Environmental Stress Cracking Test Results

NatureWorks LLC

Following NatureWorks method, “ESCR Testing on Amorphous Ingeo Biopolymer Sheet.”

All chemicals tested were diluted to 10% of original concentration as received using DI water, unless otherwise noted. *Test concluded after 7 days; NF = No Failure*

Chemical	Concentration of solution used for testing (solid wt/wt%)	Last good reading (hrs)	Failure reading (hrs)
Acetic Acid	2.5		NF
Acetone	100		0.01
Baby shampoo	100		NF
Biotex	100		NF
Chloroform	100		0.01
Ethanolamine	10		0.1
Ethyl alcohol	100	2	20
Ethyl Lactate	100		0.1
Ethylene Glycol	10		NF
Febreze, Liquid Spray	100		NF
Glycerin	100		NF
Hydrochloric Acid	1.5	1	4
Hydrogen peroxide	3%	2.5	4
Isafil 1913	10		NF
Isopropanol	10	0.1	1
Lactic Acid	9		NF
Milube A-45	10		NF
Mineral Oil	100		NF
NaOH	1		0.01
Nitric Acid	3.5	1	4
Pentane	10	24	48
Phosphoric Acid	2.5	4	27
Pluracol V-10	10		NF
Shampoo	100		NF
Shout, European version	100		NF
Shout, Liquid Spray	100		NF
Sil Spray & Wash, European	10	1	4
Sil Spray & Wash, European	100		NF
Spray & Wash, Liquid Spray	100	0.1	1
Spray & Wash, Stain Stick	10	0.1	1
Sulfuric Acid	2.5	1	4
Vegetable Oil	100		NF
Water	100		NF

ESCR Testing on Amorphous Ingeo Biopolymer Sheet

Principle

This method observes the behavior of chemical attack on Ingeo samples. Amorphous, non-oriented sheet samples are stressed to the point of crazing by bending thin strips of sheet, and then immersed into the chemical of choice. Time to failure is monitored, where the bent sheet has cracked across the length of the sheet and loses tension. Failure can be one of several mechanisms, including environmental stress cracking, solvation of the sample or chemical attack such as accelerated hydrolysis.

Scope

Any chemical can be tested that is in a water solution. Solutions using solvents other than water may result in failure due to the solvent interaction and not necessarily the chemical of interest.

Equipment and Reagents

1. Amorphous Ingeo sheet, 17 mil thickness, with dimensions of 1″ wide by 4.75″ long. This sheet is amorphous and has minimum orientation from casting process, with the strips cut lengthwise along the machine direction.
2. Binder clips, or equivalent, to hold bent sheet.
3. 100 mls cups and lids.

Procedure

Preparation of sheet

1. Sheet is produced on Randcastle line with the following conditions:
    - Zone 1 temp = 300F, zone 2 = 360F, zone 3 = 390F, die and adaptors = 390F
    - Die gap at 0.017-0.018”.
    - Chill roll temp = 125F.
    - Takeup roll speed/die gap adjusted to produce 17 mil across width of sheet
2. Sheet strips are cut out using 1″ wide tensile sheet/film cutter, discarding 1″ from each edge. Length of strips are 4.75″.

Preparation of standard

1. Run a water control with each set of samples, immersing strip into plain water. Report the failure rate of plain water with the sample set.

Preparation of samples

1. Take one strip of Ingeo sheet, and examine it. Throw out any strip that has imperfections in the middle section that will be bent, such as cracks or other contamination.
2. Bend the strip in the opposite direction of the natural curl of the sheet until the 2 ends are touching, forming a loop. Secure with a binder clip 1/4″ from the end of the strip. The bent sheet sample should not have any creases or cracks in it after bending, although there should be some micro-crazing along the bend for all samples. If there is not crazing present, do not use sample. The crazing needs to be present to yield accurate results, but again not large cracks.
3. Place chemical of interest into cup, having at least 3/4″ depth of solution.
4. Immerse the looped end of bent strip into the solution of interest, fully covering the loop at least 3/4″ from the end. Place a cap over container to prevent evaporation.
5. Visually check sample after 15 minutes, again after 1 and 4 hours, and then every 24 hours thereafter. Record time when sample has lost tension at the bend, or completely cracked in half. Some samples will soften over time and slowly collapse the loop without completely cracking in two, and once the strip has no tension will not move any further. Other samples may have a much more dramatic sample failure and snap in half, usually in the first several minutes of immersion for this mode of failure. If in doubt on when sample has failed, record time when sample has

first altered form from the starting position.

Examples of failures

- Sample has broken or cracked.
- Sample loop has lost tension or loop has flattened.
- Sample loop has softened or has changed shape.
- Then any other physical change in loop is regarded as failure.

DISCLAIMER

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Safety and Handling Considerations

Material Safety Data (MSD) sheets for Ingeo biopolymers 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 Ingeo biopolymers; 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

Ingeo biopolymers 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 recom-mended 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 Ingeo biopolymers. Use gloves with insulation for thermal protection when exposure to the melt is localized.

Combustibility

Ingeo biopolymers 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.

For additional information please contact NatureWorks via our website on the tab called FAQ’s or by clicking here.

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