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SCRATCH RESISTANT PLASTIC WINDOWS  
FOR M151 TRUCK

by

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Mobility Branch

March 1974

Final Report

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Tests were conducted with scratch resistant plastic window material installed in military vehicle canvas soft-tops in place of the vinyl plastic material in current standard use. The silicone-coated material retained optical clarity in service conditions which included operations over dusty roads and daily washing. The test material was far superior to the vinyl material which degrades optically due to wrinkling, scratching or hazing, and discoloration. The test material is more costly, but this may be offset by increased service life.		

## PREFACE

This task was conducted by the Mobility Branch of the US Army Land Warfare Laboratory, during the period April 1972 to March 1974.

A user evaluation was conducted by the 720th MP Battalion, Fort Hood, Texas, from May to August 1973. Also, a user evaluation was conducted in Europe by the 501st Military Police Company, 1st Armored Division, for a one-year period starting in May 1973.

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## INTRODUCTION

Military vehicles are equipped with a canvas top and curtain kit (soft-top) for use in all climates except arctic. Current production soft-tops use a vinyl window material. This material has not been satisfactory, because the optical qualities rapidly deteriorate with exposure and use. Wrinkling, discoloration, and hazing or scratching degrade the windows.

Field commanders have considered the poor visibility through the window material to be a safety hazard. In one instance, a field commander ordered soft-tops removed because of a high accident rate.

A coated plastic material was applied to 1/4-ton M151 vehicle soft-top kits and tested for suitability in user environments.

## DESCRIPTION

The scratch-resistant plastic windows were fabricated from plastic sheet materials coated with a thin hard coating. The coating (Abcite) is a silicone, approximately 1/3 mil thick. The sheet material was furnished coated by the manufacturer.

Window panels were fabricated from 0.06-inch thick acrylic coated sheet and 0.02 and 0.04-inch thick polycarbonate coated sheets. The acrylic material is rigid, while the polycarbonate material is relatively flexible in both thicknesses.

The coating is unaffected by hydrocarbons, alcohol, and a wide variety of solvents, as reported by the manufacturer. No solvent resistance tests were conducted as part of this program, except that several different solvents were used to clean the material prior to bonding, without effect to the coating.

The M151 vehicle soft-top consists of five canvas panels, each with one window; the top and rear curtain (one piece), two side curtains, and two door curtains.

The coated plastic window materials are shown installed in Figures 1, 2, and 3. The acrylic windows are rigid and cannot be folded. However, the canvas portions of the various soft-top panels may be folded to reduce the dimensions sufficiently for stowage, as shown in Figure 1. Both the 0.02 and 0.04-inch thick polycarbonate windows may be folded or rolled as shown in Figures 2 and 3.



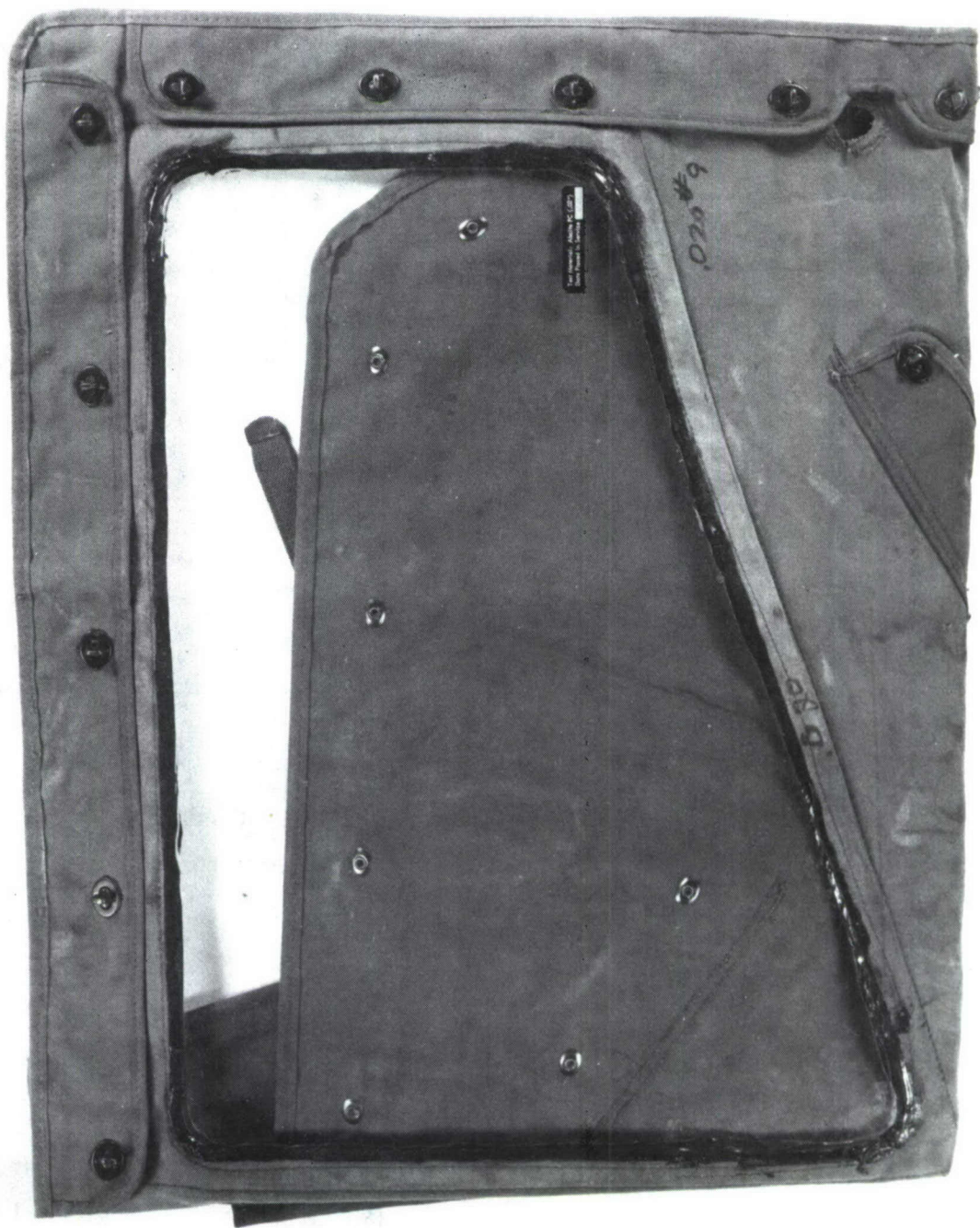


Figure 1. Scratch Resistant Window Material Installed in M151 Door Curtain





Figure 2. Scratch Resistant Polycarbonate Windows Installed in M151 Side Curtains



Figure 3. Scratch Resistant Polycarbonate Windows Installed in M151 Curtains

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## INSTALLATION

The plastic windows were installed into existing production canvas soft-tops. The standard vinyl plastic windows, which are sewed to the canvas, were removed and replaced with the scratch-resistant material.

Installation of the scratch-resistant material by sewing was not attempted. It would be impossible to sew the rigid 0.06-inch thick acrylic. Sewing of the polycarbonate material might be possible, but it was thought that the hard coating would cut the thread.

Bonding tests were conducted with samples of the coated plastic sheet and with the water-proofed and fungus-resistant canvas material used in fabrication of the soft-tops.

After a suitable bonding method was developed, several panels were prepared for six months of testing at Aberdeen Proving Ground followed by user evaluations of other panels at Fort Hood, TX and in Europe.



## TEST RESULTS

Bonding tests were conducted by bonding one-inch wide strips of canvas and plastic material. The bond was tested by measuring the average force required to peel the two strips apart.

It was found that a good bond with the canvas could not be obtained without cleaning the canvas with a solvent to remove (presumably) the water-proofing and/or fungus-resistant treatment.

A cold-rubber adhesive (Uniroyal No. 6263) produced an acceptable bond with the canvas, but not with the coated plastic. A better bond with the plastic was obtained by removing the hard-coating with fine sandpaper. However, further tests were conducted to find a bonding method which did not require preparation (other than cleaning) of the coated plastic.

Tests were conducted with silicone rubber adhesive (RTV No. 103). This produced an excellent bond with the coated plastic (the silicone rubber having a chemical similarity with the coating). Also, with suitable cleaning, and with use of a primer (SS-4124), acceptable bonding was achieved with the canvas.

A summary of the bonding tests is shown in Table 1.

TABLE 1. BONDING TESTS (PEEL STRENGTH),  
ONE-INCH WIDE STRIPS

Material	Surface Preparation		Cure, Days	Average Force, Lbs.
Canvas-to-Canvas	None	Cold Rubber	2	2 Approx.
Canvas-to-Canvas	MEK	Cold Rubber	2	5.5
Canvas-to-Abcrite	Canvas, MEK Abcrite, Cleaned	Cold Rubber	2	1.9
Canvas-to-Abcrite	Canvas, MEK Abcrite, Sanded	Cold Rubber	2	6 Approx.
Canvas-to-Canvas	MEK	RTV w.o. Primer	4	5.5
Canvas-to-Canvas	MEK	RTV w. Primer	4	7.5
			19	8.5
Canvas-to-Canvas	Toluene	RTV w. Primer	7	14.2
Canvas-to-Canvas	Naptha	RTV w. Primer	7	13.2
Canvas-to-Canvas	Trichloroethane	RTV w. Primer	7	12.0
Abcrite-to-Abcrite	Cleaned	RTV w.o. Primer	3	20

NOTE: Heavy adhesive spread was used on canvas. Light spreads yielded 50% less strength. Tests were made with RTV-102 (White). Installations were subsequently fabricated from RTV-103 (Black).

Toluene was selected as an available solvent which would produce good results in cleaning the canvas. The plastic windows were cut to size using the vinyl windows as templates and installed according to the following procedures:

1. Remove original window plastic by ripping sewed seams.
2. Clean canvas area which bonds to new window panel. Brush on Toluene generously with absorbent paper back-up to absorb solvent. Confine solvent to bonding area.
3. Let dry for at least one hour.
4. Brush on primer, SS-4124; dry for at least 30 minutes.
5. Apply heavy spread of RTV-103 (Black) to both sides of canvas opening. Bond with light pressure so as not to squeeze out adhesive. Finish off with a raised semi-circular bead. (An ice cube is the best tool for shaping the bead. The adhesive will adhere to every other kind of tool material.) Allow to dry 24 hours before disturbing.

The 0.06-inch thick acrylic panels broke upon normal handling prior to installation on the vehicle and were removed from further tests. In this thickness, the flexural limits of the stiff acrylic material is too readily exceeded; e.g., the long rear window in the top and rear curtain broke when it was picked up at one end.

Two panels of the polycarbonate-coated plastic were mounted on an M151 at APG. The vehicle accumulated 3,937 miles during a four-month period, operating over improved and unimproved roads. The vehicle was washed an unrecorded number of times during this period. At the end of this period the windows were in good clear condition, except for a few widely separated deep scratches, as shown in Figure 4. The scratches occurred when the windows came into contact with a sharp object which exerted sufficient pressure to indent the base plastic material. There were no hazy or milky scratches which normally occur on the softer plastic material due to surface abrasion with road dirt, particularly during washing.

Three panels were provided to a Military Police Company at Fort Hood, Texas. These were observed for a two-month period. They were used daily, never sheltered, and washed daily. During the same period, standard panels in the same service became hazed and scratched while the test panels remained clear, as shown in Figure 5.

Both the 0.02 and 0.04-inch thick polycarbonate panels performed equally well in the above tests.

Ten panels (0.02 and 0.04-inch thick) were furnished to a Military Police Company in Europe. These were observed for a period of 12 months and up to 18,000 miles per vehicle. A substantial portion of this mileage was over dusty road conditions, and the vehicles were washed daily for most of the period. At the conclusion of this period, the optical qualities of the windows were substantially unimpaired. Standard windows were hazed, wrinkled, and discolored.



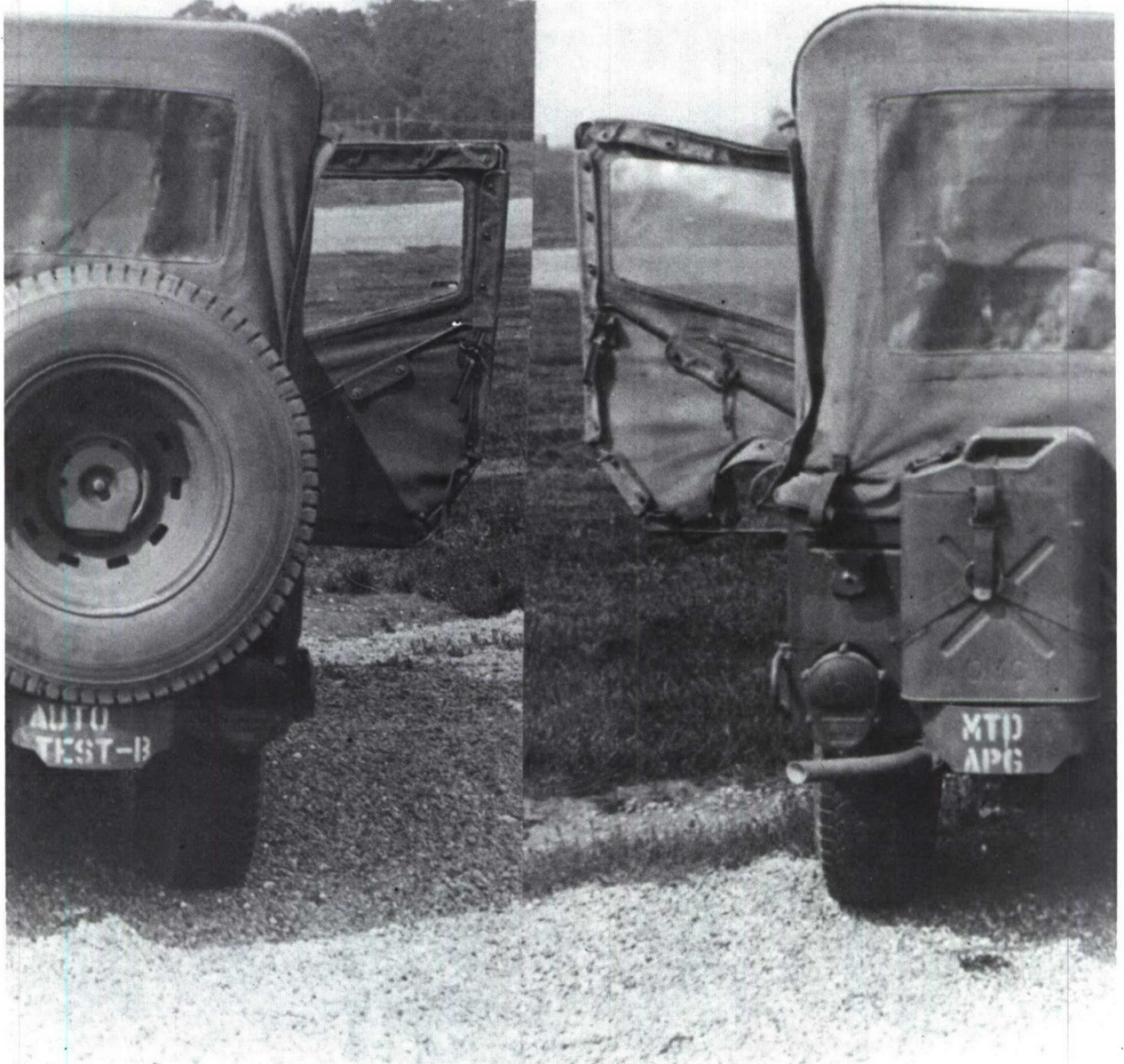


Figure 4. Comparison of Coated and Standard Door Windows  
After Four Months of Usage and Exposure at APG, MD



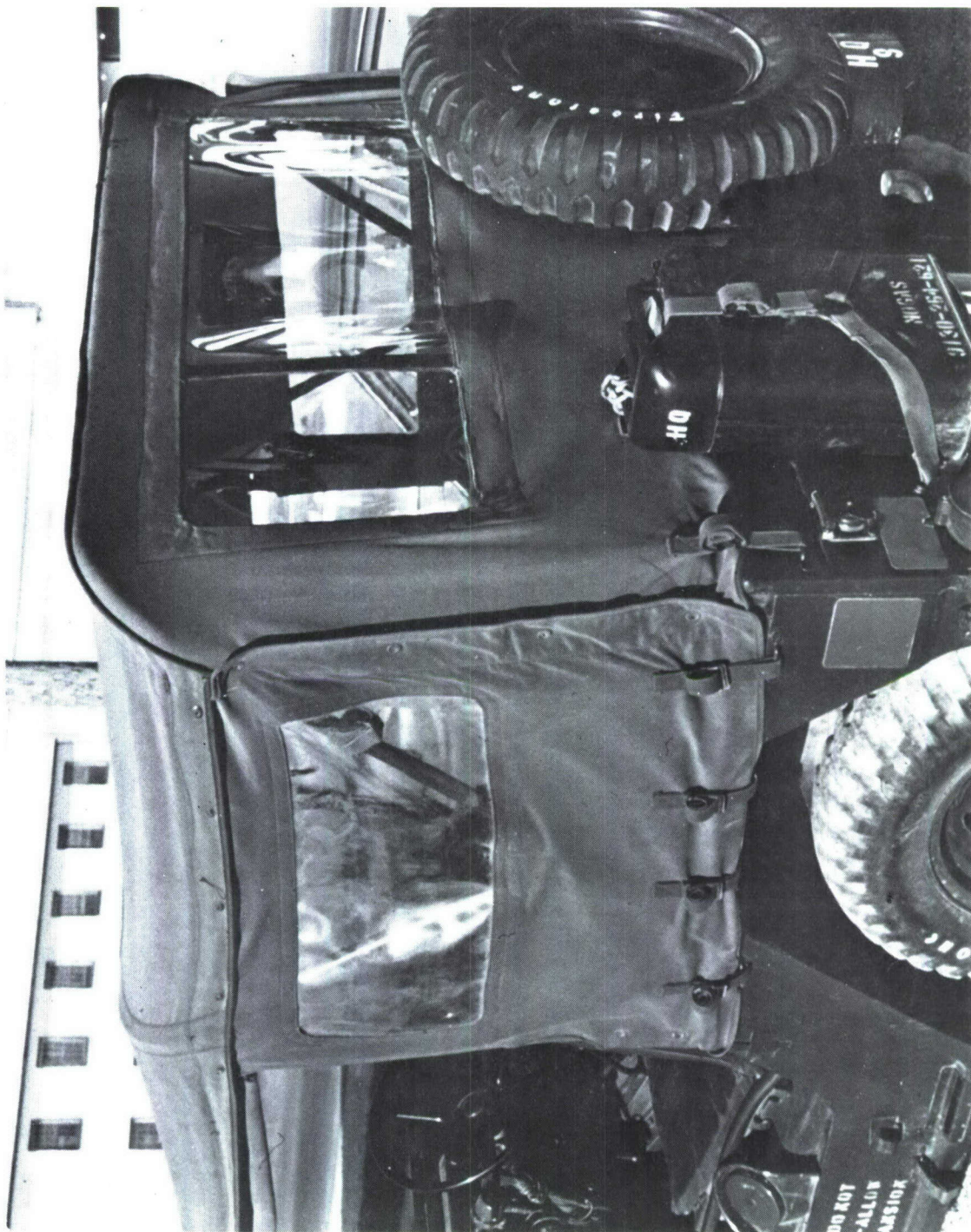


Figure 5. Comparison of Coated and Standard Windows After Two Months of Usage and Exposure at Fort Hood, Texas

All of the experimental windows in the tests retained acceptable optical qualities. They did not exhibit the hazing from fine scratches that occurs in the soft window materials. There were a few widely separated heavy scratches and pit marks resulting from gravel impacts or contact with sharp objects when sufficient pressure was exerted to yield the base plastic material. This produced a scratch mark, which was actually a loss or cracking of the coating. The loss of coating, however, did not extend beyond the actual scratch width. Also, a sharp crease of the material produced a permanent crease mark, which again is caused by cracking of the coating in the crease area.

There was no flaking or cracking of the coating from any of the windows, except for the thin scratches or indentations as noted above.

The windows did not discolor or fog during the test period.

The windows were not wrinkled after the test periods. The windows remained generally flat although they assumed some of the curves and shape of the canvas panel and provided clear and relatively undistorted visibility. One of the windows in the European evaluation was folded and cracked. Also, one of the windows became unbonded from the canvas.



## DISCUSSION

### Acrylic Versus Polycarbonate

The manufacturer of the acrylic and polycarbonate coated materials has recently discontinued the manufacture of the coated polycarbonate. The reasons stated were that the acrylic business volume alone was sufficient to fully utilize the production coating capacity and that the acrylic has better optical and weathering properties. The only advantage of the polycarbonate is better impact resistance. The manufacturer states that the polycarbonate will withstand weathering only for about two to three years, while the acrylic in accelerated weathering tests has demonstrated 25 years resistance.

Although the 0.06-inch thick acrylic did not prove satisfactory - because the limit of flexure was too readily exceeded in normal handling - it is believed that 0.125-inch thick acrylic would perform satisfactorily in soft-top applications. This thickness is currently successfully used in recreational vehicles and trailers. The 1/4-inch thickness is used in buses and trains only because vandalism is a factor.

The coated acrylic material would provide improved optical qualities, due to the greater clarity of the acrylic, but more importantly the flatness of the material would cause less glare and distortion. Also, the greater hardness of the material would resist heavy scratches and gravel pits better than the polycarbonate. The only disadvantage of the acrylic is that it is rigid, and the windows could not be rolled or folded. It is not believed that this is a significant disadvantage. However, the folded dimensions of the rear window panel - the window with the largest dimension - could be reduced by making a double window, instead of a single wide window. In practice, it has been found that the soft-tops are rarely folded for stowage.

### Cost

The February 1974 costs per square foot of the materials under discussion are as follows:

0.02-inch Abcite, Polycarbonate	\$1.36 (discontinued)
0.04-inch Abcite, Polycarbonate	\$1.53 (discontinued)
0.06-inch Abcite, Acrylic	\$1.37
0.125-inch Abcite, Acrylic	\$1.24
0.125-inch Acrylic, Uncoated	\$0.80
0.02 Polyvinylchloride, Flexible	\$0.10 Approx.

Note that the 1/8-inch thick acrylic costs less than the 1/16-inch thick acrylic.



While the cost of 1/8-inch thick coated acrylic is approximately twelve times greater than the cost of the polyvinylchloride, the dollar cost difference per vehicle is only about \$24.00 for the approximately 20 sq ft of material required. The total cost is \$131.17 (last procurement) for the complete soft-top kit; consisting of doors, side curtains, top, and bow assembly.

If the soft plastic material currently used is not suitable for the intended purpose, it cannot be considered cost effective. Further, if the windows do not provide safe visibility because of poor optical qualities, somewhat smaller size windows which do provide optical clarity would be more effective. Therefore, consideration should be given to reduction of some of the window sizes to be integrally divisible into standard sheet sizes and/or to reduce stowage dimensions. For example, the nonrectangular shape of the door windows is probably not required for safety.

#### Installation/Replacement

The bonding method of installing the windows into the canvas curtains performed satisfactorily. However, it does not lend itself readily to replacement of windows. One procedure, which would permit field replacement, would be to stock in the supply system window panels cut to size and with strips of canvas bonded to each edge. These could then be sewed into the canvas curtains. If, however, the rigid acrylic material is used, the windows could be installed in canvas pockets in the manner already in use for the glass windows of automobile convertible tops. Since the coated plastic windows would normally last for the life of the curtains, replacement would not often be necessary.

## CONCLUSIONS

When used in vehicular soft-top and side curtain kits, the silicone-coated polycarbonate window test materials provided good optical qualities after extended use and exposure. The test conditions included dusty roads and daily washings.

The optical qualities of the test materials were far superior to the current standard vinyl window materials. The standard window materials do not provide acceptable optical qualities.

The test materials provided better optical clarity because of less optical deterioration due to wrinkling, discoloration, and hazing (fine scratching).

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