[redacted] SERIAL No. 32

22 January 1943 NRL Report No.P-1987

NAVY DEPARTMENT

Report

on

Reflection Reducing Coatings for Transparent Plastic Surfaces

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

Number of Pages Text - 10 Tables - 2 Plate - 1

Authorization Bureau of Aeronautics letter dated 21 December 1942, AER-E-2573-ERM F38-2, 181359

Date of Test: December 1942 - January 1943

Prepared by :

Peter King, Associate Chemist

Reviewed by :

Allen L. Alexander, Chemist

P. Borgstrom, Head Chemist
Superintendent, Chemistry Division

Approved by :

A. H. Van Keuren, Rear Admiral, U.S.N.
Director

Distribution: BuAero. (20)

j.e.w.

APPROVED FOR PUBLIC RELEASE - DISTRIBUTION UNLIMITED

AD049175

[redacted]

SUBJECT	Page

Introduction 1
  Authorization 1
  Statement of Problem 1
  Known Facts Bearing on the Problem. 1
  Previous Work Done at this Laboratory. 1
Method
  Apparatus. 2
  Materials. 2
Experimental. 3
  Application of Films. 3
  Materials Applied to Plastic. 3
  Measurement of Light Reflected. 4
  Further Preliminary Work. 6
Data Obtained 6
  Spraying 6
  Dipping. 6
Discussion of Results 8
Recommendations 10

INTRODUCTION

(a) Authorization.

1. This study was authorized by Bureau of Aeronautics letter dated 21 December 1942, AER-E-2573-ERM, F38-2 181359.

(b) Statement of Problem.

2. The object of this investigation was to find a suitable means of applying reflection reducing coatings to transparent plastic surfaces on aircraft. The application was to be of such simplicity that the coatings could be applied to airplanes serving in the Fleet. The method should require no special apparatus and preferably should be done with equipment found at all bases.

(c) Known Facts Bearing on the Problem.

3. The deposition of thin films on lenses to reduce reflection is well known, but requires special apparatus and techniques not applicable to field application. Certain materials such as magnesium fluoride, when deposited in the proper thickness on glass, decrease the reflection from the glass surface and increase the transmission.

4. It has been found that silica, when deposited in the proper thickness, also has the property of reducing reflection from glass surfaces. This was done independently by at least three different investigators. Knowing that silica would work and that it did not require an evacuated system for application, all efforts have been concentrated on applying this type of film.

(d) Previous Work Done at this Laboratory.

5. Naval Research Laboratory Report # H-1692 entitled "Metallic Fluoride Films of Low Reflectivity" dated 10 February 1941 describes the usual method of depositing thin films to reduce reflection. The theory of this method of reducing reflection is given in great detail in this report and will not be repeated here. Also, specific directions are given for producing films having the correct properties and a good description of the appearance of a film of the correct thickness. A previous report dealing with the same type of film described here is. Naval Research Laboratory letter C-A13 (422) (451-P.K) of November 12, 1942 to Bureau of Ordnance. This is filed in NRL folder C-A13.

METHOD

(a) Apparatus.

6. The preliminary experiments were performed on pieces of Plexiglas or Lucite four inches square. These were coated by two processes: dipping or spraying.

7. The dipping process was done mechanically by having the pieces of material being coated removed from a suspension of the coating material at a constant rate. This was done with a small motor which made one revolution per minute; the speed of withdrawal was controlled by the diameter of the pully mounted on the motor. Any convenient container of the proper size can be used to hold the suspension.

8. For the spray application ordinary spraying equipment was used. A Devilbiss gun and a source of compressed air is all that is necessary.

(b) Materials.

9. Several different suspensions were used in attempting the application of thin films to plastics. A number of these were supplied by the American Optical Company and were forwarded to the Laboratory from the Bureau of Aeronautics. The composition of these suspensions is not known exactly. They were designated by the following numbers: Solution #B4, Solution #50, Solution #75, Solution #102, and Solution #115. From information furnished by the Bureau the composition of these was approximately the following:

B4 - a partially hydrolyzed ethyl silicate in cellosolve.

#50 - a colloidal silica in a mixture of solvents and containing a small amount of hydrochloric acid.

#75 - a colloidal silica in cellosolve containing some water and a wetting agent.

#102 - a water dispersion of collodial silica plus a wetting agent.

#115 - the same as #75 but much more concentrated.

The wetting agent used in these solutions is not known but is

thought to be Aerosol OT.

10. Several aqueous suspensions made from sodium silicate were also used. These are known to give good results on glass. A typical formula for them is given below. Variations of this were tried but fundamentally they were all similar.

40 grams of sodium silicate of composition

$$\frac{Na_2O}{SiO_2} = \frac{1}{3.8}$$ per liter of solution

30 cc of 50 % ammonium lactate

0.2 grams of sodium oleate

EXPERIMENTAL

(a) Application of Films

11. Before application of the film by spraying it is necessary to clean the surface of the plastic. This is done easily with soap and hot water. Care should be taken that after drying an excessive amount of lint, left there by the drying cloth, does not remain on the surface. A small amount will not interfere but large quantities will produce spots on the application of the film. The material should be applied from a spray gun held about twelve inches from the surface and at a pressure of sixty pounds. The surface should be cross-sprayed quickly, applying a full coat with no running. If running does occur, the film should be allowed to dry and then wiped off with a soft cloth. A film which has run on application is too heavy and will reflect more light than an untreated surface.

(b) Materials Applied to Plastic

12. Each suspension tried was applied to pieces of plastic and the amount of light reflected from the panel measured. The type of film necessary to produce good reduction of reflection is easily recognized and only those films which gave the proper color were measured. The films which are good appear dark purple in reflected day light when viewed normally.

13. It was found that different concentrations of the same material are necessary depending upon the method of application. For dipping, roughly ten times the strength of

suspension is needed as compared with the spraying technique. The correct concentrations have been determined and are given in a following section.

14. Solution #50 was reduced with equal parts of ethyl acetate and alcohol. The material was applied to large surfaces by spraying. Although some reduction in reflection was obtained, no good films were produced. It was claimed by the American Optical Company that films of extremely low reflectivity are produced by this material. This is no doubt true on samples prepared by spinning, the method they use in the Laboratory. However, by spraying, this same low reflectivity could not be obtained in this Laboratory. Furthermore this solution contains a large amount of ethyl acetate which attacks the transparent plastics used on airplanes, as a result of which it was thought preferable to avoid the use of this solvent.

15. Solution #75 was applied as received and also at several different dilutions. None of these was satisfactory, all having too high a reflection. Solution B4 which is to be used over #50 and #75 was tried with both and produced a much harder film. The properties of the resulting film were not satisfactory, and, despite the harder film produced, the high reflection obtained by its use did not warrant the application of this hardner.

16. Solution #102 and those prepared from sodium silicate did not perform adequately on the plastic surfaces. All water dispersions acted the same way on the plastics. None could be made to "wet" the surface and the resulting film was spotty with the spots covering only a small portion of the total area.

17. Solution #115 which was the most concentrated and offered the best possibilities, as it could be diluted as much as desired with solvents which would not attack the plastics quickly. As this solution gave by far the best results it will be dealt with in detail. It was obvious that the suspension was too concentrated as received, so it was diluted different amounts with various solvents. The compositions examined are given in Table I.

(c) Measurement of Light Reflected.

18. The measurement of the amount of light reflected from the coated panels was made with a Photox Cell and a galvanometer. This cell was chosen as it has a spectral response approximating that of the eye. The response of the entire circuit was linear over the range used in the measurements. Light from a 100 Watt tungsten lamp was focused on an uncoated panel and the light reflected to the photocell. This panel was then removed and a coated one substituted for it. The ratio of the galvanometer deflections was taken as the percent of light reflected. Knowing that the uncoated material reflects 8 percent of the light, the amount reflected by the coated panels is readily found.

TABLE I

COMPOSITIONS OF SUSPENSIONS

Suspension No.	Solution #115	Cellosolve Acetate	Cellosolve	Butanol	Ethyl Alcohol	Octyl Alcohol	Butyl Cellosolve	Ethylene Glycol	Glycerine
1	10	15	--	--	--	--	--	--	--
2	10	--	50	--	--	--	--	--	--
3	10	--	20	10	--	--	--	--	--
4	37½	--	75	37½	--	--	--	--	--
5	17½	--	55	27½	--	--	12½	--	--
6	17½	--	130	65	--	--	12½	--	--
7	17½	--	55	140	--	--	12½	--	--
8	17½	--	111	55½	--	--	12½	--	--
9	4 3/4	--	39½	12½	--	--	3 1/3	--	--
10	37½	--	75	37½	150	--	--	--	--
11	37½	--	75	37½	450	--	--	--	--
12	3 3/4	--	11½	6¼	12	--	2½	--	--
13	3 3/4	--	11½	6¼	18	--	2½	--	--
14	3 3/4	--	11½	6¼	60	--	2½	--	--
15	3 3/4	--	11½	6¼	62½	--	5	--	--
16	7½	--	11½	6¼	66	--	5	--	--
17	7½	--	33½	6¼	50	--	5	--	--
18	7½	--	11½	6¼	60	--	--	5	--
19	7½	--	32½	6¼	51	--	5	--	--
20	7½	--	11½	12½	66	--	5	--	--
21	7½	--	11½	6¼	66	5	--	--	--
22	7½	--	11½	6¼	66	--	--	--	5
23	77	--	46	25	240	--	10	--	--

The amounts of the various materials used are all in cubic centimeters

[redacted]

(d) Further Preliminary Work.

19. Some preliminary experiments show that it is possible to form a hard and at least a semi-permanent film on plastics. This is done by coating the original film with a dilute solution, in alcohol, of ethyl silicate to which has been added a drop or two of hydrochloric acid. This top coating does not interfere with the reflection reducing properties of the film but merely hardens it. There is no quantitative method of determining this hardness, but surfaces prepared in this manner will withstand washing with soap and water and drying with a soft towel. Either of these treatments will remove the soft film formed originally. It is probable that these films can be applied after the manufacture of the plastic and before the moulding.

20. Other experiments show that it is possible to obtain a reasonably hard film in one application. Excellent films have been obtained by the dipping process on both glass and plastics-which are quite hard. Twenty-four hours after application they are very difficult to remove by rubbing with a cloth. The films certainly would stand the usual abrasion encountered in service.

DATA OBTAINED

(a) Spraying

21. Table II gives the results obtained with the materials whose composition is given in Table I. Only a short comment is given but it is sufficient to tell why each was discarded. The per cent of light reflected is the per cent of the uncoated panel.

(b) Dipping.

22. Column 23 refers to the dipping technique.

TABLE II

RESULTS OBTAINED WITH VARIOUS DILUTIONS

SOLUTION #	% Light Reflected	RESULTS
1	4	Scatters too much light, visibility through panel is reduced.
2	1	Same as #1 except more scattering of light.
3	60-70	Not enough reduction, the butanol added improved wetting.
4	-	Too concentrated and gave cloudy films
5	-	Gave a bright blue film with high reflectivity, too concentrated.
6	9-18	Fair film, but extra cellosolve is dangerous from crazing viewpoint.
7	63	Not enough reduction, butyl cellosolve added to last three to slow down drying.
8	20	Fair film, but too much cellosolve.
9	-	Very poor film.
10	30	Gave purplish film but not very good reduction.
11	75	Too high.
12	70-80	Poor film reflectivity too high.
13	30*85	* one pass, second cross sprayed.
14	18	Cross sprayed, fair results.
15	-	Took three passes to give a good film.
16	10-14	Good film and good reduction in glare.
17	-	Did not work at all. Film very spotty and bright.
18	-	Solution separated absolutely no good.
19	-	Same results as #16, but as #16 has less cellosolve, this one was discarded.
20	-	Same as #16, but showed no improvement in wetting.
21	-	Solution separated, will not work.
22	-	Same as 21.
23	4-5	Excellent films but soft.

[redacted]

DISCUSSION OF RESULTS.

23. After considering all the suspensions tried #16 was chosen as the most promising. The reflection from panels coated with this suspension is only 10-15 percent of that of the untreated. This represents a reflection of between 0.8 and 1.2 percent of the indicent light and is about the minimum that can be expected from any type of film.

24. The spraying method of application is satisfactory to produce films to decrease the reflection from transparent plastic surfaces. The method does result in films which are soft and which can easily be removed with soap and water or can be rubbed off with a cloth. On the other hand they are quite effective in reducing reflection. The films produced have a speckled appearance but this does not interfere with the effectiveness of the film or with visibility through the plastic. A smooth even film would be preferable, but this does not seem possible by spray application. Due to the unevenness, the film is not the same color over the entire surface. The difference in thickness producing the different colors is only a matter of a few hundred Ångstrom units and it does not appear possible to spray a more even film than this.

25. Plate 1 (Figures 1 and 2) shows in a qualitative way the degree of reduction in the reflection from a plastic surface by this treatment. These pictures were taken with bright daylight shining directly on the plastic surface. It is readily seen that the printed matter is more visible through the coated part than through the uncoated material. Figure 1 shows a panel partially covered and Figure 2 one untreated.

26. Because of the satisfactory results obtained in the Laboratory, the Bureau of Aeronautics arranged to have the windows of a plane coated with this material. An SNC-1 plane was coated by spraying. This was done under adverse conditions; it was extremely cold and no control of air pressure was available. The pressure was adjusted by guess and the application made. The operator of the spray gun had had no experience with this type of material, but after a few minutes practice applied a good film. The results of this test were not conclusive but showed such sufficient promise that they are to be repeated. In this first service test the plastic windshields of the plane were coated and the plane was allowed to remain on the field overnight.

The coating was unchanged the next morning. The plane was flown and the pilot found nothing in the film to interfere with vision through the plastic windshield. It was observed that when the plane went to the end of the runway and turned for the take-off the direct sunlight reflected from the plastic parts. A "searchlight" flashed from the plane but appeared to have a dark brown filter in front of it. Immediately afterwards an uncoated plane turned at the same spot. This plane produced a brilliant white "searchlight" effect, showing a large difference between the two. If it is understood that this observation was made at close range, the results were satisfactory. The maximum effect will be observed when the plane itself is invisible and only the flash seen.

RECOMMENDATIONS

27. It is recommended that the coating be used to cover the plastic parts of planes. Measurements show that the amount of light reflected is greatly reduced and the first service test proved that the thin film does not interfere with the vision of the pilot.

28. It is suggested that the Bureau arrange two identical planes for experiment. One of these should be coated and the other untreated. The two should fly together away from an observer and make turns every few miles. The intensity of the flash of each should be noted and also the distance at which this flash is no longer visible. In addition, the two planes should be observed on the ground from a third plane under conditions of bright moonlight.

29. It is also recommended that further work be done toward making the film permanent.

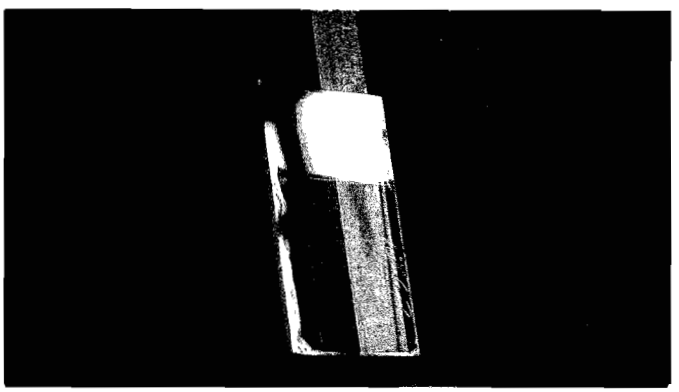

FIG. 1

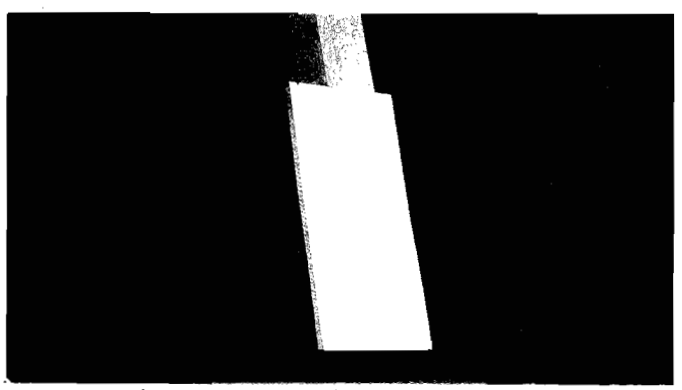

FIG. 2