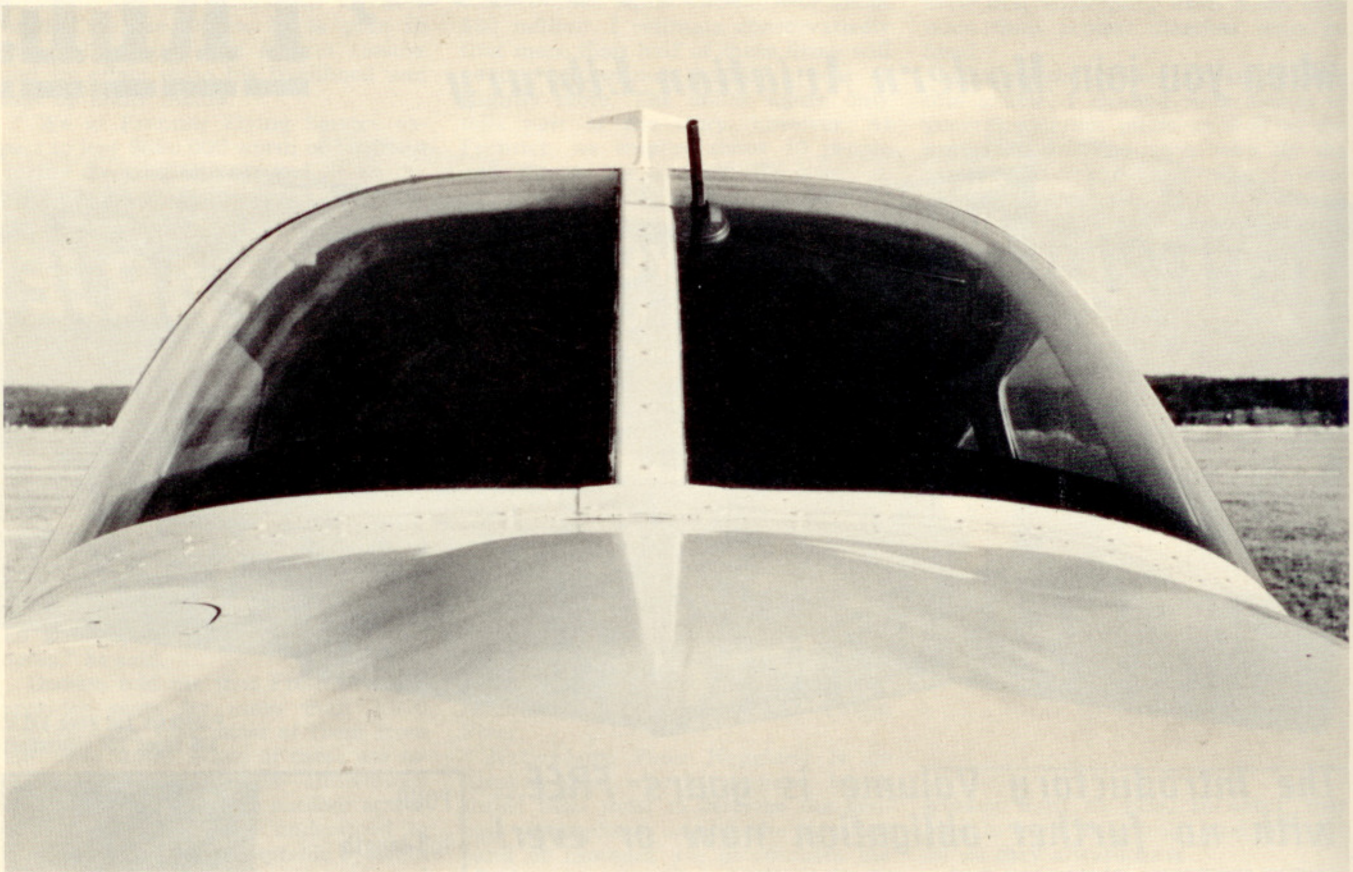


For all their strength and dependable service, aircraft acrylic windshields have soft, delicate surfaces that can easily be scratched or blemished. Fortunately, proper care of these surfaces is easy and inexpensive.

Text and Photos by RAY MARTIN / AOPA 634209

We pilots put a lot of faith in what aircraft manufacturers call "transparencies." Windshields molded of acrylic help us find our way, protect us from the elements and work to make our cabin environment safe and comfortable. They're aviation's unseen marvels.

Because windshields and windows are transparent, some pilots unintentionally relegate them to an out-of-sight, out-of-mind status. Acrylic plastic windshields are often neglected, improperly cared for and occasionally abused.

Single-ply acrylics—commonly referred to as Plexiglas, the most widely known of acrylic registered trademarks—are used almost exclusively for the window areas of most single-engine general aviation aircraft. Larger aircraft also make use of acrylics, but in multilayer applications of "stretched" acrylic.

Stretched acrylics are stronger than the "as-cast" acrylics used in light aircraft, since they must withstand bird strikes, hail, the effects of precipitation at higher speeds, colder weather and greater temperature differential between the cabin and the outside environment. These heavier-duty acrylics are used in many piston twins and some high-performance jets.

The acrylic plastics industry evolved out of an immediate aviation need at the beginning of World War II. Rohm & Haas Co. of Philadelphia, Pa., patented the Plexiglas formula and began using acrylics in the canopies and observation domes of U.S. warplanes. Because of the wartime demand for the revolutionary product, the manufacturing process for acrylics had to be made available to other companies, many of which still manufacture various acrylic products today.

Acrylics have many advantages. The material is a monolithic polymer, meaning its molecules have been combined by chemical reaction in a way that results in "massive uniformity"—it is the same substance through and through; there are no layers. Therefore, single-ply acrylic objects are not subject to flaking or delamination.

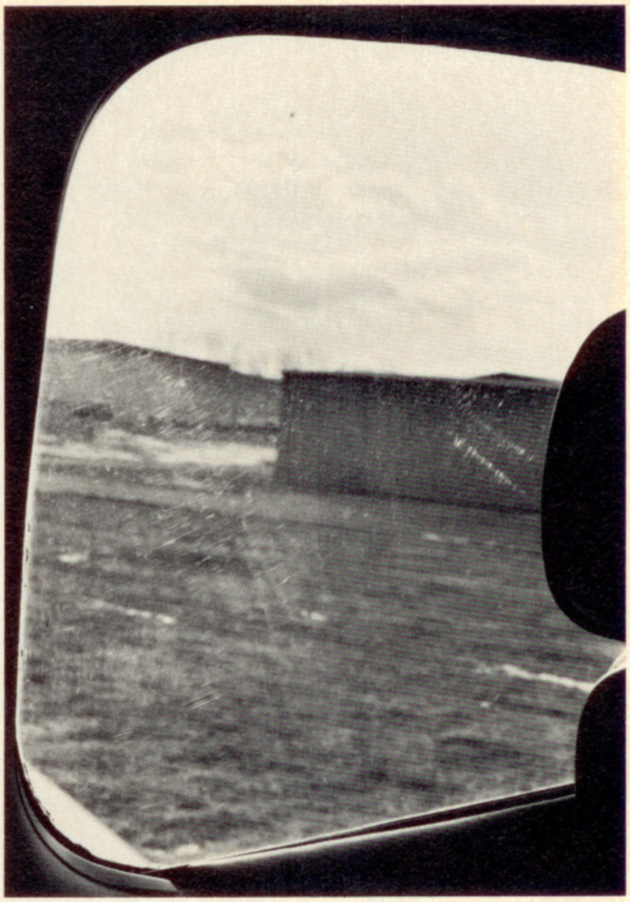
Light transmittance through acrylics is high; about 92% of the visible light wavelengths that strike an untinted aircraft windshield is transmitted through the acrylics. Most of the infrared (heat) waves also are transmitted. That's why a growing number of pilots are using interior sunscreens and exterior aircraft covers on the ground to reflect this harmful infrared heat (see "The Great Aviation Bakeoff," January 1979 PILOT).

Acrylics used for aircraft windows are specially formulated so that they absorb much of the ultraviolet wavelengths, which are harmful to both pilot and aircraft interior. Before such absorptive ingredients were used, men in high-flying military aircraft were getting sunburned by intense ultraviolet light.

Weather extremes have little effect

Caring for Acrylic Windshields

Knowing the why and how of maintaining acrylic plastic aircraft transparencies will help ensure their 'clear' advantages



The tiny scratches in this Cherokee Archer side window are most likely the result of too coarse a paper towel being used in the cleaning process. These scratches, which can result in irritating glare, can be removed by the owner with care.

on acrylics and those under restraint like, say, an acrylic windshield installed in an aircraft, are subjected to only minimal dimensional changes due to humidity and temperature changes. Test samples of untinted Plexiglas have been exposed outdoors for more than 20 years with no significant discoloration, crazing (more on this later), surface dulling, loss of light transmittance or development of haze.

Failures of all types of aircraft windshields, windows or canopies, including those of acrylic manufacture, are rare. There have been only 15 U.S. civil aviation accidents over the past five years in which these failures were listed as a probable cause or factor. Most window failures were the result of bird strikes or impact with other objects, though a few occurred during airframe overstress maneuvers and a couple were failures for undetermined reasons.

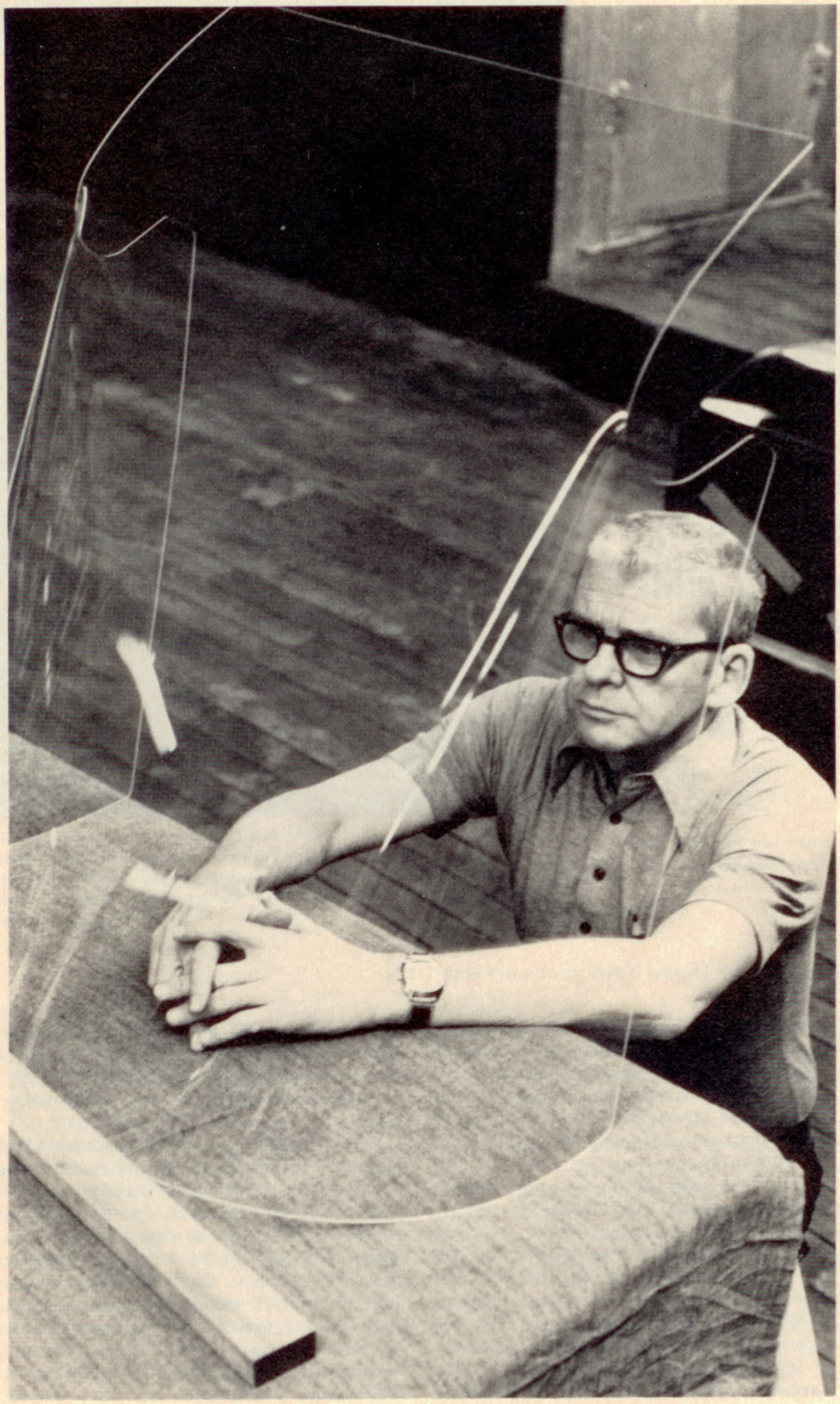
For all their advantages, acrylic plastics have two serious drawbacks: they are easily scratched and can be chemically "attacked" by various cleaning agents. Acrylics have about the surface hardness of copper and brass, and it doesn't take a whole lot of impact or abrasion to scratch an acrylic surface.

Flight materials tossed upon the aircraft glareshield can often scratch the acrylic. If the impact force is great enough, a slight weakening of the acrylic can occur. By far the greatest damage to acrylics occurs, though, through the use of improper cleaning agents and poor cleaning technique.

Most general aviation aircraft manufacturers mold their own acrylic windshields and windows to meet visibility and distortion requirements of Part 23 (covering airworthiness standards) of the Federal Aviation Regulations. Oftentimes, stretched acrylic windshields and those acrylics requiring more exacting specifications, such as for use in corporate and commuter operations, are purchased from outside specialty firms. PPG Industries, Sierracin Corp. and Swedlow, Inc., are among the largest of a handful of suppliers of stretched aircraft transparencies.

The single-ply Plexiglas used in many aircraft applications is of three basic types—Plexiglas G, Plexiglas II-UVA, and Plexiglas 55. Plexiglas G, an all-purpose grade, is the type most extensively used in light general aviation aircraft. At less than half the weight of glass and aluminum, Plexiglas G can have from six to 17 times greater impact resistance than glass in thicknesses of one-eighth inch to one-quarter inch.

Many of the acrylic plastics used in the aircraft industry, including Plexiglas G, can be tinted, though Plexiglas II-UVA is offered in limited tints and Plexiglas 55 is not tinted. Tints serve a dual function; they cut down some of the ultraviolet rays of the sun (though all three grades have built-in UV inhibitors) and help eliminate



Above. A quality control inspector in the forming department at Piper Aircraft's Lock Haven, Pa., plant inspects a just-formed acrylic transparency that will become the windshield of a Super Cub. Sitting at about a pilot's distance from the transparency, the inspector checks for distortion and light transmittance, as well as for visible blemishes and scratches. Like this windshield, those of most general aviation aircraft are formed by simply draping a heated, cut-to-size acrylic sheet over a mold and letting it cool.

Right. More complex windshield shapes, such as this rear canopy of a Piper Tomahawk trainer, are formed by draping heated acrylic sheets over a pressure head and then, to exacting standards, blowing the sheets up like bubbles.

glare from bright sunlight reflecting off a white cloud bank or snow-covered terrain. Tints usually are gray or green in aircraft applications.

Like all acrylics, Plexiglas G becomes soft and pliable when heated and can be easily molded. It is available in sheet thicknesses ranging from .030 inches to 4.25 inches. The thickness of the Plexiglas used in Piper's two-place Tomahawk trainer is .125 inches all around, while the twin-engine Piper Aztec has a .25-inch windshield and bonded, double-ply acrylic side windows of .150 inches and .060 inches. Thickness of unstretched acrylic is important from the standpoint of impact resistance and, to a lesser degree, noise reduction.

Plexiglas II-UVA (with additional "ultraviolet absorbing" characteristics) has the same basic qualities as Plexiglas G, but is manufactured to more exacting standards of optical quality, surface quality and thickness tolerances. Since it is a stronger sheet because of biaxial stretching, Plexiglas 55, the third type, is found in many larger aircraft.

The first step in the transparency manufacturing process occurs when fabricators use saws to cut windshield "blanks" out of large acrylic sheets.

Since Plexiglas G is an unshrunk sheet, these blanks must be cut a little larger to allow for a uniform shrinkage of 2.2% and an increase of 4% in thickness caused by heating during the forming process. Plexiglas II-UVA and 55 are preshrunk and can be cut pretty much to size.

After a blank is cut, it is stripped of its protective masking paper and one edge is clamped on an overhead trolley rack. After lint and dust are cleared away by an air pressure hose, the sheet is rolled into a hot oven. Forced circulation of air distributes the heat evenly throughout the oven so that the sheet will be heated uniformly over its entire surface.

The sheets must be heated to temperatures of from 290°F to 340°F for Plexiglas G and 55. If the sheet becomes too hot, degradation—such as tearing—can result. Also, too hot a surface gets very soft and is more apt to pick up fingerprints, glove marks, dirt or other imperfections (called "mark-off") later during the forming process. If too low a temperature is used, excessive stresses can lead to crazing.

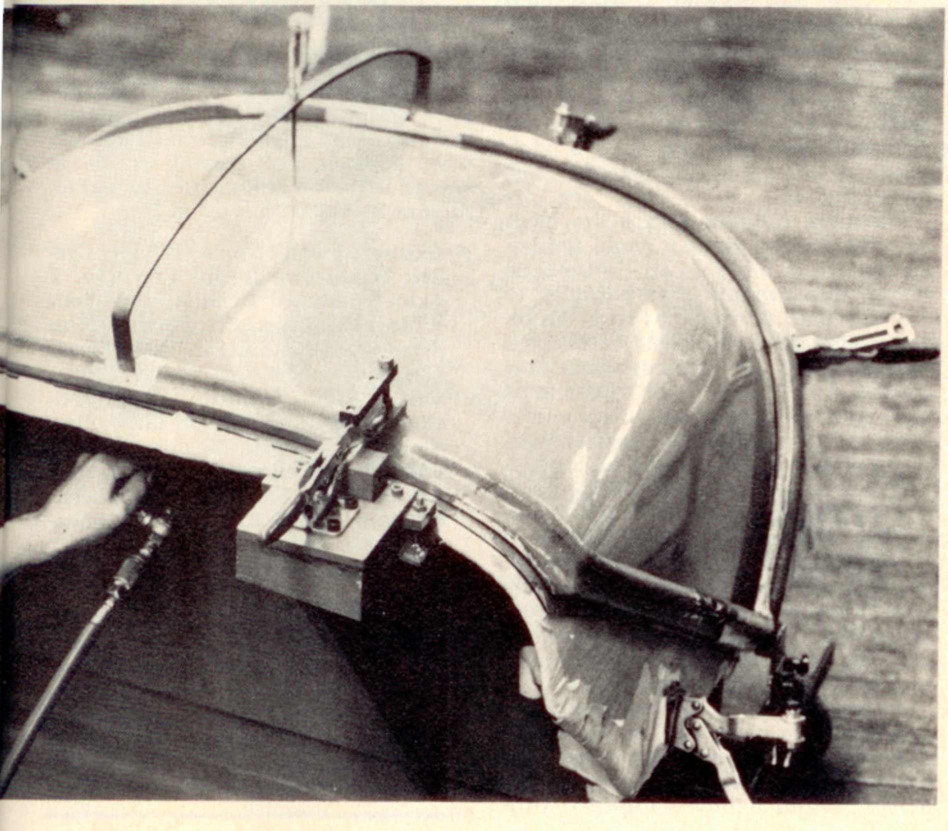
"Cooking" time varies, but is usually about a minute for each 100th-inch of sheet thickness. After heating, the now-quite-flexible sheet is ready for the mold. Forming must occur at temperatures above 275°F to minimize mark-off, yet keep the center of the sheet hot enough to avoid excessive stresses.

Two-dimensional acrylic windshields (so-called because no compound curves are imparted during forming) are formed by draping the flaccid sheets over molds usually made of wood, metal or plastic. Molds are covered with billiard felt, soft cotton flannel, velvet or other soft materials to prevent mark-off.

After draping, fabricators clamp the acrylic into place so that it adheres completely to the mold. Then, the acrylic is cooled to below 180°F before removal. Earlier removal would cause the sheet's "elastic memory" to revert to its flat sheet form. If, on the other hand, it cools on the form too long, it could crack.

Three-dimensional acrylic pieces—like the compound-curved "bubble" canopies on the Piper Tomahawk and Gulfstream American Cheetahs and Tigers—are formed by air pressure instead of on molds. A heated acrylic sheet, placed over a pressure head, is merely blown up like a balloon and allowed to cool and harden.

After forming, acrylic windshields and windows—now called transparencies—are examined by quality control inspectors for impurities, scratches or distortion. The rejection rate can be high; it is expensive to replace a windshield after it has been installed in an aircraft. During this inspection stage, minor blemishes and scratches can be buffed out. Then, the transparencies are remasked for delivery to the production line or are sprayed with removable protective coatings to protect the surface.



Where quality of optics is a critical factor, or nonacrylic pieces must be bonded to the surface, transparencies undergo an annealing process. This involves heating them at temperatures lower than those used for forming, followed by slow cooling. The end result is to reduce or eliminate internal stresses caused during fabrication and to provide greater dimensional stability and resistance to crazing.

Crazing refers to the tiny, surface cracks that occur in acrylics due to localized stresses, which are relieved by physical separation or parting of the material. These cracks are difficult to discern by casual observation since they are approximately perpendicular to the surface, narrow in width and seldom in excess of 0.01 inches in depth.

If the craze is in a random pattern, it usually can be attributed to the adverse action of improper cleaning agents, or other solvents such as alcohol, ammonia or avgas. Crazing in approximately parallel lines indicates relief of directional stress induced by cold forming, excessive loading or thermal shock. The effect of crazing, like scratches, is an increase in light scattering, which can turn a windshield into a sheet of glare if the angle is right; a pilot can go from VFR to solid IFR instantly.

Cracks, which can develop from scatches that cause structural degradation, relate to the relief of internal stresses resulting from manufacture or installation, or from external impact. The result of this stress relief is a fracture that penetrates the entire thickness of the windshield.

The effect of cracking can be an inflight catastrophic failure, the minimal result of which would be a sharp increase in total drag of the aircraft. Airframe mechanics can sometimes drill stop holes at the ends of cracks, or apply acrylic patches to the cracked surfaces by using cements, bolts or heat.

Few line personnel, and pilots, know how to clean acrylics properly. Oftentimes, you'll see a well-meaning line boy squirt some cleaner on the windshield and then have at it with a coarse, service-station-weight paper towel or grimy oil rag. This will almost assuredly scratch the acrylic.

Other people are sometimes seen using glass cleaners or household spray cleaners on their windshields. Many of these products can chemically attack the acrylic surface and cause crazing. Acrylics of aircraft being readied for painting are particularly susceptible to harmful chemicals. Solvents such as acetone, benzene, carbon tetrachloride, fire extinguisher fluid, dry cleaning fluid and lacquer thinners should never be used to clean acrylics.

The best way to clean exterior acrylic surfaces is to wash them with plenty of nonabrasive soap and water, Rohm & Haas notes. Use your bare hands to locate and dislodge any caked dirt or mud. Be sure, however, to remove any rings from your fingers since they could scratch the surface.

Water can be applied to the acrylic by a soft, clean cloth, sponge or chamois. The water should be lukewarm if possible, since that makes a better cleaner than cold water. Grease and oil can be removed with hexane, kerosene or nonaromatic aliphatic naphtha. These substances are available in paint and hardware stores. Drying can be accomplished with a clean, damp chamois or cotton flannel.

When cleaning interior acrylic surfaces, first dust—not wipe—the surface with a soft, clean cloth. Then, carefully wipe the surface with a soft, wet cloth or chamois. Keep the cloth or chamois clean by rinsing it often in clear water.

If, after cleaning the acrylic, there are no visible scratches, the surfaces may be waxed. Waxes fill in minor scratches and improve the appearance of the acrylic. Rohm & Haas recommends applying wax in a thin, even coat and then bringing it to a high polish by rubbing lightly with dry, soft cotton flannel.

Excessive rubbing with a dry cloth must be avoided since it could scratch the surface or build up an electrostatic charge that attracts dust particles to the surface. Blotting with a clean, damp chamois or cloth will remove this charge. Unless you often dry-wipe your acrylics, you probably won't have to be too concerned about static accumulation. Occasional rain and high humidity naturally prevent static buildup.

If you're operating in a particularly dry climate, however, and wish to use liquid, antistatic coatings, these may be applied in a very thin coat. If the liquid beads as it's being applied, the coat is too thick and the excess should be removed with another cloth. After allowing the coating to dry, bring it to a high gloss with a soft cloth.

Although deep scratches should be removed by a mechanic, minor visible scratches can be removed or reduced by the pilot himself. Take a small pad of soft cotton flannel dampened with water and add a little polish. Rub the acrylic in a straight to-and-fro motion parallel with the scratch to be removed, or with a circular motion.

Don't rub one spot too long since you could soften or blemish the area. You may also find that it will require several applications to remove even minor scratches, though the whole start-to-finish process shouldn't take a lot of time. After the scratches are treated, the polish should be removed with a soft, clean cloth and an anti-static coating or wax applied.

Light frost, by the way, can best be removed from aircraft acrylics by starting the engine and patiently letting the defroster clear it away. If the frost is heavy, though, it can be carefully cleared away by using felt-tipped or rubber-tipped scrapers. Avoid scratching the surface.

Keeping your aircraft acrylics clean and scratch-free will help you enjoy your flying all the more, whether or not you may realize it. Beyond eye comfort considerations, identifying a closing aircraft as such instead of a splattered June bug is reason enough to become a believer in clean, well-maintained windshields. □

Acrylic Care Products

Though not intended to be a complete list, the following acrylic plastic maintenance products, available in most pilot or auto supply stores, is offered by Rohm & Haas Co., manufacturer of Plexiglas:

- Cleaners and Polishes: Glance, Cee-Bee Plastishine A; du Pont No. 7 Auto Polish & Cleaner: du Pont White Polishing Compound; Film Fyter Windshield Cleaner; Glasticote 18A; Indosil-21 Compound; Klear-Shield Glass Cleaner; Lea Plastishine; Meguiar's Mirror Glaze Plastic Polish MGH-10; Meguiar's Mirror Glaze Plastic Cleaner MGH-17; Min-Kreme ESC; Simoniz Body Sheen; Simoniz Liquid Kleener; and Simoniz Paste Kleener.
- Anti-fogging agent: Super-Clear 350 AF.
- Anti static and cleaning solutions: Anstac 2M; Dextrol Lektrostat MRC; AR-3; AR-101; AR-400; and Nudeea 1306.
- Waxes: Dura-Glass Wax; Johnson's Cream Polish; Johnson's Instant J-Wax; Johnson's J-Wax Paste; and Johnson's Jubilee.