EASTMAN

TENITE™
cellulosic plastics

Weathering of Tenite™ butyrate

Plastics made from wood pulp—a renewable resource

Weathering of Tenite™ butyrate

Introduction

Tenite™ butyrate, a plastic produced from cellulose acetate butyrate, was first marketed in 1938. Commonly known as "butyrate," it has been used in an array of injection molding and extrusion applications and has become one of the best known and most widely used cellulosic thermoplastics. It can be easily processed using most methods of forming thermoplastics. Butyrate also offers a very useful combination of toughness, hardness, and strength. The most desirable combination of properties for any particular application may be attained by proper choice of formulation and flow.

Factors that influence weathering damage

Many butyrate applications involve exposure to solar radiation. Cellulose esters, like most polymeric materials, degrade when exposed to this radiation and other environmental conditions that cause weathering. Consequently, one phase of Eastman's research efforts over the years has been directed toward improving the ability of Tenite™ butyrate to resist weathering. Special outdoor formulations now being produced may be expected to remain useful for at least 5 years outdoors in any part of the continental United States and in other areas of the world with comparable climates. During the critical phases of fabrication, transportation, warehousing, and installation of outdoor applications, butyrate provides a resistance to breakage far superior to that of many plastics marketed for outdoor use. Even though its toughness decreases with prolonged outdoor exposure, tests have shown that after several years of outdoor use, the best outdoor formulations of Tenite butyrate still retain higher impact strength than unweathered specimens of many competitive materials.

Most weather effects are caused by the ultraviolet portion of the sun's radiation. The energy contained in ultraviolet light is capable of directly rupturing the long chains of a cellulose ester (chain scission); in addition, in the presence of oxygen, ultraviolet radiation causes oxidation of the plastic. The infrared portion of sunlight warms the plastic and accelerates the harmful effects of ultraviolet light. In the continental United States, conditions that cause weathering are several times more severe in summer than in winter. This is partly due to the increased amount of ultraviolet light that penetrates the atmosphere and reaches the ground during the summer and partly due to higher temperatures. In addition to seasonal variations, solar radiation on the ground is influenced by latitude, altitude, and clarity of the atmosphere. The average strength of solar radiation decreases as latitude (either north or south of the equator) increases, and increases slightly as altitude increases; but at any latitude and altitude, the amount of radiation that reaches the ground can be greatly reduced by dust, smoke, or clouds in the atmosphere.

Cellulose esters can be partially protected from the direct chain scission and the photo-catalyzed oxidation previously discussed. Protection from chain scission is obtained with special stabilizers known as ultraviolet inhibitors; protection from oxidation is obtained with antioxidants. Ultraviolet inhibitors, commonly referred to as UVIs, are chemical compounds that absorb ultraviolet light and disperse the energy contained in UV radiation in a form that is less harmful to the plastic. Most materials synthesized for the purpose of being used as UVIs are transparent and essentially colorless, but there are also some pigments and dyes that function as ultraviolet inhibitors.

The deterioration in cellulosics caused by weathering depends on the particular cellulose ester, plasticizer, stabilizer system, wavelength of the incident radiation, total amount of radiation absorbed, temperature of the plastic, atmospheric humidity, industrial contaminants in the atmosphere, and possibly other factors.

Experimental weathering and useful life

The development of weather-resistant formulations of Tenite™ butyrate is based on information Eastman has accumulated through a test program carried on continuously since the early 1940s. The total program involves outdoor weathering, accelerated weathering tests of many types, preparation and testing of hundreds of different plastic formulations, and synthesis of many organic compounds that might be useful UVIs; many are covered by Eastman patents. Since about 1950, work with UVIs for cellulosic plastics has concentrated on cellulose acetate butyrate.

Actual outdoor performance is the most reliable criterion by which the outdoor usefulness of a plastic can be judged. Eastman's outdoor weathering program involves exposure of many hundreds of samples at weathering stations in Kingsport, Tennessee (Lat. 36° 32' N, Long. 82° 34' W, El. 1,200 ft); Homestead, Florida (Lat. 26° 38' N, Long. 81° 51' W, El. 9 ft); and Phoenix, Arizona (Lat. 33° 27' N, Long. 112° 3' W, El. 1,080 ft). Atmospheric humidity is very high in Florida, very low in Arizona, and variable in Tennessee. Results obtained at these stations should be indicative of performance to be expected under comparable conditions of latitude, elevation, temperature, and humidity throughout the world.

Weathering conditions are more severe in Arizona and Florida than in Tennessee, and generally more severe in Arizona than in Florida. Solar radiation at Phoenix averages more than 185,000 langleys[1] per year on a horizontal surface; the average daytime high temperature exceeds 38°C (100°F) during the summer months.

Experimental weathering is done in an open location with the samples facing south and inclined northward at an angle of 45° from vertical, subjecting the specimens to the maximum sunshine exposure with a fixed mounting in the central northern latitudes. (This mounting is specified in Test Method D1435 published by the American Society for Testing and Materials.) Less severe exposure would increase the life expectancy of the material over that indicated by the test results. For example, a meter cover mounted on the east wall of a house might receive less than half the available sunshine, and its useful life should be substantially longer than that of a test specimen. Differences in weathering due to different mounting directions are accentuated by the fact that the rays of the midday sun contain much more energy than the early morning and late afternoon rays.

[1]Langley is the unit used to denote one gram calorie per square centimeter. The incident radiation and temperature figures given are based on information published by *Isolation Data Manual*, SERI/TP-220-3880, DE90000353, July 1990, p. 22.

The degree by which the useful life of a normal application can exceed that of a test specimen is illustrated by the history of a butyrate sign installed over a shop in New York City several years ago. The sign was made from a butyrate formulation containing a UVI of only moderate effectiveness (with a useful life of about 2 years in Arizona), yet it remained in service for about 9 years.

Deterioration of cellulosic plastics caused by weathering first appears as a dulling of the surface. As deterioration proceeds into advanced stages, the surface crazes and cracks; the formation of each fissure exposes underlying plastic to the action of the weather.

The onset of surface crazing does not mean the end of the usefulness of Tenite™ butyrate. It will still have good tensile strength, elongation, and impact strength. Elongation is one of the best methods for determining the toughness of a plastic. A brittle material will break with little elongation and will show a smooth, glassy break. A tough material will show a ductile break with good elongation before breaking occurs. The average tensile strengths and elongations of 3.2-mm (0.125-in.) thick specimens of an outdoor type of Tenite butyrate continuously exposed outdoors for periods of up to 36 months at the Phoenix, Arizona, testing station are shown in Figures 1 and 2.

The results of outdoor weathering tests conducted in Kingsport, Tennessee, on the same outdoor type of Tenite™ butyrate in 3.2-mm (0.125-in) thicknesses show the retention of good impact strength during the weathering program. For this test, samples were weathered in a vertical position facing due south.

Samples were removed from the field station at 1-year intervals, and impact strengths were determined. The results of this testing are shown in Figure 3.

Figure 1

Tensile strength at break of Tenite™ butyrate weathered in Arizona

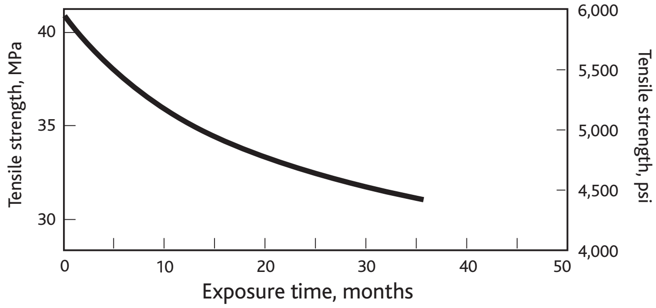


Figure 2

Elongation at break of Tenite™ butyrate weathered in Arizona

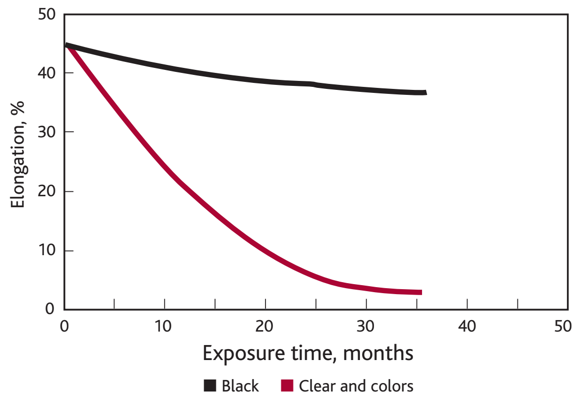
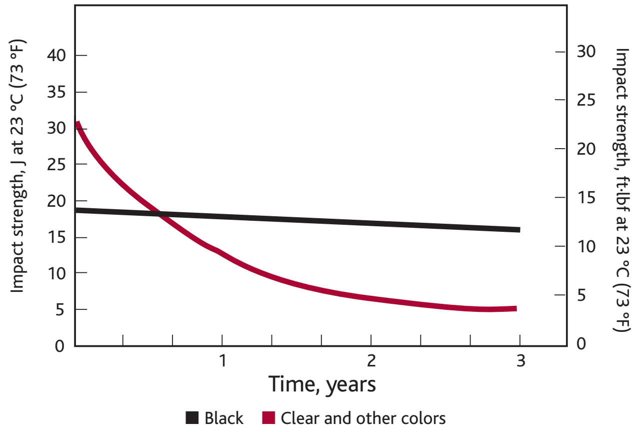


Figure 3

Plaque impact strength (ASTM D3029) of weathered Tenite™ butyrate struck on weathered side



Tenite butyrate formulations for outdoor use

Various formulations of Tenite™ butyrate have different degrees of resistance to solar radiation. As mentioned previously, formulations unprotected by UVI or heavy pigmentation, although ordinarily suitable for indoor use indefinitely, generally give only a few months of satisfactory outdoor service.

The most weather-resistant butyrate formulations are typified by Tenite™ butyrate 465. The most used formulas in this group are Tenite butyrate 465, 485, and 513. These special outdoor materials ordinarily remain useful for 5 years or more exposed continuously in Arizona. These formulas are used for such applications as covers for electric meters and housings for fire alarms, where continuous, longtime outdoor exposure is intended. The weathering inhibitor in these formulations has a slight tendency to discolor after long exposure where heavy industrial atmospheric contamination is prevalent; the discoloration sometimes becomes noticeable if light colors are used.

Like cellulose esters, dyes and pigments may be affected adversely by sunlight. In many instances, they change color or lose their color under the influence of light and oxygen. An investigation of many years' duration involving exposure of samples under a carbon arc to accelerate the effects of weathering, as well as actual outdoor weathering tests, has resulted in the selection of colorants for butyrate outdoor formulations as stable as the plastic materials themselves.

Articles made of outdoor types of Tenite butyrate in suggested colors, therefore, should give at least 5 years' service under even the most adverse weather conditions found in the continental United States. These most adverse conditions represent exposure to solar radiation that measures approximately 185,000 langleys per year on a horizontal surface and are found, in general, south of about 35° N latitude and between about 100° and 115° W longitude. Comparable exposure in other parts of the world should have similar effects.

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