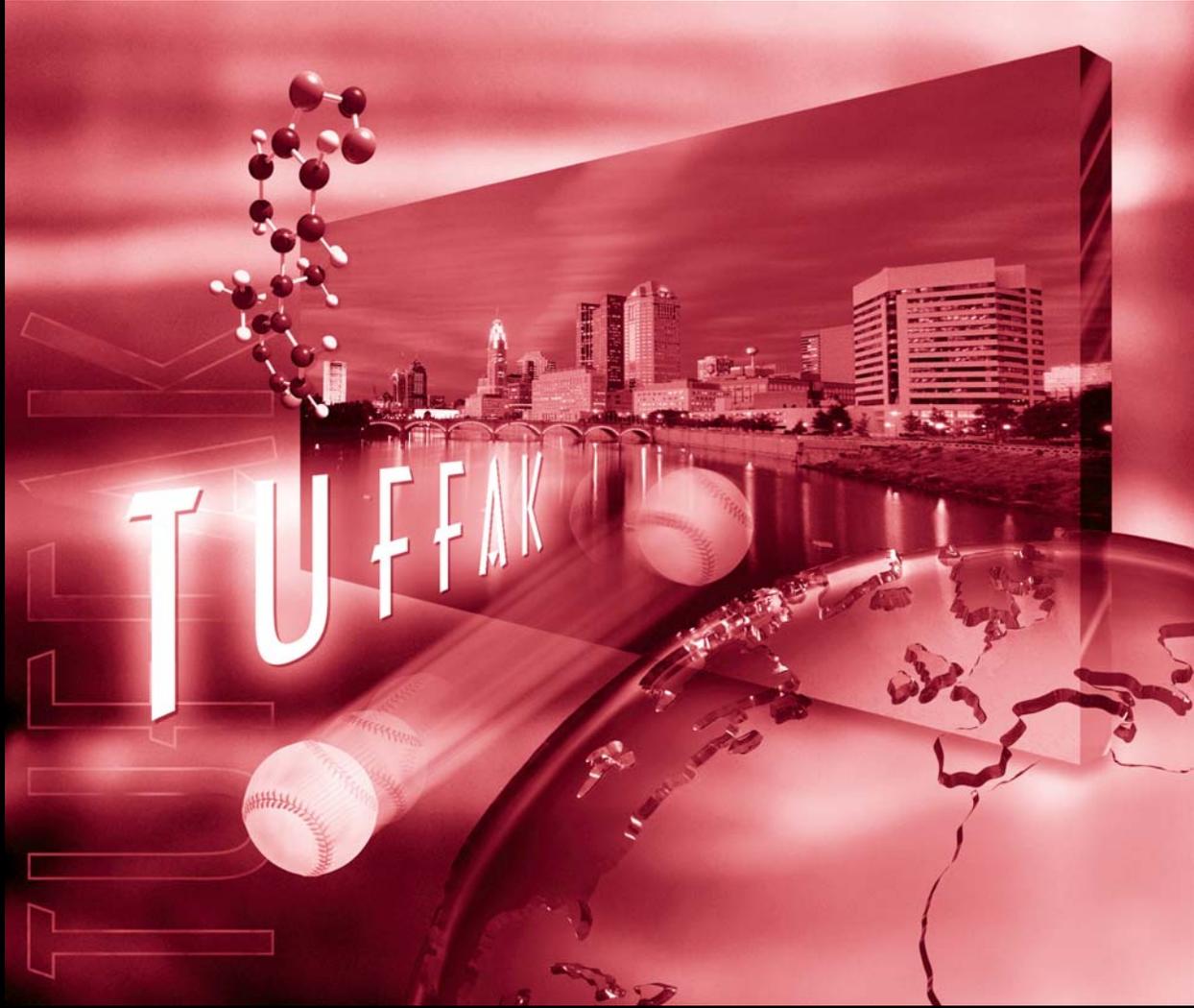


TUFFAK[®] XL

Weatherable Polycarbonate Sheet



GENERAL INFORMATION
AND PHYSICAL PROPERTIES



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I N T R O D U C T I O N

Tuffak® XL polycarbonate sheet is a newer grade of a high-impact polycarbonate plastic sheet product produced by Altuglas International. Virtually unbreakable, Tuffak XL sheet is 300-times stronger than single-strength glass, and significantly tougher than other transparent sheet materials of equal thickness. In addition being inherently tough, Tuffak XL polycarbonatesheet is light in weight, transmits approximately 85% of incident light, and possesses excellent weather resistance.

General-purpose polycarbonate sheet tends to yellow after exposure to sunlight, i.e., ultraviolet radiation. This yellowing is accompanied by a marked reduction in impact-resistance. Surface haze, another consequence of UV exposure, reduces the light-transmitting properties of general-purpose polycarbonate and further detracts from an initially attractive surface gloss.

Tuffak XL weatherable polycarbonate sheet, is manufactured via a proprietary process that imparts a UV-resistant structure, which in turn provides the sign and glazing industries with the following advantages over standard, general-purpose polycarbonate sheet:

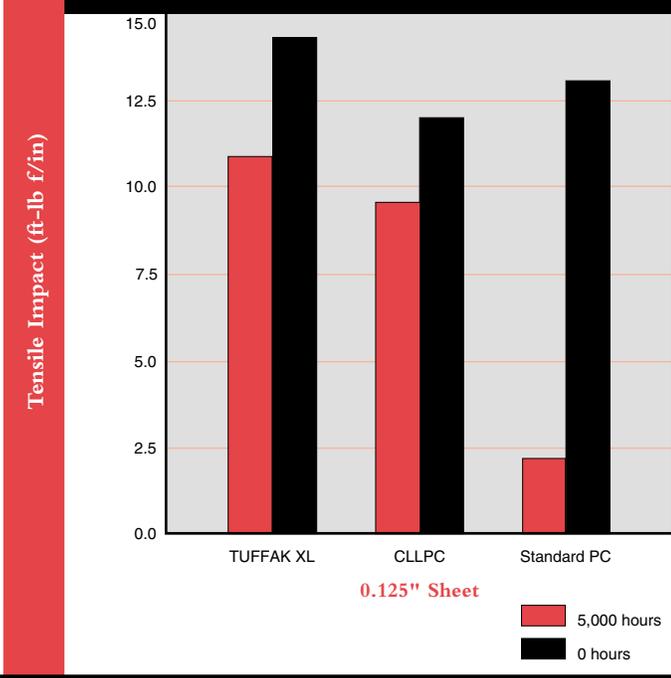
- Preserves impact properties significantly longer
- Resists yellowing
- Maintains a higher degree of light transmittance over time

These weatherability advantages are realized without sacrificing thermoformability, general fabricating properties, and many other characteristics that make polycarbonate the material of choice in demanding applications.

TUFFAK® XL Weatherable Polycarbonate Sheet

FIGURE 1 – TUFFAK XL

Tensile Impact of Aged Sheet – 5,000 hrs Xenon Weather-O-Meter



ARTIFICIAL WEATHERING STUDIES

IMPACT RESISTANCE

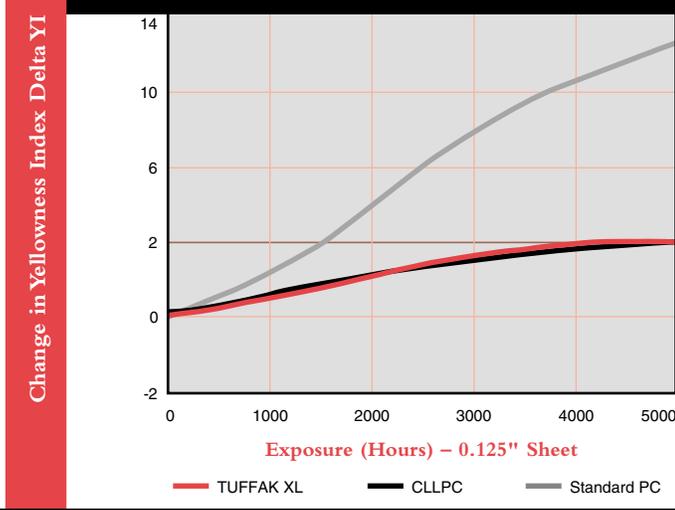
Polycarbonate sheet has long been the material of choice in applications demanding a high degree of impact resistance, such as vandal-resistant glazing and sign faces in high-traffic, high-vandalism areas.

However, the degradative effects of weather and the sun (especially ultraviolet radiation) reduce important impact-resistance properties that prompted the decision to use polycarbonate in the first place.

To evaluate the toughness of Tuffak XL polycarbonate sheet compared with other materials, Atoglas employed *Tensile Impact Testing*. Samples of Tuffak XL polycarbonate, general-purpose polycarbonate and a competitor’s coated UV-resistant polycarbonate sheet were exposed to UV radiation via a Xenon Weather-O-Meter device for 5,000 hours and then subjected to tensile impact testing. Tuffak XL sheet proved to have greater impact-resistance properties than the other materials both before and after the test (Figure 1).

FIGURE 2 – TUFFAK XL

Yellowness Index – Xenon Weather-O-Meter



RESISTANCE TO YELLOWING

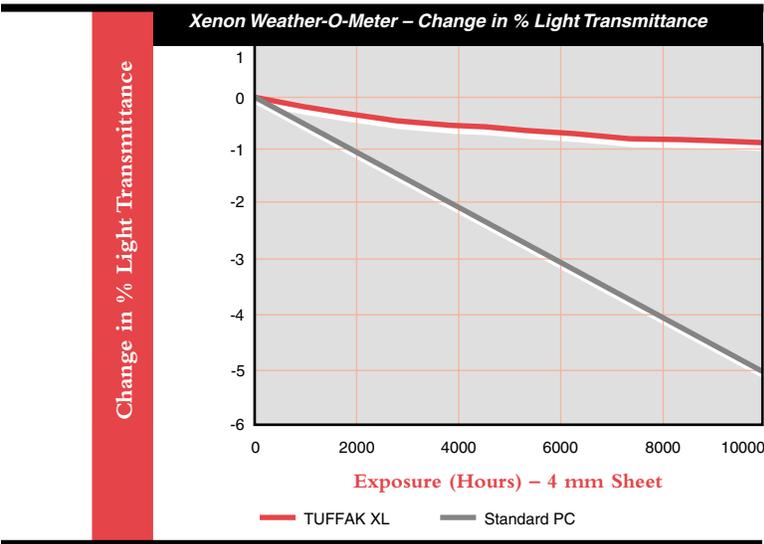
The Xenon Weather-O-Meter’s accelerated weathering effect also shows the changes in a material’s optical properties as it ages under the influence of “weather.”

Increased yellowness in relation to the length of exposure time is a result of the degradative effects of UV radiation. Yellowness Index (YI) is a term used to quantify the perceived yellowness of a material. Generally, the higher the Yellowness Index, the yellower the sample. Yellowness, an undesirable property in most transparent plastic sheet applications, is a particularly severe problem with general-purpose polycarbonate, as shown in Figure 2.

Tuffak XL polycarbonate sheet provides excellent protection against UV-induced yellowing.



FIGURE 3 – TUFFAK XL



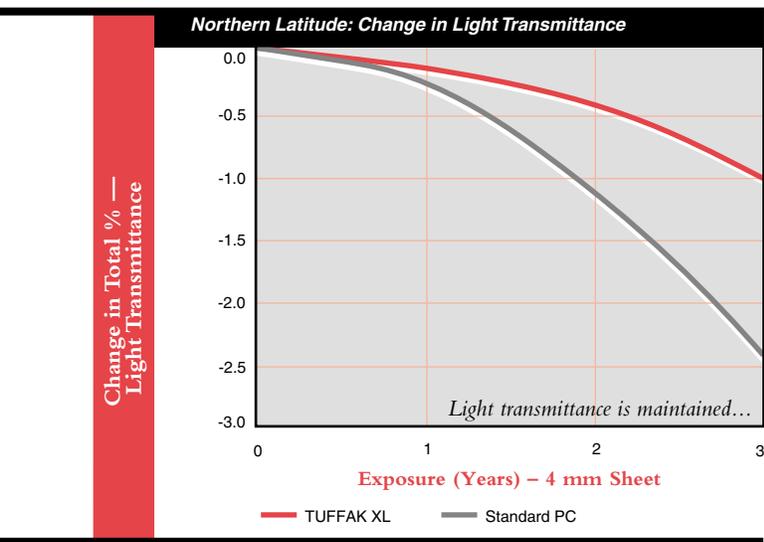
HAZE DEVELOPMENT

(DECREASE IN LIGHT TRANSMITTANCE)

In addition to Yellowness Index, another parameter used to evaluate the weatherability properties of a material is light transmittance. Light transmittance is affected by surface haze and yellowness, which combine to reduce the amount of incident light that can be transmitted through the thickness of the sheet.

As shown in Figure 3, there is a significant reduction in the level of light transmitted through a sheet of standard polycarbonate after it has been exposed to UV radiation. But Tuffak XL polycarbonate sheet maintains its clarity, since surface haze (i.e., “dullness”) and yellowing are held in check by the UV-protective structure.

FIGURE 4 – TUFFAK XL

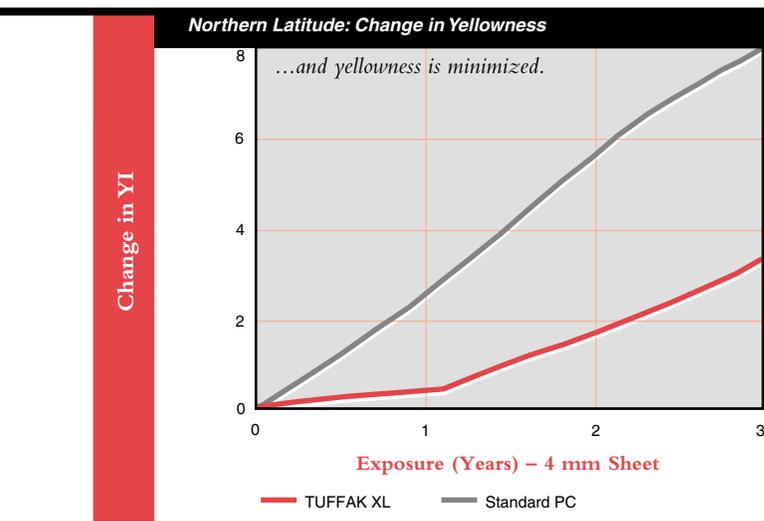


ACTUAL OUTDOOR WEATHERING

YELLOWNESS AND LIGHT TRANSMITTANCE

While accelerated artificial weathering studies provide one means of evaluating the weathering performance of plastics, actual outdoor weathering exposures are, of course, also an important, if slower, source of information. The results of the real-world/real-time weathering studies, as shown in Figures 4 and 5, support the conclusions drawn from the accelerated artificial studies: Tuffak XL polycarbonate exhibits improved UV-resistance performance over general-purpose polycarbonate.

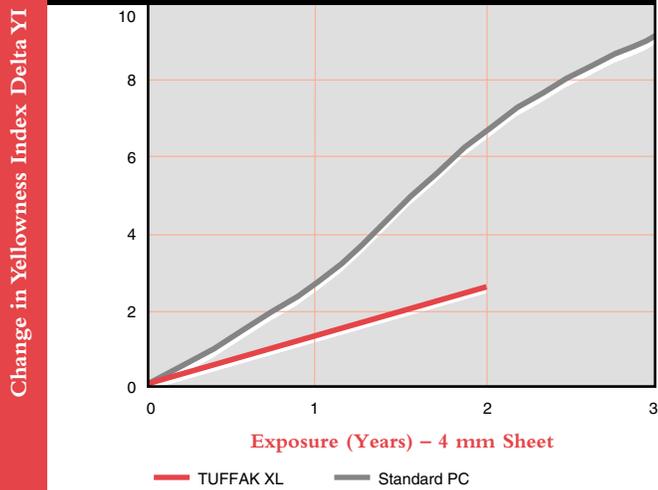
FIGURE 5 – TUFFAK XL



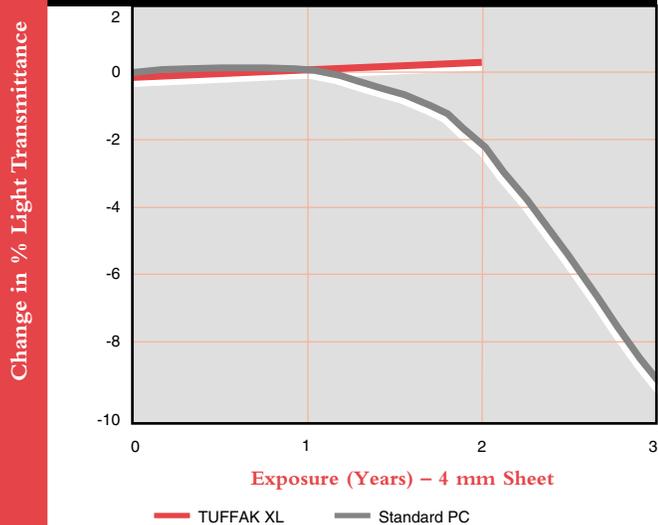
The superior weatherability of Tuffak XL polycarbonate sheet is once again illustrated in these exposure studies conducted in Florida, as depicted in Figures 6 and 7.

FIGURE 6 – OUTDOOR WEATHERING

Florida: Change in Yellowness Index

**FIGURE 7 – OUTDOOR WEATHERING**

Florida: Change in Light Transmittance

**FORMING AND FABRICATING**

Tuffak XL polycarbonate sheet can be thermoformed, cold formed, and brake formed under the same conditions and using the same molds fabricated for use with standard-grade polycarbonate sheet. No special mold surfaces or surface preparations are needed, in contrast to systems required for UV-coated polycarbonate products.

High-temperature (from 370°F to 415°F) thermoforming is required for deep draws or sharp detail. It is critical that Tuffak XL sheet be dried to a moisture level of less than 0.04% before high-temperature forming to avoid formation of moisture bubbles. The sheet should be dried in a 250°F circulating air oven with the time dependent upon sheet thickness. See the Tuffak Forming and Fabrication Manual (ADV980496) for complete details.

Low-temperature (300°F to 350°F) thermoforming is sufficient for simple drape-forming Tuffak XL polycarbonate parts, and pre-drying is not necessary.

Cold forming is used when a retainer frame can be used to hold the Tuffak XL sheet to a shape. To ensure that stresses will not cause crazing, the minimum radius of curvature when cold forming must be $100t$ (where t equals sheet thickness).

Other fabrication and machining techniques, described in the general Tuffak A manuals, fully apply to Tuffak XL polycarbonate sheet applications.



OTHER PROPERTIES AND INFORMATION

The improved weatherability of Tuffak XL sheet is achieved with a proprietary technology that actually “builds” an ultraviolet barrier into the sheet while maintaining the integrity of an all-polycarbonate composition. This technique can provide realizable processing performance advantages in addition to providing better weather resistance.

The technology used to produce Tuffak XL sheet overcomes the technical challenge of protecting a polycarbonate substrate with dissimilar coatings to provide improved weathering. The substantial differences between the polymer used in the coating and the polycarbonate material, with respect to heat-distortion temperatures, can cause a situation known as “mold sticking” during thermoforming operations.

Since Tuffak XL sheet is all polycarbonate, it can be heated and formed without regard to dissimilar heat-distortion temperatures, thus eliminating concern for “mold sticking.” A coated polycarbonate sheet must be heated to a higher temperature in order to optimize its forming characteristics. This process can overheat the coating, softening it beyond its optimum

forming point. Then, when the softened coated side comes in contact with a mold or tool surface, it will, on occasion, selectively stick to the mold and separate from the substrate.

The table below summarizes the physical properties of Tuffak XL weatherable polycarbonate sheet, comparing them with those of our standard polycarbonate sheet product, Tuffak A.

WHITE TUFFAK XL SHEET

Tuffak XL polycarbonate sheet is also available in a white translucent color, 25700. It combines superior impact resistance with long-term weatherability in a colored sheet. The unique integration of an ultraviolet barrier into the sheet’s molecular structure also provides excellent long-term resistance to the white pigmented sheet. As a consequence, when Tuffak XL 25700 sheet is used for outdoor sign faces, they stay bright for years without dulling, hazing, or fading.

White 25700 is available in sheet thicknesses ranging from 0.060" to 0.236". The light transmittance of these sheets is 24% at each of the above thicknesses. These transmittance values are well established in the sign industry, due to the brilliant whiteness of color when illuminated and superb color retention properties over time.

Typical Physical Properties (0.125") — TUFFAK XL and TUFFAK A Sheet*

	Units	TUFFAK XL	TUFFAK A
OPTICAL			
Transmittance	%	87	85 – 91
Haze		1	0.5 – 2.0
MECHANICAL			
Tensile stress at yield	10 ³ psi	9.3	8 – 9.5
Tensile stress at break	10 ³ psi	10	9 – 11.5
Tensile strain at break	%	125	100 – 130
Tensile modulus	10 ³ psi	330	330 – 350
Flexural modulus	10 ³ psi	330	320 – 350
Izod impact strength	ft-lb/in	17	12 – 18
Rockwell hardness	M-scale	75	70 – 75
	R-scale	118	118
THERMAL			
HDT (unannealed)	°F		
264 psi load		270	265 – 290
66 psi load		288	285
Coefficient of thermal expansion	in/in/°F	3.9x10 ⁻⁵	3.9x10 ⁻⁵

* Values reported are averages and should not be used for specification purposes.

10-YEAR LIMITED PERFORMANCE WARRANTY

The performance of Tuffak XL polycarbonate sheet has been proven via laboratory testing. A ten-year limited warranty backs the material against excessive yellowing, loss of light transmission and breakage.

For specific details, contact Atoglas or your local Tuffak sheet distributor.

HEALTH AND SAFETY PRECAUTIONS

All thermoplastic materials produce some gases or vapor at high temperatures. Drying, machining and thermoforming Tuffak XL sheet will not result in harmful concentrations of vapors when handled in areas with adequate ventilation* and in accordance with techniques, processing conditions and temperatures recommended herein. It is always good practice to provide local exhaust ventilation as close to the point of possible generation of vapors as practical.

Any dust produced by the machining of Tuffak XL sheet is considered nuisance dust. The American Conference of Governmental Industrial Hygienists (ACGIH) recommended TWA for nuisance dust is 10 mg/m³—total dust; and 5 mg/m³—respirable dust.

Worker exposure to dust can be controlled with adequate ventilation,* vacuum dust removal at the point of generation, or the use of suitable protective breathing devices.

*Suggestions for the design of exhaust ventilation are provided in *Industrial Ventilation—A Manual of Recommended Practice*, published by the ACGIH (1988); and American National Standards Institute *Fundamentals Governing the Design and Operation of Local Exhaust Systems*, Z9.2-1979.



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**TUFFAK® XL Weatherable
Polycarbonate Sheet**

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See MSDS for Health & Safety Considerations.

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