moisture removal from regrind and reclaimed materials- with further processing required in the case of Polyethylene (PET); based on its chemical characteristics.

A PET reclaim extrusion line will not operate properly if the drying and crystallizing system cannot supply properly conditioned material to the feed throat at the desired moisture content, temperature and intrinsic viscosity (I.V.). A properly engineered drying and crystallizing system can mean the difference between having a quality product or an unusable finished good. It is well worth the time investment to consider multiple processing features of new equipment for your system:

Correct sizing of your upstream equipment relative to the desired throughput rates for recovery, as well as overall extrusion rates will be the first consideration for successful processing of reclaimed materials.
For example: many sheet producers – especially thermo-formers producing shapes with round configurations (i.e.: cups and lids) could easily have a 60% or greater scrap factor to consider. For PET sheet lines, this percentage of potential “loss” would quickly convert their business to a “non-profit” organization.

Considering typical reclaim percentages then becomes a relatively simple mathematical calculation. If a processor is running a thermoforming sheet line with a throughput rate of 1000 pounds per hour and has a maximum potential scrap factor of 60%, the recovery or reclaim rate desired should be sized to accommodate this potential, and will be equivalent to the needed rate of recovery at a reclaim rate of 600 pounds per hour.

## Size Reduction

The first consideration for reclaiming materials for re-use would be for size reduction equipment to obtain reclaim characteristics that can be processed more similarly to the original virgin material. Screening of the material to a consistency that provides greater bulk-densities and good flow characteristics are always deliberate and essential for further downstream processes.

Granulators configured with accessories to accept materials as-processed by the extrusion line are also desirable to avoid undue intervention by an attendee for this portion of the process.

## Crystallization Methodology

For PET processors, there are further considerations for the conditioning of reclaimed PET. In its natural state, PET is an opaque crystalline resin. Clear products can be produced by rapidly cooling the molten polymer to form an amorphous solid. In a process called “glass transition”, amorphous PET forms when its molecules are not given enough time to arrange themselves in an orderly fashion as the melt is cooled.

At room temperature these molecules are frozen in place, but if enough heat energy is put back into a controlled process, the molecular structure begins to migrate, allowing crystals to nucleate and grow. This procedure is known as solid-state crystallization.

Crystallization, or re-crystallization, has become an important process when considering potential losses of valuable petro-chemical “waste”. The massive amounts of post-consumer waste produced daily from food and beverage containers alone is staggering.

As mentioned previously, losses of in-house scrap-factors for large sheet producing facilities would accumulate startling amounts of waste in a just a matter of weeks – not to mention a stunning housekeeping problem.
Consider these statics for general reclaim of consumer products:

- Each year, 29 billion plastic water bottles are produced for use in the United States, according to the Earth Policy Institute, an environmental organization in Washington, D.C.
- Manufacturing them requires the equivalent of 17 million barrels of crude oil, so rising oil and natural gas prices have only exacerbated the high price of virgin plastic.
- *Plastics News* lists the price of PET virgin bottle resin pellets approaching $1.00 a pound, compared to 60 to 70 cents a pound for PET recycled pellets.

*Scienceline.org*

Selection of a properly sized crystallizer vessel is directly related to the bulk-density of the material, the size and shape of the particulates and the relative residence time or dwell time required to orient the molecular structure. Consistent agitation of the vessel is essential to disturb the tendency of the glass-transition phase to agglomerate. Thinner materials such as sheet or film will crystallize much more rapidly than more dense pellets, thicker sheets or blends of these materials.

Crystallization requires a heat source of forced-air through the column of material. A Hot-Air dryer is employed to control airflow with consistent temperature-controlled heating at the correct transition temperature to create an environment for molecular migration.

Special care in controlling the transition near the upper third of the vessel will have significant impact on successful crystallization.

## Dust Removal

Re-processing of sheet and other regrinds, inherently produces a small percentage of nuisance dust from size reduction granulation. There are several methods of separating dust from the process, including; high-tech de-dusting equipment, cyclonic elutriation, central dust-collection systems, and/or simple cyclonic separators. All of these solutions have the ability to remove significant amounts of dust and fine particles post-granulator, or further downstream – with price variations to match the amount of dust removal desired.

## Energy Conservation

Recent mandates for the use and distribution of energy-efficient motors have had an impact on the cost to operate machinery in the United States and abroad. Since the cost to operate generally rapidly outweighs the initial equipment investment, consumers and suppliers are always looking for ways to reduce, recoup and reuse energy – especially when heating and cooling are necessary processes involved in the manufacturing of finished goods. Engineers are always looking for ways to use otherwise lost energy sources and to return them to the process or use them in other localized process.

## Off-the-shelf PLC Control Solutions and Controls Integration

Customers requiring feedback and historical data from their equipment have distanced themselves from simplified “relay-logic” control systems to avoid troubleshooting issues and to have nearly infinite control of their processes.

This ability is not possible with a series of block timers and relays.
In an effort to answer this need, equipment manufacturers looked to the electronics industry for inexpensive solutions, which were generally proprietary boards with no standardized features for generally accepted protocols.

As technologies rapidly advanced in processing speeds, many of these components quickly became obsolete, rendering entire lines useless for a lack of viable replacements. Initially, Programmable Logic Controllers (PLCs) were an expensive luxury that few could justify.

Now that robust PLCs have become quite affordable, many equipment producers have realized that the era of proprietary components has reached an end-of-life cycle, and are supplying PLCs with greater expansion capabilities, faster processing, and recoverable data that can be logged and tracked – also lending itself to nearly fool-proof troubleshooting of equipment – or entire systems.

PLC manufacturers, as well as governing institutions such as SPI have realized the need to integrate entire systems with a common communication standard generally referred to as “protocol”. These firmly established protocols allow users to have a common, standardized and regulated transmission of data between all equipment, computers and peripherals.

## Gas-Fired Options

Natural Gas and Propane remain as efficient and viable options for processes requiring reliable heating.
In some areas of the United States and abroad, natural gas supplies are prevalent and readily available. High consumption users have been awarded subsides and deep reductions from gas producers. For these consumers with equivalent thermal usages for gas, the use of this natural resource outweighs electric heating costs.
Most equipment manufacturers have options available for gas-fired heater in lieu of electric heating elements.

## Typical Reclaim Extrusion Line - Summary of Equipment
## Focus on PET

### Granulation

Select size-appropriate granulator for rates equivalent to the highest scrap-recovery rate.
Select screen size for best bulk-density and flow characteristics
Evacuate granulator chamber with method best suited to dust separation and recovery of usable materials

### Dust Collection

Several methods are generally employed – and best solved immediately following granulation

### Crystallization

Amorphous PET requires crystallization.
Controlled heat and forced-air provide the methodology to initiate crystallization.
Agitation is essential as the transition phase creates tacky agglomerates that must be broken apart to achieve optimal crystallization and to avoid "chunks" of agglomerates.

### Blending

Once the amorphous material has been reduced in size for efficient handling; conveying and flow characteristics, it can blended with virgin material, colorants or other additives.

### Desiccant Drying

PET is a hydroscopic material and will readily bond with atmospheric moisture which must be removed prior to entry to the extruder or molding machine.

The drying vessel is sized for the "worst-case" bulk-density that will be processed at any time, thus allowing for adequate dwell-time in the vessel for proper drying.
This residence time is commonly 4-6 hours at ~350degF with 1CFM per pound, per hour airflow at the established temperature.

### Loading Systems

Generally, sheet recovery conveying and handling (post-granulator with dust removed) can be accomplished with a common vacuum conveying system – with considerations for the bulk densities of the reclaim and rates desired.

Where simplified dust-removal systems are employed and removal is not accomplish 100%, and/or the processor can use the fine particulates, filtered-receivers can be installed to avoid undue maintenance of the rudimentary screen filter found with most standard receivers.

### Poly-Lactic Acid (PLA) – "Going Green"

PLA, a plant-based polymer typically derived from corn nucleotides, has gained a foothold in the market as a viable replacement for petroleum-based products.
This product group has been touted as the new "renewable resource" that is also a bio-degradable solution to off-set the fact that we have become a "throw-away nation."

PLA is also a hydroscopic material as is PET, and will become amorphous requiring crystallization.
Although this material has similar characteristics to PET, it is significantly more "finicky" to process and prep for extrusion.

The crystallization phase uses much lower (and tightly controlled) temperatures, becoming tackier and "gummy" during transition to the crystalline state.
Once stabilized, it has more common "plastic" characteristics.
Desiccant dryer is a bit more conventional, but also requires lower temperatures.

### Newer Processing Technologies

#### Extruder designs

Several new technologies are being developed to help plastics processors to increase throughput rates, process lower quality regrinds and blends, and/or to eliminate conventional equipment such as dehumidifiers.

At least one manufacturer is working toward developing a new main screw and barrel design that utilizes a single main screw with peripheral "satellite" screws rotating in the opposite direction, driven by a ring gear in the main barrel
This design provides for more of internal exposure of the polymer and thus allowing for vapor or moisture removal at the machine.
The drawback of these technologies today is the extreme cost for the initial investment, and the fact that most existing machines cannot to retro-fitted with the necessary components, necessitating the purchase of a new extruder or main extrusion components.

#### Infrared Processing

Infrared (IR) technology is being developed as a well-controlled heat source that generates IR "waves".
IR waves excite and heat materials from the inside out to assist in expediting the release of moisture from wet and hydroscopic materials. Heated materials can also be tumbled in IR equipment to assist in the crystallization of some polymers.
IR has become an interesting and promising technology for some processing requirements.

***The limiting factors of IR processing:***

These systems do not operate in the necessary closed-loop / low-dew-point environments needed for many popular polymers and thus require further heated, and closed-loop, low dew-point drying.

Lamps and associated hardware can become overheated and require consistant air movement to keep the lamps and bases cool.

The lamps cannot tolerate dusty environments and can become fouled easily when processing dusty materials, and regrinds.

Complex zone controls and lots of moving parts for the internal tumbler beds.

## Re-Pelletizing and Conditioning of Recovered and Recycled Materials

Several companies have worked closely with polymer chemists to provide innovative machinery to convert reclaimed plastics from granulated sheets, shapes and containers back to a uniform pellet that increases the bulk-density, provides for much better flow characteristics, and for controlling the process for a wide variety of polymers to "condition" these materials to nearly approach virgin specs in some cases.

## Conclusion

A properly sized and configured crystallizing and drying system can provide the most economical and modular solution to produce a product with higher quality, improved efficiency and lower cost when reviewed and specified in advance.

New innovations by machinery manufactures and polymer chemists will assist the industry to reclaim and reprocess otherwise lost resources.

## References

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