Crystallizing and Drying of PLA

The majority of NatureWorks® polylactide (PLA) grades are semi-crystalline polymers with relatively slow nucleation and crystallization rates. As a result, most extruded objects from these grades such as sheet and pellets will be 100% amorphous after normal quenching operations. These grades include 2002D, 4032D, 4042D. Extruded pellets or sheet from 2100D could possibly contain some crystalline domains depending upon the quench history. Fully amorphous grades such as 4060D and 8300D will never crystallize and there should be no attempt to process them in crystallization equipment. In addition, all PLA is subject to hydrolysis when heated in the presence of water. Therefore, drying is required to prevent a loss in properties. This document fully explains the drying and crystallization options for PLA and provides some resources for equipment testing, purchasing and toll manufacturing.

Theory Behind Drying and Crystallization of PLA:

PLA is a hygroscopic thermoplastic. That is, it readily absorbs moisture from the atmosphere. The presence of even small amounts of moisture will hydrolyze PLA in the melt phase, reducing the molecular weight. As a result, the mechanical properties of PLA decrease and the end-product quality is compromised. Therefore, PLA must be thoroughly dry just prior to melt processing. In many cases, recycled PLA may also have to be crystallized prior to drying.

Unlike the other major packaging resins (e.g., polyolefins, polystyrene, and PVC), PLA is produced by a condensation reaction. This reaction, which also produces water, is reversible. Therefore, when undried PLA is melted the resin and water chemically react. Hydrolysis occurs and key mechanical properties of the PLA are reduced. This hydrolysis reaction also changes PLA melt viscosity and the crystallization rate, making it very difficult to process into a quality end product.

Virgin PLA resin is crystallized and dried to 400-ppm moisture level prior to leaving the production plant. The resin is sold in boxes with moisture resistant foil liners to maintain that moisture level. If the PLA is received in undamaged boxes and liners, the drying requirements are minimal but still required. In addition, if the foil liner has been opened, drying will be required. The resin is crystallized to allow easier drying. Uncrystallized PLA becomes sticky and clumps when its temperature reaches 60°C (140°F). This is PLA's glass transition temperature; the point at which the amorphous portion of the pellet begins to soften. Regrind or recycled PLA may or may not be crystallized. Flake from clear thermoformed parts, trim scrap, or cast sheet, is highly amorphous. Flake from oriented film or oriented sheet will be a mixture of crystalline and amorphous fractions, while that from fibers will be highly crystalline.

It is the process, the shape and degree of crystallinity, and the percentage of regrind that will determine if the recycled PLA will need to be crystallized. A rule of thumb is that a crystallizer is not required if the amorphous portion of the feed stream is less than 40% of the total and the extruder has screw-cooling capabilities. However, this generalization ignores wide variation in the level of crystallinity and size distribution in the flake. Also, some screw designs have a higher degree of flexibility in handling amorphous regrind than do others. If the process is using amorphous regrind, it is absolutely critical to have screw that has cooling through the root of the screw through the feed section and half way into the melting section of the screw. Due to the rapid rate of moisture pick-up of PLA, any regrind that has been stored needs to be dried adequately, prior to re-extrusion. Most processors of recycled PLA choose to crystallize the recycle in order to eliminate any problems with drying. Crystallization permits trouble-free drying in conventional equipment at 150°F-190°F. Amorphous PLA requires drying at much lower temperatures 43-55°C (110 - 130°F), to prevent sticking in the dryer.

Most PLA drying is done in dehumidifying hoppers using hot air at a very low dew point. The dehumidified air passes through a bed of PLA to extract moisture from the resin. A desiccant material, such as silica, absorbs moisture from the circulating air. Dual desiccant bed systems are common, in which one bed is on-stream while the stand-by bed is being regenerated. Either a time cycle or a predetermined decrease in air dew point is used to shift airflow from one bed to the other.

Due to rapid growth in PLA processing many new plastic converters are manufacturing end products from PLA. A number of these companies are just now learning how critical drying is when producing high quality PLA end products. Others may not be aware of the differences in behavior between amorphous and crystallized grades of PLA. It is important to note that inadequate drying, (on a ppm level) causes a large portion of all quality problems in PLA processing.

PLA Best Practices:

Drying: PLA must be dried to <250 parts per million (ppm) moisture and maintained at this moisture level to minimize hydrolysis during melt processing. This is not optional with PLA; it is absolutely essential. A dry resin will help control the Relative Viscosity (RV) loss, which should be less than 0.1. A reduction in RV greater than this can result in a product outside of the useful range for several extruded PLA applications. Controlling RV loss is critical to maintaining impact strength, melt viscosity, and other key properties of the starting material.

The crystallized PLA should be dried at 65 – 90°C (150 - 190°F), using dehumidified air with a dew point of –40°C (-40° F). Higher drying temperatures can lead to softening and blocking of polymer in the dryer. Lower drying temperatures will result in extended drying times.

Dew point is an absolute measure of air moisture and is independent of air temperature. Dew point should always be used to control dryer performance, therefore, the dryer should be equipped with a dew-point monitor and alarm plus a temperature monitor on the dryer inlet line. Airflow is another critical component to drying. Airflow to the dryer heats the resin and absorbs its moisture. Sufficient airflow maintains the resin at the proper temperature for its entire residence time. The data in the figures below were obtained using airflow of 0.016 m^3 per minute per kg of polymer (0.25 cubic foot per minute (cfm) per pound). This was sufficient for the relatively small, 90 kg (200 pound) capacity dryer, used in the experiments. Commercial extrusion lines typically require higher air volumes and generally use 0.032 – 0.064 m^3/min per kg (0.5 – 1.0 cfm/pound of resin). NatureWorks recommends consulting your dryer manufacturer and obtaining their recommendations for minimum airflow for their dryer design. At any rate, a volumetric flow indicator is recommended to monitor airflow.

In laboratory experiments, NatureWorks measured the drying times for various grades of PLA at different drying air temperatures. Figure 1 below shows 4 different drying curves.

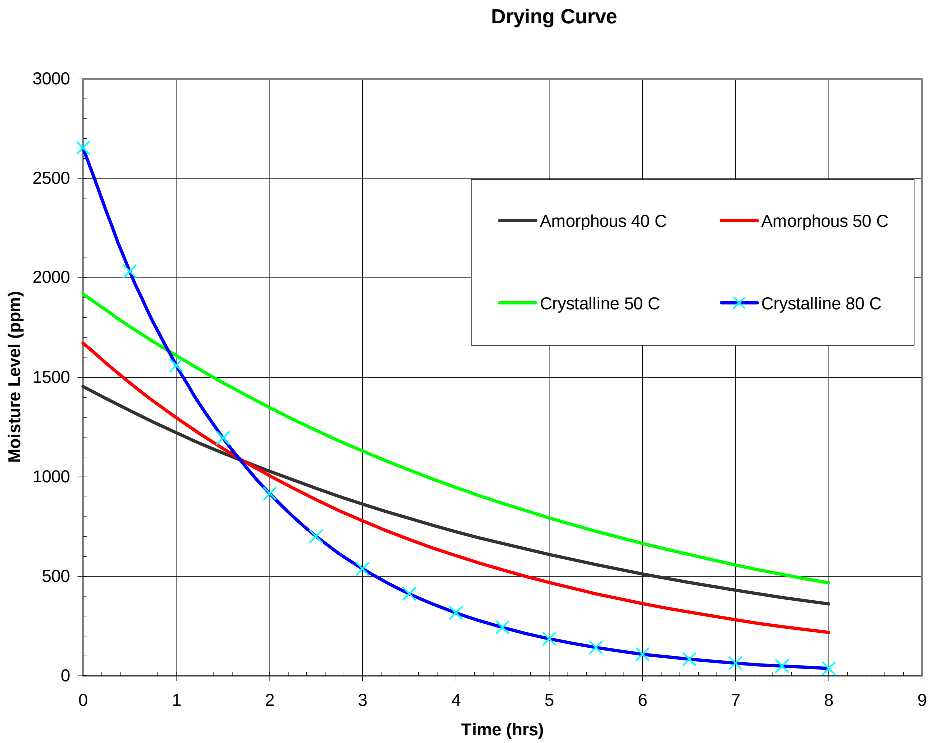

Figure 1: Drying Curve of PLA pellets at various temperatures. Airflow volume rate was 0.016 m^3/min per kg (0.25 cfm/lb) of pellets. The air dew point was – 40°C.

From these data, one can extract drying half times ($t_{1/2}$), which is the time required for the PLA to reduce its moisture concentration to one half the initial value. The drying half times from amorphous and crystalline PLA are listed in Table 1 below.

PLA Product and Temperature	Drying Half Time ($t_{1/2}$)
Amorphous Pellets	
40°C (104°F)	4.0 hr
Crystalline Products	
40°C (104°F)	4.3 hr
50°C (122°F)	3.9 hr
60°C (140°F)	3.3 hr
70°C (158°F)	2.1 hr
80°C (176°F)	1.3 hr
100°C (212°F)	0.6 hr

Table 1: Drying Half Times for PLA Pellets with Dry Air (- 40°C/-40°F dew point) at 0.016 m^3/minute per kg (0.25 cfm/lb).

Drying times are determined by measuring the initial moisture content and using the drying half time values in Table 1. The half time is the time in hours it takes for the moisture level in PLA to drop to ½ of its initial value. For example, if you wanted to dry PLA with initial moisture content of 1600 ppm down to 200 ppm at 80°C (176°F), you would need to use the half time of 1.3 hours. Therefore, it would take 1.3 hours to drop the moisture level from 1600-ppm to 800-ppm. It would then take an additional 1.3 hours to drop the moisture it from a level of 800-ppm to 400-ppm. Finally it would take an additional 1.3 hours to drop the level from 400-ppm to 200-ppm for a total of 3.9 hours at 80°C (176°F). Other times and temperatures will be appropriate depending upon the initial moisture level and the time available for drying.

Another best practice for minimizing moisture-related degradation of PLA is to dry any blending ingredients, colorants, additives, or internal scrap that could potentially contribute moisture to the base resin. If any portion of the formulation is hygroscopic, it must be dried according to the supplier's recommendation. Some non-hygroscopic components may not have to be dried if their equilibrium moisture content and percentage of the formulation are small.

Crystallization: As mentioned before, crystallized PLA pellets and flake will not stick or clump together at temperatures above the glass transition temperature, 60°C (140°F). This allows the material to be dried at much hotter temperatures. NatureWorks has done extensive experimentation and determined that PLA pellets and flake will not stick together or clump if the crystallinity level is greater than 10 joules/gram. At this level of crystallinity or greater, the PLA pellets will appear cloudy instead of the very transparent appearance of the amorphous pellets. It is critical that the pellets achieve a uniform crystallinity so that some amorphous pellets do not remain which could cause clumping problems in subsequent drying steps. There are a number of types of crystallizers in the industry as explained below but just as in drying, there are some best practices for achieving desirable results.

The crystallizer should be capable of heating the regrind at a steady rate with constant agitation or motion of the regrind to prevent clumping. The clumps that form due to sticking of amorphous or partly amorphous resin do not break up as the temperature rises without mechanical interference. In fact, they will stick to the container walls and thermocouples and cause bridging as the clumps grow. A well-designed crystallizer not only minimizes the formation of clumps, but also is efficient at breaking up any clumps that may form. Optimum crystallization temperatures for NatureWorks™ PLA depend upon the grade. Low D percent grades such as 2100D, 4032D and 3001D can be crystallized at 100 - 110°C (210 - 230°F) while equilibrium grades such as 2002D 3051D and 4042D should be crystallized at 88 – 99°C (190 - 210°F). At these temperatures, it will take between 10 – 20 minutes for PLA to crystallize PLA. Amorphous grades such as 4060D will never crystallized and should not be loaded into a crystallizer.

With equilibrium grades, it is often advantageous to add 200 – 400 ppm of an external lubricant such as erucamide to reduce the COF of the pellet bed. This serves to reduce agitator loads and aids in preventing agglomeration particularly at higher rates.

Figure 3 below is a graph of the degree of crystallinity as a function of time for various inlet air temperatures. As you can see, at all but the lowest temperature, the flake was crystallized above the recommended 10 J/gm limit in 20 minutes or less.

Regrind exiting the crystallizer should be checked for moisture level as some drying action occurs in the crystallizer. Knowledge of moisture level at this point will allow efficient use of the drying resources.

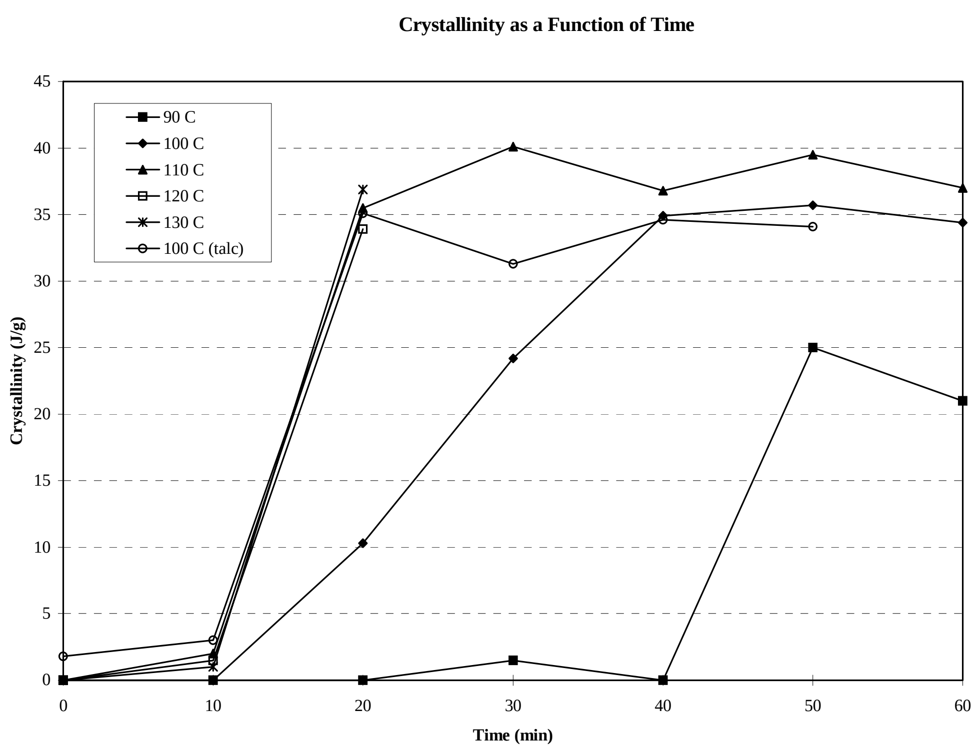

Figure 3: Crystallization of PLA as a Function of Time. Conair Model CR500 500 liter crystallizer with 17 rotating blades and 3 stationary breaker bars. The agitator arm rotated at a fixed speed of 2 RPM. The Hopper capacity was 0.4 m^3 (14 ft^3). The heating capacity was 33 KW and the blower output at full damper opening was 10 M^3/min (360 CFM).

Moisture Control: Drying must be coordinated with production at all times. Dryness of the PLA must be maintained until it enters processing equipment. It is best to use dried material right away so it does not absorb ambient moisture. Depending on ambient conditions, dried PLA that is not kept in a sealed enclosure can pick up enough moisture in five minutes to defeat most of the benefits of drying.

To maintain dryness, it is best to vacuum load the pellets and/or regrind directly from a centralized drying unit to feed hoppers above the processing equipment. In some instances, portable hopper dryers are used and the dried resin is conveyed directly to the feed hopper.

Moisture Analysis: The Best Practice for moisture analysis of dried samples is to check two to three samples at the end of each drying cycle to confirm that moisture content is below 250 parts per million. NatureWorks recommends using a Karl-Fischer titration method that heats the sample at 150°C (302°F) for 30 minutes.

Equipment

Dryers

There are a large number of dryer manufacturers who can design and specify a dryer suitable for your needs using the above data. NatureWorks, LLC does not recommend any particular dryer supplier since there are many that provide a quality product. Ideally, any dryer that is being considered for PLA should have the following features:

1) Desiccant beds capable of achieving a dew point of – 40°C (- 40°F) in the supply air
2) An after cooling unit between the drying hopper and desiccant bed to eliminate high temperature spikes in the supply air which can cause blocking when drying amorphous products.
3) Excellent temperature control in the PLA drying range, 40 – 100 °C (104 – 212°F)
4) Ability to use dry air to convey pellets from the drying hopper to the extruder hopper (closed loop conveying).
5) High temperature alarm on the inlet air temperature and shut off control to prevent melting or blocking in the hopper
6) Dew point monitor and indicator
7) Air flow indicator

Note: A new type of dryer has been introduced recently, using Infrared drying (IR). Due to the high rate of energy transfer with IR heating in combination with the specific wave length used, the energy costs involved with these systems can be greatly reduced, along with the size. First tests have shown that virgin PLA can be dried and amourphous flake crystallized and dried within only about 15 minutes. The output level of these tests were at a rate between 200 - 300 kg/h (440 - 660 lbs/h). As this technology is still developing, it is necessary to discuss the individual drying purpose (e.g. virgin or blend of virgin/flake) with the equipment manufactures UPM or Kryenborg.

Crystallizers

General Background

There are four general types of crystallizers used in the industry for crystallizing either pellets or ground flake: Vertical Hopper Units with Convection Heating, Horizontal Conductive Units, Solid State Reactors Tumblers and Fluidized Bed Crystallizers. In addition, IR dryers have been shown to effectively crystallize PLA during drying. NatureWorks LLC has used all five types of crystallizers on various PLA products. Each type of unit has its own advantages and limitations.

Vertical Hopper Unit with Convection Heating

This is the most common type of crystallizer in the industry. The vertical hopper crystallizer resembles a vertical drying hopper with the addition of a center agitator arm. This arm is powered by a drive unit typically mounted on the top of the vessel. While there are many dryer manufacturers that have tried to retrofit existing dryer designs with a simple agitator, the key to proper operation with PLA is the design of the agitator arm. One company, Conair Franklin has tested and developed a design that not only works well for PET, but has also been demonstrated with PLA. In this design, the central agitator arm is equipped with many angled agitator arms which are specially designed to keep material in motion and prevent agglomeration. In addition, there are a number of stationary breaker bars mounted into the vessel walls that help break any polymer agglomerates. More recently, Una-Dyn has developed a line of crystallizers and associated dryers that are uniquely suited to the properties of PLA. In this design of dryer, the polymer is heated by way of forced air from an external blower and electrical heater that is blown into a bottom mounted diffusion plate. Spent air is typically exhausted into the surrounding atmosphere although recycle systems could be designed. In operation, the material is continuously drawn out of the unit from the bottom while a level indicator controlling a hopper loader maintains a constant level at the top of the hopper. It is necessary to start up the unit with a previously crystallized material in the bottom half of the hopper since airflow, heat transfer and agitation is not sufficient enough at the bottom to immediately crystallize the polymer. Once the unit is started and temperatures are at steady state, fresh amorphous material can slowly be added to the system to build the level. Once the level is achieved, material can be drawn off of the bottom. The unit operates best in steady state continuous mode. In some cases, it is necessary to feed a mixture of crystallized resin and fresh feed, to avoid blocking. It is recommended to start with a 50/50 blend of fresh amorphous resin and crystallized resin. After stable operation is established, the mixture can be moved to lower fractions of pre-crystallized resin, while avoiding sticking or blocking.

The advantages of these units are the relatively low cost and small footprint. They integrate well with most conventional drying systems. Depending upon the design of the agitator, they may be susceptible to material agglomeration, which could hinder rates.

Horizontal Conduction Heating Units

This is a unique crystallizer design that relies on high pellet to metal contact area to heat the material and constant particle motion to eliminate agglomeration. Bepex International LLC makes a unit called a Torusdisc. The Torusdisc is a disc dryer using hot air or gas as drying media in combination with a heating jacket and a heating rotor. The Torusdisc rotor consists of special heated discs within a cylindrical housing, which is jacketed. The rotor is designed with vertically mounted double walled hollow discs. Heating media flow through the rotor, the discs and the jacketed vessel surrounding the rotor. These discs provide 85% of the total heating surface.

The rotor speed varies from 0.1 up to 0.5m/s and is independent from the residence time, so optimum mixing and heat transfer can be obtained. The residence time can be adjusted from minutes up to several hours. The compact size makes it especially appropriate for high heat transfer requirements at minimum floor space requirements.

The Torus disc crystallizer has been used successfully with all semi-crystalline grades of NatureWorks™ PLA. Advantages are once that the process window has been identified, operation is trouble free. There is less air movement and heating so operation costs are less. However, initial equipment cost is high.

Solid State Reactors (Also known as Tumbler Dryers or Vaccum-Dryers)

This is basically a jacketed tumbling mixer that has special rotary unions that allow a vacuum to be applied to the unit. This is batch type unit and generally, the throughput is low since there is a lot of time required to load the unit, heat the unit while tumbling and pulling a vacuum, cool the unit to resin pack out temperature and finally unloading the unit. The vessels can range up to 9, 000 kg (20,000 lbs) in capacity. PLA will not increase in RV as PET will but the unit does dry the resin as it crystallizes. Advantages are the ease of use and drying during crystallization. Disadvantages are that it is a batch operation and throughputs can be low on small units due to long cycle times (typically about 8 hours for PLA). All semi- crystalline grades of PLA have been processed on this type of crystallizer.

Fluid Bed Crystallizers

These units are essentially modified pellet classifiers that use heated air to crystallize the regrind. Typically used for pellets, they have also been used successfully for ground flake. They have a extensive experience crystallizing PET and PET copolymers. While there have been no commercial experience with PLA, successful laboratory tests have been performed with all grades of semi-crystalline PLA.

Fluid Bed Crystallizers

The Witte Company, Inc
P.O. Box 47, 507 Route 31 South
Washington, NJ 07882-0047 USA
Jim Schak
908-689-6500 (FAX) 908-537-6806
jschak1@aol.com
www.witte.com
Note: Crystallizers are not featured as such on the web site. They have extensive experience designing fluid bed crystallizers for PET pellets and flake. They do have equipment in the New Jersey lab for evaluation.

Barr-Rosin Ltd.
48 Bell Street
Maidenhead, Berkshire
SL6 1BR
United Kingdom
Tel: +44(0) 1628 641 700
Fax: +44(0) 1628 776 118
www.barr-rosin.ca
Note: Mfg of fluid bed crystallizers. Extensive experience with PET and PET copolymers (crystallization rates similar to PLA). Lab facilities avalable.

Bühler GmbH
Ernst-Amme-Strasse 19
D-38114 Braunschweig
Phone.: ++ 49 (531) 594-0 (FAX).: ++ 49 (531) 594 22 54
Email: stefan.scheiber@buhlergroup.com

Vertical Hopper Units with Convection Heating

Conair Franklin
Route 8 North
Franklin, PA 16323
412-312-6280   (FAX) 412-312-6004
Pete Stoughton
Pstoughton@conairgroup.com
www.conairnet.com
Note: Crystallizers are not featured on their web site. They do have a brochure they can fax you upon request. They have extensive experience designing PET crystallizers for pellets and flake. They do have equipment in the Franklin, PA lab for evaluation.

Labotek A/S
Strøbjergvej 29
DK-3600 Frederikssund
Denmark
Tel: +45 / 48 21 84 11
Fax: +45 / 48 21 80 00
email: info@labotek.com
http://www.labotek.com
Note: Have designed and built PET crystallizers. NatureWorks has no experience with crystallizers from Labotek but owns a dryer unit and has been satisfied with performance and service.

Novatec, Inc.
222 E. Thomas Avenue
Baltimore, MD 21225 USA
Phone: 410-789-4811 (FAX): 410-789-4638
novatec@novatec.com
www.novatec.com
Note: NatureWorks has no experience with crystallizers from Novatec but has had good experience with dryers

Universal Dynamics, Inc
A Company of Mann Hummel ProTec
13600 Dabney Road
Woodbridge, Va. 22194-0396
Phone 703-491-2191 Fax 703-490-7001
Email info@una-dyn.com
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Horizontal Units with Conductive Heating

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P.O.Box 98, 7000 AB Doetinchem,
The Netherlands,
Tel. +31 314 37 33 33.
Fax +31 314 37 33 00.
www.hmbv. nl

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48157 Münster
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SL3 6EP
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+44 (1753) 48 55 20

roy.fowler@upm.co.uk
http://www.upm.co.uk

Companies that will crystallize on a tolling basis

NTM Inc. **Vertical Hopper with Convective Heating**
25 Old Mill Road
Greenville, SC 29607
Phone: (864) 675-9376 (Fax): (864) 675-9378
Contact Person: Mr. Curtis Harper
Extension 111
charper@ntmplastics.com
www.ntmplatics.com

Bepex International LLC **Horizontal with Conductive Heating**
Contact person: Mr R. Imholte
333. N.E. Taft Street
Minneapolis, MN 55413
Tel.: (1) 612 3314370
Fax: (1) 612 627 1458
E-mail: info@bepex.com
rimholte@bepex.com

St. Jude Polymers Corporation **Solid State Reactors**
110 Industrial Park
Frackville, PA 17931
Stephen Babinchak
Sales and Supply Manager
Tel: (570) 874-1220 Fax: (570) 874-2980
agbabin@f-tech.net
www.stjudepolymer.com

Ametek Compounding **Horizontal with Conductive Heating**
Green Acres Industrial Park
42 Mountain Road
Nesquehoning, PA 18240
Mark Rother
Sales Manager
(877) 878-0675 ext 245 Fax: (570) 645-8564
mark.rother@ametek.com
www.ametek.com

Safety and Handling Considerations
Material Safety Data (MSD) sheets for PLA polymers are available from NatureWorks LLC. MSD sheets are provided to help customers satisfy their own handling, safety, and disposal needs, and those that may be required by locally applicable health and safety regulations, such as OSHA (U.S.A.), MAK (Germany), or WHMIS (Canada). MSD sheets are updated regularly; therefore, please request and review the most current MSD sheets before handling or using any product.

The following comments apply only to PLA polymers; additives and processing aids used in fabrication and other materials used in finishing steps have their own safe-use profile and must be investigated separately.

Hazards and Handling Precautions
PLA polymers have a very low degree of toxicity and, under normal conditions of use, should pose no unusual problems from incidental ingestion, or eye and skin contact. However, caution is advised when handling, storing, using, or disposing of these resins, and good housekeeping and controlling of dusts are necessary for safe handling of product. Workers should be protected from the possibility of contact with molten resin during fabrication. Handling and fabrication of resins can result in the generation of vapors and dusts that may cause irritation to eyes and the upper respiratory tract. In dusty atmospheres, use an approved dust respirator. Pellets or beads may present a slipping hazard. Good general ventilation of the polymer processing area is recommended. At temperatures exceeding the polymer melt temperature (typically 170ºC), polymer can release fumes, which may contain fragments of the polymer, creating a potential to irritate eyes and mucous membranes. Good general ventilation should be sufficient for most conditions. Local exhaust ventilation is recommended for melt operations. Use safety glasses if there is a potential for exposure to particles which could cause mechanical injury to the eye. If vapor exposure causes eye discomfort, use a full-face respirator. No other precautions other than clean, body-covering clothing should be needed for handling PLA polymers. Use gloves with insulation for thermal protection when exposure to the melt is localized.

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Combustibility
PLA polymers will burn. Clear to white smoke is produced when product burns. Toxic fumes are released under conditions of incomplete combustion. Do not permit dust to accumulate. Dust layers can be ignited by spontaneous combustion or other ignition sources. When suspended in air, dust can pose an explosion hazard. Firefighters should wear positive-pressure, self-contained breathing apparatuses and full protective equipment. Water or water fog is the preferred extinguishing medium. Foam, alcohol-resistant foam, carbon dioxide or dry chemicals may also be used. Soak thoroughly with water to cool and prevent re-ignition.

Disposal
DO NOT DUMP INTO ANY SEWERS, ON THE GROUND, OR INTO ANY BODY OF WATER. For unused or uncontaminated material, the preferred options include recycling into the process or sending to an industrial composting facility, if available; otherwise, send to an incinerator or other thermal destruction device. For used or contaminated material, the disposal options remain the same, although additional evaluation is required. (For example, in the U.S.A., see 40 CFR, Part 261, "Identification and Listing of Hazardous Waste.") All disposal methods must be in compliance with Federal, State/Provincial, and local laws and regulations.

Environmental Concerns
Generally speaking, lost pellets are not a problem in the environment except under unusual circumstances when they enter the marine environment. They are benign in terms of their physical environmental impact, but if ingested by waterfowl or aquatic life, they may mechanically cause adverse effects. Spills should be minimized, and they should be cleaned up when they happen. Plastics should not be discarded into the ocean or any other body of water.

Product Stewardship
NatureWorks LLC has a fundamental duty to all those that make and use our products, and for the environment in which we live. This duty is the basis for our Product Stewardship philosophy, by which we assess the health and environmental information on our products and their intended use, then take appropriate steps to protect the environment and the health of our employees and the public.

Customer Notice
NatureWorks LLC encourages its customers and potential users of its products to review their applications for such products from the standpoint of human health and environmental quality. To help ensure our products are not used in ways for which they were not intended or tested, our personnel will assist customers in dealing with ecological and product safety considerations. Your sales representative can arrange the proper contacts. NatureWorks LLC literature, including Material Safety Data sheets, should be consulted prior to the use of the company's products. These are available from your NatureWorks LLC representative.

NatureWorks®

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In Japan, call 81-33-285-0824