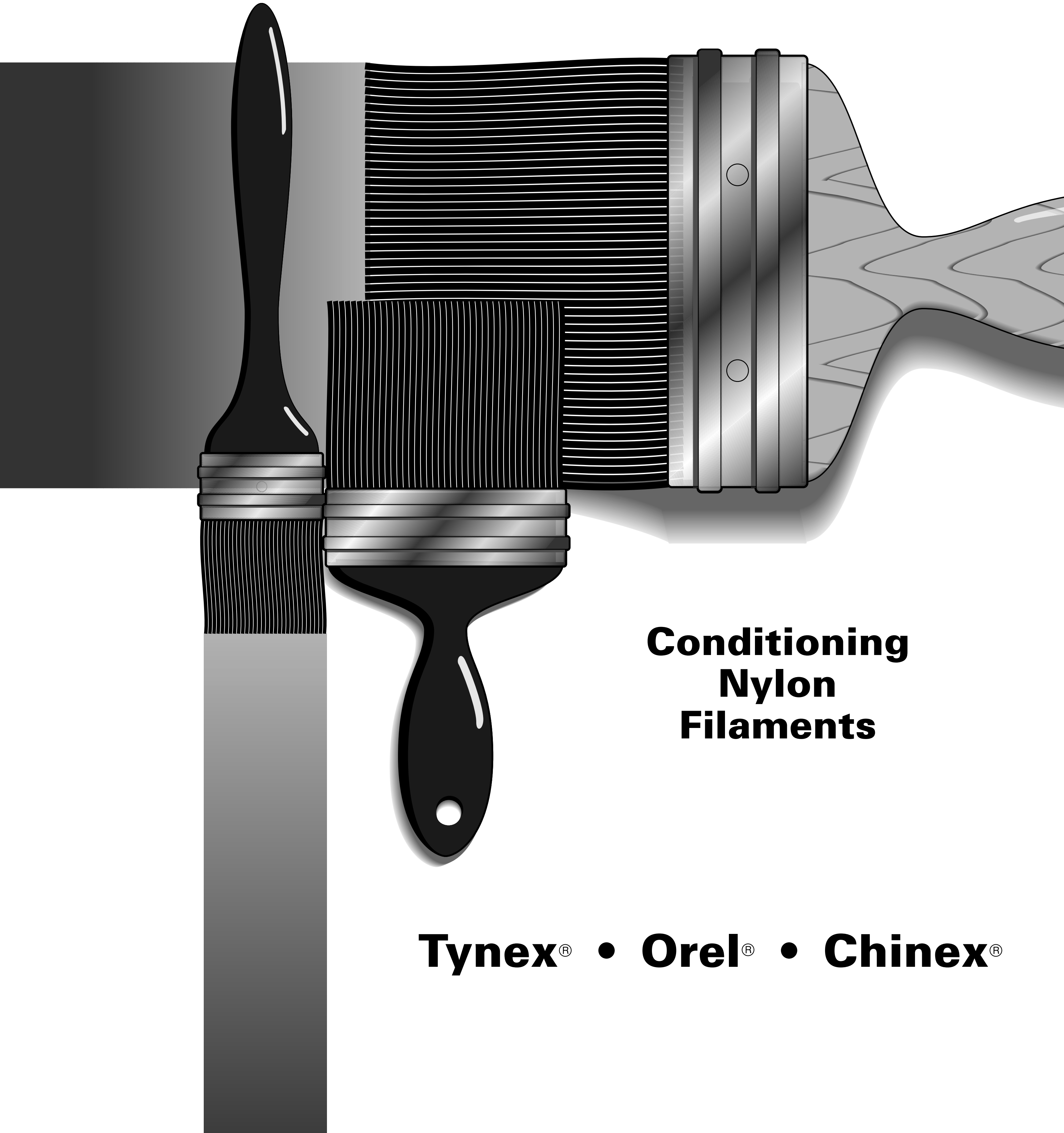
Technical Information

DuPont Filaments



Conditioning Nylon Filaments

Tynex® • Orel® • Chinex®

DuPont Filaments
Effects of Conditioning Nylon Filaments

Polymer Chemistry Background

As nylon filaments are manufactured, process conditions are adjusted to optimize the filaments' physical properties for their specific use. These process variables will affect the thermal history of the filament. This thermal history, along with other variables like draw tensions and draw ratios, establish how the polymer molecule chains of the filament line up and crystallize. The positioning of the molecules greatly influences the performance of the filament in its end-use environment.

Nylon is a crystalline resin polymer. Each filament consists of molecules with both highly ordered and random orientation segments along their very long lengths. Polymers with a high level of structured order are said to have a high degree of crystallinity. It is the degree of crystallinity that gives certain physical properties to the filament. For a specific polymer, the properties can be affected by additives and the length of the molecule (molecular mass).

Generally, an increase in the degree of crystallinity affects properties in the following ways, as described by Kohan in *Nylon Plastics* (John Wiley & Sons, 1973).

As Degree of Crystallization Increases

Property Increases	**Property Decreases**
Stiffness or modulus	Impact resistance
Density	Elongation
Yield stress	Thermal expansion
Chemical resistance	Permeability
Electrical properties	Swelling
Glass transition temperature	Mechanical damping
Melting point	
Abrasion resistance	
Creep resistance	
Dimensional stability	

From this list, you can see why Tynex filaments, made from type 612 nylon, can offer a good balance of stiffness, abrasion resistance, chemical resistance, and dimensional stability.

Making Chemistry Work for You

The performance of a filament in a specific application can often be explained by looking at what happened as it was made. Think of polymer molecules as long springs that get stretched and twisted during the extrusion process. The rate of extrusion, melt temperature, and die configuration affect how much stretching is done to the polymer chain. Once out of the die, the polymer molecules begin to cool and try to contract back to their initial lengths as they crystallize and become a solid filament strand. The rate of cooling and the stresses caused by the extrusion dictate the extent to which the molecules crystallize. This crystallinity establishes the initial density of the filament. By the time the filament is quenched (cooled in water) and wound onto a spool, the primary degree of crystallinity is set.

Crystallinity can change. Not all of the polymer molecules get a chance to return to their initial unstretched length before they solidify. Over time, as filaments are subjected to the heat and moisture in their applications, the molecule chains slowly relax, relieving the stresses locked in during extrusion. Often, it is desirable to cause these relaxations to occur quicker, in a controlled manner, by exposing the filaments to a second heat-set step. This is often called annealing or secondary crystallization. This can be done by passing the filaments through a hot air oven or hot liquid baths (like dye baths).

For nylon filaments, the annealing rate can be increased by raising the temperature and increasing the amount of absorbed water in the filament. Nylon polymers get many of their unique properties not only from the length of the polymer chains and the movement interference from other chains and side groups, but also from bonding between adjacent molecule chains. This is called "hydrogen" bonding. During annealing, the filament temperature is controlled at a point high enough to let the molecules move slightly, but below the point of melting. Moisture helps to disturb the weaker hydrogen bonds in the lower stress level. Maintaining a slight tension on the filaments restricts the molecules from falling into a disordered alignment. Once the molecule chains are untwisted, the molecules have more opportunity to align with neighboring molecules and form new hydrogen bonds.

Annealing (secondary heat treatment) will give a filament greater crystallinity and lower stress levels. The additional hydrogen bonds or “tie points” between molecules help to prevent the molecules from moving too far when the filament is flexed, thus improving bend recovery and minimizing curl.

Dyeing Effects

Sometimes, a filament treatment such as dyeing in hot liquid can cause secondary crystallization and the same changes as annealing. The liquid bath must be at a temperature high enough to let the molecules move. Filament immersion in liquid for greater than four hours at 90°C (194°F) and above generally results in annealing and stress reduction. It is also necessary to restrain the filament during heat setting to prevent curling during the relaxation phase. The filament strands will be “set” to whatever straight or curved position they are restrained in during the heat-set operation.

It is unlikely that the different filament suppliers use identical processing steps as they produce filament for specific end uses. So the conditions needed to cause a secondary heat set will vary. The introduction of additional moisture during this step, whether through humidified air or immersion in a liquid, has proven to be effective at lowering the temperature required to relax the polymer chain stresses. Because dyeing is a liquid-base process, the moisture needed is readily available.

The changes caused by a secondary heat set can yield better dimensional stability and improved bend recovery. The amount of improvement depends on the heat history of the filament and the conditions chosen for the secondary heat set.

Typical Questions
Conditioning Nylon Filaments

What properties are affected by dyeing and conditioning?

—Stiffness, yield stress, bend recovery, crystallinity

Why does filament sometimes curl when dyed or conditioned?

—Relaxation of filament stress

Why do brushes made from dyed filament clean easier?

—Wetting and dispersion agents in dye act as surfactants that reduce paint adherence to the filament.

What happens when you expose tapered filaments to hot water or dry heat?

—Stress relaxation can occur. If unrestrained, the filament may curl. Immersion in hot water is often used to test for curl.

Why does filament that has been dyed seem to make a better paintbrush?

—Less likely to curl

—Additional conditioning helps bend recovery

—Enhanced crystallinity makes flagging easier

—Dye additives make cleaning easier

Should I dye filament or buy pigmented filament?

—Dyeing affects only outer surface. Tipped and flagged filaments still have clean, white appearance. Dyeing can also deliver additional benefits of improved bend recovery and easier cleaning.

—Fully pigmented filament is colored inside and out. Tipping and flagging do not produce a highlighted tip. Pigmented filament can still be further conditioned to gain benefits often seen from dyeing.

DuPont Filaments

Tynex® A Abrasive Filaments
Floor Care Brushes
Industrial Brushes

Tynex® Filaments
Toothbrushes
Cosmetic Brushes

Tynex®, Chinex®, Orel® Tapered Filaments
Paintbrushes

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