EASTMAN

TENITE™ cellulosic plastics

From trees to plastic

Contents

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From trees to plastic

A renewable resource

A toothbrush. A screwdriver. A child's toy. A pair of eyeglasses. Each day we come in contact with familiar household objects. But what do they have in common? For more than 60 years, these products have been made of Tenite™ cellulosics. In fact, Tenite acetate, introduced in 1929, was the first of the modern thermoplastics. Even with this long history, Tenite™ acetate, butyrate, and propionate continue to be as up-to-date as Eastman Chemical Company's computer-controlled manufacturing can make them.

Cellulosics are remarkable because they are the only plastic made from a renewable resource: softwood forests, harvested under a program of sustainable yield that represents environmentally responsible management of our natural resources. In the United States, programs of reforestation after harvest in softwood tree farms have proven so successful in recent years that the U.S. Department of Agriculture Forest Service reports growth exceeding harvest by more than 33%.

From trees to plastic

Trees to cellulose
4.78 lb of wood chips = 1 lb of cellulose

Cellulose to ester
0.59 lb of cellulose = 1 lb of ester

Ester to plastic
0.92 lb of ester = 1 lb of plastic

Trees to plastic
2.60 lb of wood chips = 1 lb of plastic

From trees to cellulose

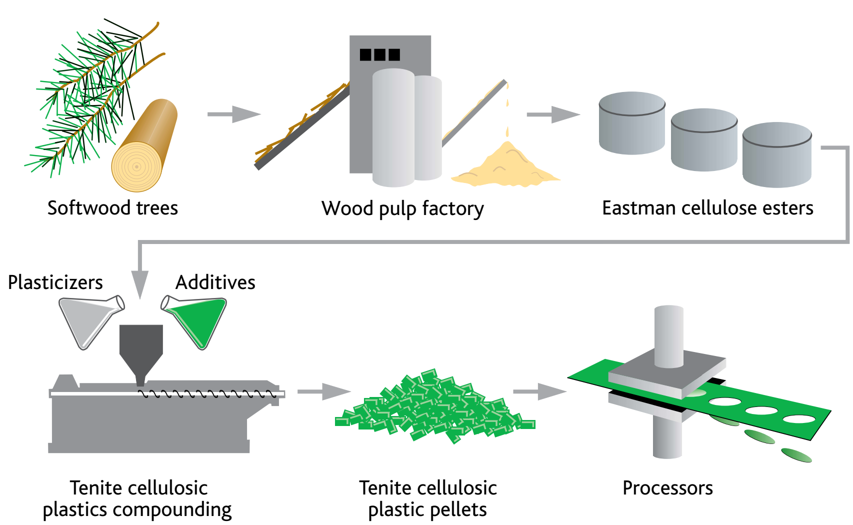
In the process of converting trees to cellulose, little is wasted. The bark is removed before pulping and is used as fuel for the conversion process itself. The tree is chipped and then cooked in a digester to separate cellulose fibers. Lignins and resins produced at this stage can also be used for other chemical products or as fuel.

The resulting pulp of alpha cellulose and hemicellulose is treated with various bleaching chemicals to reduce the hemicellulose content and remove the last traces of lignins and resins. At this stage, the pulp is clean and white. It is pressed to remove water, then dried and wound onto rolls. This is the high quality, high-alpha cellulose used to manufacture cellulose esters for plastics. Only the highest quality pulps are used for Tenite™ cellulosics.

From cellulose to ester

Cellulose esters are made by reacting high-purity cellulose with selected acids and anhydrides in a multistage process. The choice of acids and anhydrides determines the chemical composition and properties of the final Tenite™ cellulosic plastic; the cellulosic plastics—acetate, butyrate, and propionate—are chemically different.

In esterification and hydrolysis, the cellulose, acids, and anhydrides are reacted under controlled catalyst concentrations and temperatures to determine the chemical makeup and viscosity of the cellulose ester. A viscous solution—the cellulose ester dissolved in acid—is formed at this stage. The solution then undergoes ultrafine filtration to remove traces of unreacted cellulose fibers and by-products. This ultrafine filtration is critical in making high quality material required for injection molding and extrusion applications. Then, in a process known as precipitation, the cellulose esters are separated from the viscous solution of water and acids as a solid powder. Following precipitation, the cellulose esters are washed to remove residual acids, then dried.



From ester to plastic

Cellulose ester, plasticizer, and additives are compounded in the final manufacturing step to produce the finished cellulosic plastic.

Pulp end use vs. quality

Pulp end use	Pulp quality
Plastic ester	Highest
Fiber acetate ester	↑
Industrial filament rayon	
Textile filament rayon	
Rayon staple	
Cellophane	
Fluff	
Paper	Lowest

Compounding: custom recipes

A fully formulated Tenite™ cellulosic plastic will contain one of the three base esters and a variety of additives (such as plasticizers, heat stabilizers, slip agents, and ultraviolet inhibitors) compounded into a homogeneous mixture. To ensure high quality formulations, each additive passes separate quality tests before it is used.

A custom compounder of cellulosics since 1932, Eastman produces Tenite acetate, butyrate, and propionate in a variety of formulations and plasticizer content ranging from 3% to 35% in 3.2-mm (⅛-in.) pellets for molding and extrusion.

Dedication to quality

The emphasis given to continual quality improvement and controlling variables in manufacturing results in quality Tenite cellulosics.

At Eastman, focused operator teams use a structured approach to standardize processes by identifying key variables and specifying desired operating ranges. Statistical Process Control (SPC) and other advanced evaluation tools generate the data that bring variables under control and provide consistent quality within an order and from order to order.

- **Dedicated lines for plasticizers**
  A good example of data-driven innovation is the use of dedicated plasticizer charging lines. These dedicated lines include highly accurate metering pumps that make precise control of the plasticizer/ester blend a reality.
- **Near infrared (NIR) technology**
  (accurately measures plasticizer content during compounding) A method to reduce variability and permit real-time control is provided through NIR technology. The plasticizer content of a formula is quickly and precisely determined, confirming that a mixture is properly compounded. NIR offers reduced variability and is a more accurate test than the conventional flow temperature test.
- **Twin screw compounding**
  Twin screw compounding provides improved extrusion finish and processability for Tenite™ cellulosics.
- **Quality processes**
  Tenite™ cellulosics are manufactured under quality processes that are ISO 9002 certified, which means they are manufactured to the same standards every time.

Benefits

Tenite™ cellulosic plastics, the first of the modern thermoplastics, have been used for more than 60 years because they:

- Have an excellent balance of properties, including toughness, hardness, strength, surface gloss, clarity, chemical resistance, and a warm feel.
- Are available in a variety of formulas, plasticizer levels, and additives.
- Are easily molded, extruded, and fabricated.
- Are resistant to attack or change by a wide variety of common household, industrial, and medical chemicals.

Properties

Tenite™ cellulosic plastics, noted for their excellent balance of properties, are available in a variety of formulas and plasticizer levels and can be tailored to the requirements of the user.

Mechanical

Tenite™ acetate, butyrate, and propionate are specified by the percentage of plasticizer.

The mechanical properties of Tenite™ cellulosic plastics differ with plasticizer level. The type and amount of plasticizer affects the mechanical properties of the plastic. Lower plasticizer content yields a harder surface, higher heat resistance, greater rigidity, higher tensile strength, and better dimensional stability; higher plasticizer content increases impact strength.

Electrical

Electrical properties of Tenite acetate, butyrate, and propionate are similar. All have a high dielectric constant, good dielectric strength and volume resistivity, and a high dissipation factor.

Color

Tenite acetate, butyrate, and propionate are available in natural, clear, selected ambers or smoke transparents, and black translucent. Color concentrates are available in a range of let-down ratios in the following formulas: Tenite acetate 100, Tenite butyrate 200, and Tenite propionate 300.

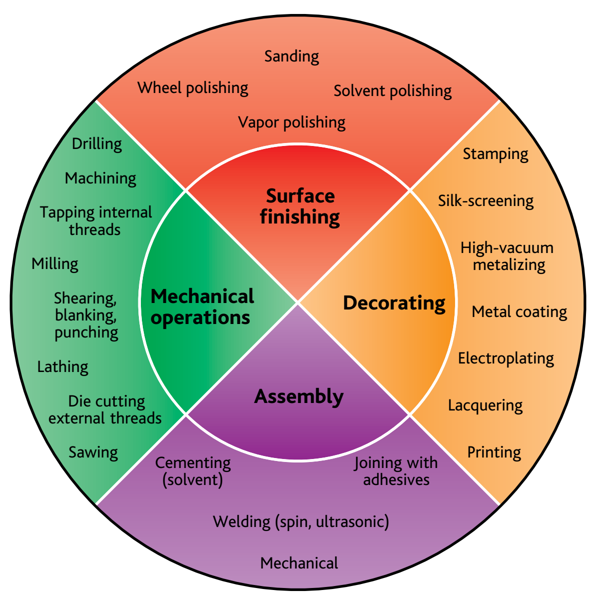
Chemical resistance

Tenite™ cellulosic plastics are characterized by exceptional resistance to chemically induced stress cracking. Tenite cellulosics are resistant to attack or change by a wide variety of common household, industrial, and medical chemicals such as toothpaste, aliphatic hydrocarbons, bleach, detergents/soaps, ethylene glycol, salt solutions, vegetable and mineral oils, alcohols, and lipids.

Processing and secondary operations

Tenite™ cellulosics are noted for their outstanding processability. These cellulosics are easily molded, extruded, or fabricated. They are unique in their ability to accept various types of secondary fabrication, including solvent polishing, cutting, cementing, drilling, and decorating. Figure 1 illustrates their exceptional versatility. In addition, clean scrap can be reprocessed, minimizing waste and systems costs.

Figure 1 **Secondary operations**



Applications

Cellulosics are frequently chosen not only for their good balance of properties and ease of processing but also for their extraordinary appearance characteristics.

Special formulations of Tenite™ butyrate and propionate for outdoor applications or formulations that meet FDA food contact regulations are available.

Typical uses of Tenite™ cellulosics

Tenite acetate

Ophthalmic sheet
Tool handles

Tenite butyrate

Automotive and furniture trim
Displays and profiles
Pen barrels
Tool handles
Toys and sporting goods

Tenite propionate

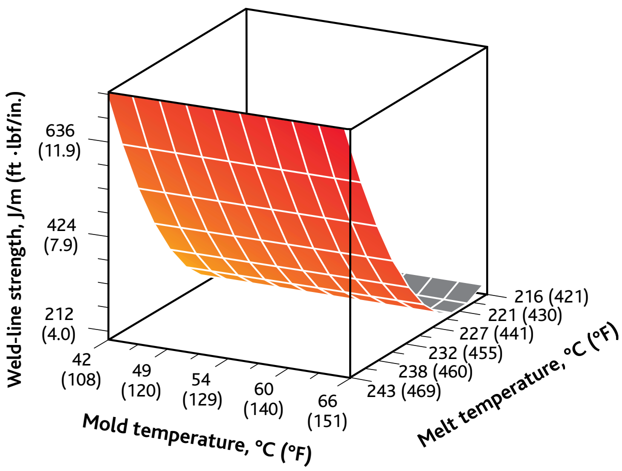
Appliance parts
Cosmetics and personal care containers
Film and tubing for packaging
Health care supplies
Ophthalmic and optical safety frames
Toothbrush handles
Sunglasses

Improving a classic

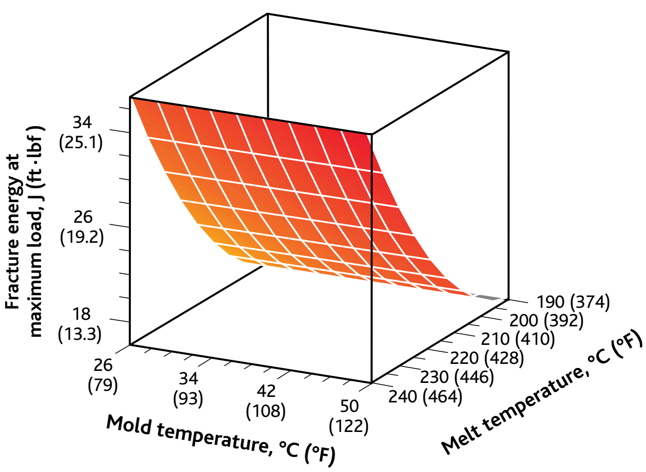
The HT series formulations in Tenite acetate, butyrate, and propionate demonstrate that it is possible to improve a classic. The basic composition of cellulosics is unchanged; however, HT formulations are superstabilized for processing at the higher melt temperatures used for injection molding and extrusion. Tests show a dramatic improvement in the impact strength of a part when its melt temperature is increased. During initial compounding and in end-use processing, color stability of HT formulations are superior to that of standard formulations, which may permit the use of more regrind.

Testing with HT formulations also produced a measurable improvement in weld-line strength, the most important factor in the overall strength of a molded part.

Figure 2 **Effect of molding conditions on weld-line strength (Tenite™ propionate 384—14%)**



Effect of molding conditions on plaque impact resistance (Tenite™ propionate 382—16%)



Eastman's commitment to a greener, safer earth

Public concern about protecting the environment is increasing. Air, land, and water pollution, excessive energy consumption, solid waste management, and recycling are major issues worldwide. Eastman is also concerned about these issues and is committed to providing sound solutions to these problems through its people, technology, and resources.

Eastman aggressively promotes Responsible Care®,[1] an American Chemistry Council initiative focused on improving industry's performance in many areas, including community awareness, emergency response, distribution, pollution prevention, employee and process safety, and product stewardship. Eastman continually looks for ways to reduce waste, manufacture and transport its products more safely, protect employees and the community, and communicate with its neighbors.

Recycling

Consistent with its sense of product stewardship, Eastman supports plastic recycling. Eastman is recognized as a leader in environmental initiatives, as exemplified by the company's pioneering advocacy of recycling and its innovative technology that returns postconsumer PET plastic back to its original chemistry. Recycling is a valid waste management strategy for high-volume disposable goods. Recycling is a valid waste management strategy for high-volume disposable goods.

It is important to recognize that recycling represents only one facet of an integrated plan for combating the solid waste management dilemma. Eastman also supports source reduction, incineration, and municipal composting as valuable technologies in reducing the amount of material destined for landfills.

Because products made from Tenite™ cellulosic plastics are durable and often intended to be reused, the limited recyclability of Tenite cellulosic plastics is currently not an issue.

[1]*Responsible Care is a registered service mark of the American Chemistry Council.*

Table 1 Formula guide

	Basic formula	Basic plus odor mask	Basic plus UVI	Basic plus odor mask and UVI
Tenite™ acetate (Specific gravity approximately 1.28)	105			
	132			
Tenite™ butyrate (Specific gravity approximately 1.19)	264	285 530 550		485 ■ 576 ◆581
		565 ■ 575 ◆ 580		
		438		
				465 ● 513
Tenite™ propionate (Specific gravity approximately 1.20)	**358** ◆380 ▲◆385		307 ◆381	
	350			
	360 ▲**371** ■375			
	■377 ◆382 ▲◆383		■376 ◆384	

***Bold numbers** = Regulatory compliance information for food-contact use is available on request. (For Tenite propionate 350, only plasticizer contents of 14% or less meet FDA requirements.)*

● = Contains lubricant for extrusion
▲ =Contains mold release
■ = Standard inventory clears
◆ = HT series formula

Table 2 Typical properties

Property	Unit	ASTM method	Acetate 105-35	Butyrate 264-10	Propionate 360-12
Specific gravity		D792	1.26	1.19	360-12
Tensile strength @ yield [50 mm/min (2 in./min])	MPa	D638	22.8	33.1	31.7
	psi		3,300	4,800	4,600
Elongation @ break (50 mm/min [2 in./min])	%	D638	30	50	45
Flexural modulus (1.27 mm/min [0.05 in./min])	MPa	D790	1,300	1,400	1,400
	10^5 psi		1.9	2.0	2.1
Flexural yield strength (1.27 mm/min [0.05 in./min])	MPa	D790	33	46	41
	psi		4,800	6,600	6,000
Izod impact strength, notched, @ 23°C (240°C) (3.2 mm X 12.7 mm [⅛ in. X 3½ in.] specimen)	J/m	D256	235 (59)	240 (96)	416 (107)
	ft•lbf/in.		4.4 (1.1)	4.5 (1.8)	7.8 (2.0)
Deflection temperature (conditioned 4h @ 70°C [158°F])					
1.82 MPa (264 psi)	°C (°F)	D648	57 (135)	74 (165)	75 (167)
0.455 MPa (66 psi)	°C (°F)		70 (158)	85 (185)	83 (181)
Light transmission (1.52 mm [0.06 in.] thickness)	%	E308	>90	>90	>90
UV light screening (>99% absorbed)	%	E308	—Formulations available on request—		
Haze (1.52 mm [0.06 in.] thickness)	%	D1003	<8.5	<8.5	<8.5
Coefficient of linear thermal expansion	mm/mm•°C	D696	11–17 X 10^{-5}	11–17 X 10^{-5}	11–17 X 10^{-5}
	in./in.•°F		6–9 X 10^{25}	6–9 X 10^{-5}	6–9 X 10^{-5}
Dielectric strength	kV/mm	D149	14.5	16.6	15.9
	V/mil		368	422	404
Dielectric constant	@ 10^6 Hz	D150	3.5	3.3	3.3
Dissipation factor	@ 10^6 Hz	D150	0.05	0.02	0.03
Volume resistivity	ohm•cm	D257	1.6 X 10^{-3}	1.6 X 10^{-5}	2.6 X 10^{-5}
Surface resistivity	ohms/sq	D257	6.8 X 10^{-4}	1.4 X 10^{-6}	3.9 X 10^{-6}

Table 3 Typical markets

	Acetate	Butyrate	Propionate
Automotive (extrusion)	—	485E-10	—
Blister packaging	105E-24	485E-10	360E-12
Containers and tubing	105E-28	485E-10	360E-12
	—	285E-10	—
Face shields (sheeting)	105E-26	—	—
Face shields (molding)	—	—	307A-15
Furniture trim	—	485E-10	—
Medical devices	—	—	360A-09
Ophthalmic (molding)	105A-28	264A-10	360A-12, 382A-12
Ophthalmic (sheeting)	105E-26	—	360E-09, 382E-09
Optical safety frames (molding)	132A-27	—	360A-16, 382A-16
Profiles	—	485E-16	384E-16
	—	285E-16	360E-12
Recreational	—	485A-16	—
Sheeting	—	485E-10	—
Sunglasses (molding)	132A-27	—	384A-09 to -12
Tool handles	105-35	530E-16	—
Toothbrushes	—	—	383A-08 to -12
Toys	105A-30	285A-22	358A-18
	—	—	360A-16
Writing instruments	105A-30	285A-16	360A-16

Classifications: A = Injection molding E = Extrusion

Table 4 Packaging and minimum shipments

		Fiber drums		Cardboard boxes	
Net weight		125 kg	(275 lb)	450 kg	(1,000 lb)
Tare weight per pallet		50 kg	(110 lb)	26 kg	(57 lb)
Diameter		594 mm	(23.375 in.)	—	—
Height		902 mm	(35.5 in.)	940 mm	(37 in.)
Length		—	—	902 mm	(35.5 in.)
Width		—	—	1,118 mm	(44 in.)
Shipping cubage per pallet		1.246 m^3	(44 ft^3)	0.960 m^3	(33.917 ft^3)
12.2-m (40-ft) trailer	Containers per load	144 drums		42 boxes (on 42 pallets)	
	Total weight	18,000 kg	(39,600 lb)	18,900 kg	(42,000 lb)
6.1 mm (20-ft) trailer	Containers per load	80 drums		24 boxes (on 24 pallets)	
	Total weight	10,000 kg	(22,000 lb)	10,800 kg	24,000 lb)

Other Eastman publications on Tenite™ cellulosic plastics

Publication number	Title
PP-101	Chemical resistance of Tenite™ acetate
PP-102	Chemical resistance of Tenite™ butyrate
PP-103	Chemical resistance of Tenite™ propionate
PP-104	Weathering of Tenite™ butyrate
PP-107	Measurement of stresses in parts made of Tenite™ cellulosic plastics
PP-108	Film and sheet extrusion from Tenite™ cellulosic plastics
PP-109	Extrusion of tubing and profiles with Tenite™ cellulosic plastics

Data sheets are available for cellulosic formulas.
Translations are available for several publications.

To request a publication, or for additional information, contact Eastman at one of the addresses listed on the back cover or visit www.eastman.com.

EASTMAN

Eastman Chemical Company
Corporate Headquarters
P.O. Box 431
Kingsport, TN 37662-5280 U.S.A.

Telephone:
U.S.A. and Canada, 800-EASTMAN (800-327-8626)
Other Locations, (1) 423-229-2000
Fax: (1) 423-229-1193

Eastman Chemical Latin America
9155 South Dadeland Blvd.
Suite 1116
Miami, FL 33156 U.S.A.

Telephone: (1) 305-671-2800
Fax: (1) 305-671-2805

Eastman Chemical B.V.
Fascinatio Boulevard 602-614
2909 VA Capelle aan den IJssel
The Netherlands

Telephone: (31) 10 2402 111
Fax: (31) 10 2402 100

Eastman (Shanghai) Chemical Commercial Company, Ltd.
Building C, No. 399 Shengxia Road,
Pudong New District
201210, Shanghai, P.R. China

Telephone: (86) 21 6120-8700
Fax: (86) 21 5027 9229

Eastman Chemical Asia Pacific Pte. Ltd.
9 North Buona Vista Drive
#05-01 The Metropolis Tower 1
Singapore 138588

Telephone: (65) 6831-3100
Fax: (65) 6732-4930

www.eastman.com