WADC TECHNICAL REPORT 55-272

DEVELOPMENT OF ELECTRICALLY CONDUCTIVE TRANSPARENT COATINGS FOR ACRYLIC PLASTIC

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FOREWORD

This report was prepared by the Markite Company under USAF Contract No. AF 33(616)-2027.

The contract was initiated under Project No. 7312, "Finishes and Materials Preservation, Task No. 73125", "Transparent Conducting Coatings for Aircraft Materials", formerly RDO No. 616-13, "Optical Coatings for Aircraft Material", and was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with Mr. Stanley A. Szawlewicz acting as project engineer.

This report covers period of work from April 1953 to April 1955.

The report includes material descriptive of proprietary processes of the Markite Company. In issuing this report the Markite Company does not grant the right to use any process or product covered by pending or issued patents.

ABSTRACT

The Marklad process, a procedure involving repeated contact between a plastic surface being treated and small particles previously coated with a transferable conductor, has been adapted to the application of transparent static dissipating coatings to acrylic plastic, including curved surfaces such as occur in aircraft canopies.

It has been established that coated meter windows having resistivities readily attained by the Marklad process will adequately protect sensitive meter movements against external static charges or the accumulation of charges on the windows themselves.

Flat sheets have been coated so as to have resistance in the range of 1 to 10 megohms per square, light transmission of 75 to 85%, and haze of 1.0 to 2.5%. Uniformity has been improved so that 90% of the area of a flat sheet is encompassed within one order of magnitude. Methods are indicated for having all areas within these limits. Procedures have been extended in the direction of handling curved surfaces. Undercoats and overcoats which promote the uniformity of Marklad coatings and protect them against wear and washing have been developed. Undercoated and overcoated antistatic coatings have withstood the tests of Fed. Spec. L-P-406b, Method 1093, Spec. MIL-C-5547 and Spec. MIL-P-80A without deterioration of anti-static properties.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

M. R. Whitmore

M. R. WHITMORE
Technical Director
Materials Laboratory
Directorate of Research

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SECTION I

INTRODUCTION

STATEMENT OF THE PROBLEM

To quote Exhibit 'A' to the subject contract:

"In the interest of promoting flight safety, the Air Force is in search of suitable electrically conducting transparent coatings for acrylic plastic canopies and side panels. This low conductivity coating is required for the dissipation of electrostatic charges formed on the external surfaces of transparent enclosures during flight through dust, snow and ice clouds. This work is directed toward a continuous conductive coating having improved optical and electrical properties. Through prior efforts in this field, a discontinuous type coating has been developed as an interim measure."

Target requirements were divided into groups as follows:

1. Mechanical Properties

The coated materials should have essentially the same mechanical properties as the base acrylic sheet. The coating should not be removed when abraded according to Fed. Spec. L-P-406b, Method 1093, nor when rubbed vigorously with a moistened cotton handkerchief cloth. It should not be removed nor visibly scratched nor have its light transmission reduced below 80% when abraded according to Spec. MIL-C-5547.

2. Optical Properties

Coated quarter inch acrylic sheet should have a light transmittance of at least 85% and a haze not greater than 1%. The refractive index, thickness and uniformity of thickness of the coating should be such as to minimize surface reflectance and color interference effects. The coating should be non-porous in order that finger marks and oil smears may be easily removed with detergent and water. The coated material should be capable of withstanding 300 hours exposure to accelerated weathering tests, Fed. Spec. L-P-406b, Method 6021 without cracking, peeling or crazing and after test should have a light transmission of at least 80% and a haze not greater than 2%.

3. Electrical Properties

The surface resistance as measured by Fed. Spec. L-P-406b should be in the range of 1 to 10 megohms per square and should be relatively insensitive to relative humidity, temperature and atmospheric pressure. With suitable collector electrodes, it should be capable of carrying direct currents of 0.1 milliamperes per square foot without failure or discoloration. The dielectric loss factor should be less than 0.02 per Fed. Spec. L-P-406b, Method 2021 at frequencies up to 150 mc.

4. Coating Process

The process should deposit continuous uniform coatings over compound shapes expected in formed plastic canopies and side panels without accelerating failure of the base plastic material. It should eventuate in a commercial process capable of operation on a production line basis. Means for applying collector electrodes without deterioration of coating or base plastic should be provided.

Markite Company was advised on May 5, 1954 that changed methods had removed the pre-existing interference of surface static with navigation. Work on the contract was, as requested, immediately suspended.

Subsequent examination of the interest of the Air Force in anti-static coatings for acrylic plastics indicated at least two other specific needs:

a. Large flat sheets of plastic for such application as plotting boards.

b. Plastic dial plates for sensitive meters, such as microammeters.

By Change Order 4 to the subject contract, emphasis was shifted in the above indicated direction and samples to be submitted in partial fulfillment of contract were directed to be 3 x 3 1/2 foot flat sheets. Anti-static properties and other properties were to be substantially as previously specified.

THE MARKLAD PROCESS

The Markite Company approached the above described problem through the evaluation and adaptation of its development, Marklad conductive coatings with suitable primers and overcoats, to the particular applications of interest. Use of coating elements in various combinations was considered:

a. Marklad conductive coating
Overcoat

b. Primer
Marklad conductive coating
Overcoat

c. Primer
Marklad conductive coating

The Marklad conductive coating common to the several systems consists of a transparent layer or film of graphite so deposited as to provide a substantially continuous conductive area in the requisite 1 to 10 meg/sq. range. The Marklad coating is free of gross or fine scratches. In view of end use considerations, care was taken to avoid other blemishes such as opaque clots of almost any size which might reduce transmission, increase haze or otherwise impair important optical properties.

The Marklad process as applied to the production of transparent conductive coatings on plastics consists essentially of subjecting the plastic substrate to a multitude of repeated contacts with relatively small particles which have been previously coated with a transferable conductor.

More specifically, the process which was selected as showing greatest promise for extrapolation to the coating of large areas and complicated shapes, consists of vibrating the article to be coated within a bed of coated impactors. Alternatively, the article to be coated may be immersed in a bed of impactors which are subjected to a vibratory or oscillatory motion.

In order to secure requisite optical properties, an extremely thin conductive film must be employed. Since, moreover, severe and special weathering and erosive conditions are anticipated in flight service, means of further protection of the thin conductive coating were deemed necessary.

Considerable emphasis was placed on the investigation of overcoat and primer systems designed to provide the necessary protection.

SECTION II

METHODS OF MEASUREMENT

LIGHT TRANSMISSION AND HAZE

Light transmission and haze were measured by means of a Gardner pivotable sphere hazemeter, Type V-10, according to Fed. Spec. L-P-406b, Amendment 1, 25 September 1952, Method 3022.

Mr. Stanley A. Szawlewicz has pointed out that this method of measurement may have given values of light transmission which are too high. "Plexiglas II has an index of refraction approximately equal to 1.50 at 550 millimicrons. Substituting this figure in the Fresnel equation for reflectance,

$$R = \frac{(\text{index} - 1)^2}{(\text{index} + 1)^2}$$

gives a reflectance loss of 4% for each surface of Plexiglas, or a transmittance of 92% disregarding absorptance. Most recording spectrophotometers such as the one manufactured by General Electric give values of luminous transmittance (integrated over the visible spectrum) of 91 to 92% for this material for 1/4 inch thicknesses".

Nominal light transmissions of over 94% have been "measured" according to the reference hazemeter for undercoated Plexiglas (cf., p. 23).

The hazemeter was modified (Figure 1) so that the surface of a 1 x 3 ft. panel could be explored. The center housing of the hazemeter between the light source and the light collector was removed, the equipment was installed in a darkroom and the 1 x 3 ft. panel was supported immediately in front of the light collector. By moving the panel and rotating it, every portion of the panel could be brought into position for measurement.

Larger flat panels and curved panels were examined by means of a light source and light meter or by visual comparison with smaller panels previously measured by specification methods.

SURFACE RESISTANCE

Initially, surface resistance was measured by holding the Marklad Plexiglas against two parallel conductor strips which

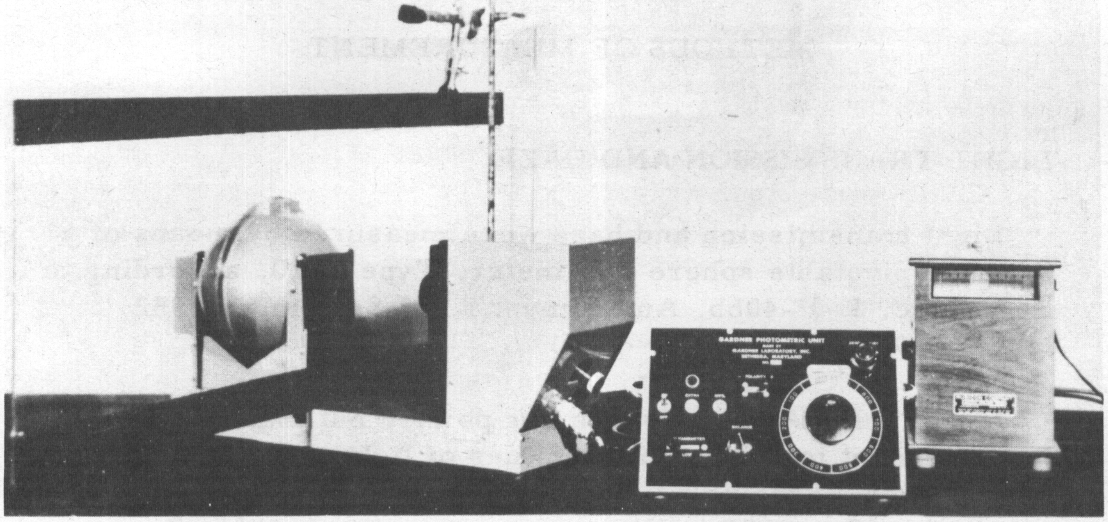


Figure 1

GARDNER PIVOTABLE HAZEMETER
MODIFIED FOR DARKROOM USE

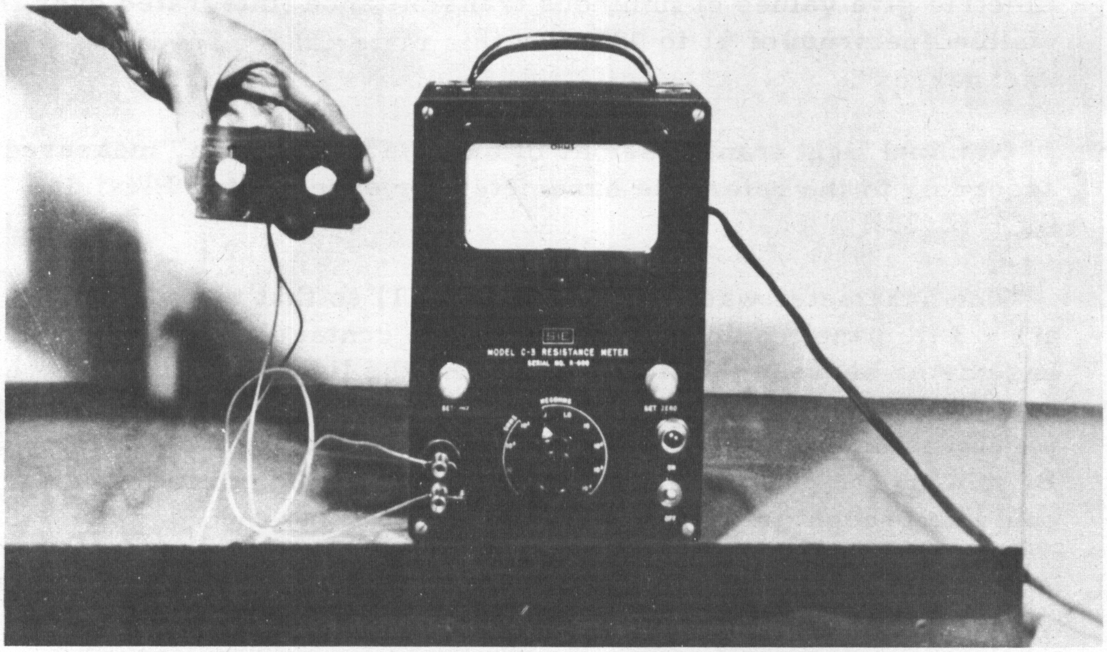


Figure 2

PROBES FOR MEASURING SURFACE RESISTANCE

were connected to a Model C-3 Southwestern Industrial Electronics Company ohmmeter. The electrode strips consisted of 0.0005" silver foil adhered to soft rubber strips by means of double-faced pressure sensitive adhesive tape.

Checks, based on measurements made by applying silver lacquer contacts directly to the plastic sheets, indicate that the method is reliable.

For exploring the surface of large panels, contacts were prepared by covering corks with silver foil, mounting them rigidly in a base and providing electrical leads (Figure 2). The factor for determining megs/sq. was calculated from the dimensions and spacing of the contacts according to the formula in Fed. Spec. L-P-406b, Method 4041, Sec. 4, Par. 4.6.3 and was checked against measurements made using the parallel conductor strips described above. Measurements of resistance made with the parallel strips and those made with the new contacts agreed within 10%.

SAND ABRADER

A Gardner Sand Abrader was modified as suggested in WADC letter of 12 October 1953 to permit tests according to Fed. Spec. L-P-406b, Method 1093. The hopper for holding abrasive and the valve were removed from the Gardner Sand Abrader and a motor-driven rotating hopper was built and attached and the abrasive tube was shortened, all according to specification.

Trials of the first hopper gave uneven distribution of the abrasive, abrading more rapidly around the edges of the test area than in the center. A new hopper was built with the holes close to the point of the cone. This equipment gave even distribution of the abrasive shown in Figure 3.

POLISHING AND RUB TESTS

Equipment for applying the polishing test according to Spec. MIL-C-5547 comprised of a panel holder and a weighted rubbing pad, was installed.

The panel holder consisted of a 12 x 12 x 1/4 inch sheet of Plexiglas from which a 3-9/16 x 3-9/16 inch square portion was removed in the center. This holder was mounted on a wooden base. The sample to be tested was dropped into the hole in the Plexiglas panel and was supported by the wooden base so that its surface was flush with that of the panel. This permitted the rubbing surface to move back and forward smoothly over the test panel. The wooden support was cut away in the center, a 3 x 3 inches square being removed so that the under surface of the test sample would not be scratched by contact with the support during the rub test.

The rubbing surface consisted of canton flannel covering a pad of sponge rubber 1/4 inch thick. This pad was attached to the bottom of a 4-1/2 x 4-1/2 inch plywood box 6 inches deep. This box was then loaded with steel balls to a total weight of 5 lbs., to give approximately the pressure required by the specification, 0.25 psi.

Wire handles were attached near the bottom of the box. looselv, so that the operator could move the box backwards and forwards without exerting any vertical pressure on the test surface.

Similar equipment was built for testing the resistance of the coating to rubbing with dry or moist cotton cloth. In this case the rubbing pad was covered with cotton handkerchief cloth.

A third similar tester was built for tests by scrubbing with Aerosol solution. This equipment is shown in Figure 4.

Equipment for conducting the craze test according to Fed. Spec. L-P-406b, Method 3053.1 (referenced in MIL-P-5425A) was built and is shown in Figure 5.

STATIC DISSIPATION

Equipment in accordance with Fed. Spec. MIL-P-80A (Ships) was constructed. Voltage accumulated during severe controlled rubbing was followed by means of an electrostatic voltmeter. Severity of the test was increased by doubling the force applied during rubbing.

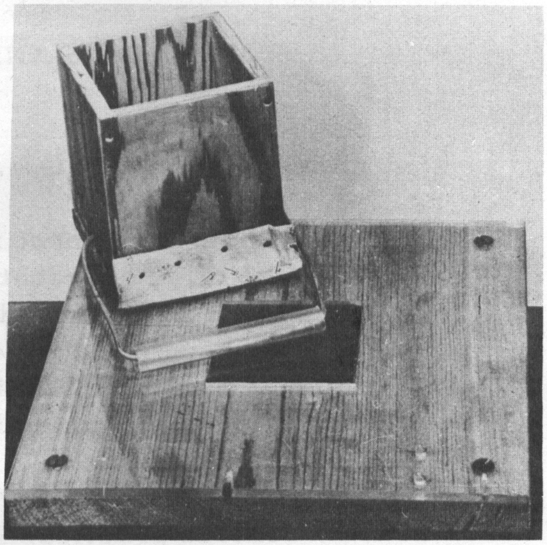


Figure 4

RUB TEST EQUIPMENT

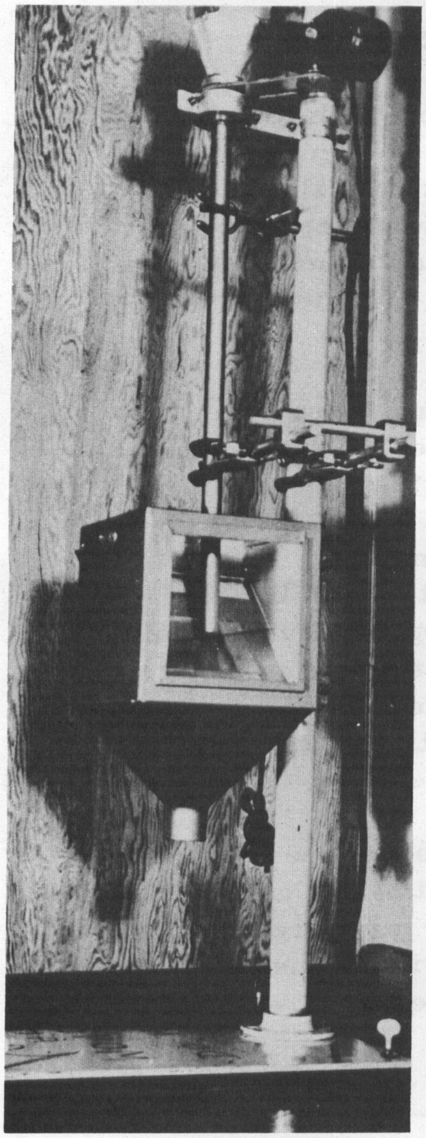


Figure 3

MODIFIED SAND ABRADER

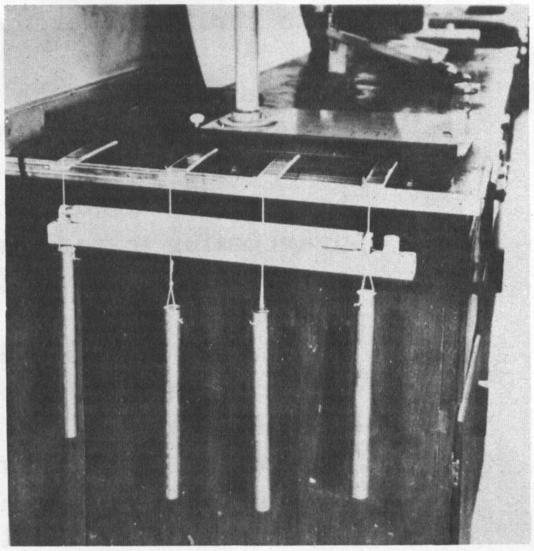


Figure 5

CRAZE TEST EQUIPMENT

SECTION III

PRIMERS AND OVERCOATS

REQUIREMENTS OF ANCHORING SYSTEMS

Although the most immediate purpose to be served by the use of an overcoat and/or primer system is the protection of the Marklad coating, mere physical protection is not enough; the underlay and overlay materials must meet a number of additional requirements including freedom from objectionable opacity, haze and interference effects.

General practicability of application is also essential; formulations (including solvent balance) must be such as to assure good adhesion to the respective substrates (acrylic plastic for the primer and the Marklad coating relative to the overcoat) without causing checking or other harmful effects to the respective substrates. Use of emulsions where possible offers an opportunity to eliminate checking. Since the most promising coating materials are insulating organic finishes, it is necessary to restrict the amount of overcoating if the overall surface resistance is to remain under the stipulated 10 megs/sq.

There is evidence that the basic process may be one of anchoring rather than truly overcoating the conductive material. In fact, some improvement in rub resistance has been secured by merely treating with thinner or with overcoating materials possessing extremely low solids contents.

The use of a primer or surface pre-treatment offers other important advantages, particularly in the matter of "uniformizing" the surface. Commercial polymethylmethacrylate (in common with most materials) tends to exhibit variation from sheet to sheet and over individual sheets due to residual oil films, masking adhesives, polishing waxes, handling contamination, etc. The Marklad process is quite sensitive to such variations;

usually Markladng takes place preferentially over organophillic areas and can result in corresponding extreme variation in optical and electrical properties. The application of a primer permits tailoring to the predeterminable primer surface characteristics.

Again, overcoating by itself, frequently yields objectionable interference patterns due to minute thickness variations and interface refractive index inequalities. It appears that better anchorage and avoidance of interference effects may be obtained by priming and overcoating with the same material.

SOLUTION TYPE ANCHORING SYSTEMS

As directed by contract, initial effort in the development of an anchoring system was devoted to the investigation of solutions of resins and waxes. The Contracting Agency had had encouraging results with a specific overcoat of this type.

Primers investigated in an initial series of experiments are listed in Table 1.

Manufacturers' recommendations were followed with regard to choice of solvents. Primer coats were applied to bare 3 1/2 x 3 1/2 x 1/4 inch panels of Plexiglas which had been cleaned with ethanol. Where blush or other defects were observed, brief studies of solvent balance were carried out before a solvent system was selected. A particularly strong tendency to blush or orange peel was observed with ES-4 (cf. Contract AF33(038)-23319). Except as noted in Table 2, coatings were applied with a DeVilbiss Type EGA, Series 501 spray gun. To minimize oil or water contamination, compressed nitrogen instead of air was used as the propellent. A very finely atomized spray was employed, the gun being held approximately 18 inches from the Plexiglas (UVA II) acrylic plastic panels. The pieces were coated with overlapping passes in one direction and the process repeated with overlapping passes at 90° to the first coat.

Table 1

Solution Type Primer and Overcoat Formulations

Formulation		Wt-%	Wt-% Non-Volatile
701-S5	Halowax* 1000	2	2
	Toluene	98	
701-S7	Halowax* 1052	2	2
	Toluene	98	
701-S8	Halowax* 1001	2	2
	Toluene	98	
701-S9	Halowax* 1013	2	2
	Toluene	98	
701-S10	Paraffin (Gulfwax)	2	2
	Toluene	98	
701-S12	Johnson's Wax (Beautiflor Liquid Wax)	2	2
	Toluene	98	
701-S17	Acryloid** C-10	2	0.4
	Toluene	98	
701-S25	Acryloid** B-7	3	0.6
	Toluene	82	
	Tetralin	15	
701-S30	Acryloid** A-10	2	0.6
	Xylene	78	
	Butyl Acetate	20	
701-S31	Acryloid** B-72	2	0.8
	Xylene	78	
	Butyl Acetate	20	
701-S32	A.T.C.-1*** (used without propellant)	--	unknown
701-S33	Acrylic Cleaner***	--	15
701-S34	ES-4****	1.5	0.6
	Butyl Acetate	50.5	
	Ethyl Acetate	35.4	
	Cyclohexanone	12.6	

*Mfg. by Halowax Corp. Higher numbers correspond to higher chlorine contents.

**Mfg. by Rohm and Haas Company - Acryloids are solutions of acrylic polymers and copolymers. A-10 is the hardest, C-10 the softest; "B" series materials are intermediate - Cf., trade literature on Acryloid-Acrysol "Acrylic Ester Resins".

***Supplied by WADC

****Supplied by WADC, cf., Contract AF-33(038)-23319

The test panels were Marklad (v.i.) in beds containing 0.06 or 0.12% of graphite, the beds having previously been operated at least 2 1/2 hours to insure adequate aging. The Markading time in each case was chosen to bring the measured surface resistance within the lower part of the specification range of 1 to 10 megohms per square. Haze and light transmission as well as resistance were measured. Results are shown in Table 2. It should be pointed out that the average haze of untreated panels was 0.4% and the average light transmission 93.7%, by no means insignificant values in the light of target specifications. The primer designated S-25, a 0.6% solids solution of Acryloid B-7 in toluene and tetralin, was outstanding as to low haze appearing in Marklad panels.

Test panels were overcoated in various combinations and examined for resistance, haze, light transmission and interference effects. Results are shown in Table 3. It was noteworthy that best results were obtained where the primer and overcoat were identical. Primer S-25 was again outstanding as to haze and absence of interference effects.

Formulation S-25 was used as the basis for studies of the Marklad process itself over a period of several months. During this time questions arose as to the effect of uniformity of primer thickness on uniformity of Markading. Also of interest was the possible influence of mild baking of the undercoat.

Twenty-four panels were primed at 1, 2 and 3 times the thickness required to give an effective base for Marklad. Half of these panels were dried at room temperature for different lengths of time. The other half were dried at 72°C for different periods. These panels were Marklad and then tested for electrical and optical properties.

The results showed that if the panels were dried at room temperature for 1 hour or more a variation in primer thickness of 300% had no appreciable effect on the electrical or optical properties. The trend indicated slightly better optical properties in the panels with the

Table 2

Evaluation of Solution Type Primer Formulations

Panel	Primer	Graphite Loading- Wt. %	Time of Marklad Mins.	Res. Megs/Sq.	% Haze After Primer	% Haze After Marklad	% Light Transmission After Primer	% Light Transmission After Marklad
701-98	701-S25	0.06	8	1.5	0.4	0.8	92.6	86.9
701-99	701-S12*	0.12	18	2.5	0.7	3.5	93.5	77.7
701-100	701-S33*	0.12	26	3.0	0.2	4.7	93.5	72.7
701-101	701-S32**	0.12	10	0.5	1.2	3.8	93.0	70.6
701-102	701-S5	0.12	22	2.5	0.5	4.8	94.2	73.6
701-103	701-S8	0.12	21	2.0	1.0	5.5	93.9	72.8
701-104	701-S9*	0.12	20	2.0	0.6	3.5	95.2	78.2
701-105	701-S7*	0.12	20	1.0	1.0	3.7	94.8	78.0
701-106	701-S10*	0.12	24	1.4	1.0	4.1	94.8	77.4
701-108	701-S31	0.06	6	1.4	0.5	2.4	95.0	83.2
701-109	701-S17	0.06	7	3.5	2.0	5.2	93.6	80.5
701-111	701-S25	0.12	5	0.5	0.3	1.7	93.0	83.7
701-112	None	0.12	20	2.0	No Primer	2.9	No Primer	80.3
701-113	701-S25	0.12	4	1.0	0.4	1.7	94.0	82.4
701-114	701-S30	0.12	10	1.5	1.0	2.5	93.8	80.0
701-116	701-S34	0.06	12	2.8	2.1	1.6	93.0	84.0

*Buffed by multiple hand rubbing with powder puff.

**Rubbed on with 701-S32 dampened powder puff, dried and buffed as above.

Table 3

Evaluation of Solution Type Overcoat Formulations

Panel	Primer	Overcoat	Before Overcoat Res., Megs/Sq.	Before Overcoat Haze %	Before Overcoat Lt.trans., %	After Overcoat Res., Megs/Sq.	After Overcoat Haze %	After Overcoat Lt.trans., %	Interference Effects
701-86	701-S25	701-S25	2.3	0.9	86.2	4.0	0.9	86.3	None
701-87	701-S25	701-S25	1.9	0.8	86.5	3.0	0.8	86.7	None
701-88	701-S25	701-S25	3.5	0.9	87.3	5.0	0.9	87.8	None
701-89	701-S25	701-S25	2.5	0.8	87.0	4.0	0.8	87.2	None
701-90	701-S25	701-S25	3.0	0.8	85.4	5.0	0.9	85.7	None
701-100	701-S33	701-S25	3.0	4.7	72.7	5.0	3.7	76.1	Red, Low
701-101	701-S32	701-S25	0.5	3.8	70.6	1.0	3.7	73.2	Red and Blue, High
701-102	701-S5	701-S25	2.5	4.8	73.6	3.0	3.6	75.6	Red, Low Blue, Medium
701-103	701-S8	701-S25	2.0	5.5	72.8	3.0	4.1	75.6	Red, Low
701-105	701-S7	701-S25	1.0	3.7	78.0	2.0	2.9	80.0	Red, Low
701-106	701-S10	701-S25	1.4	4.1	77.4	2.0	3.4	80.0	Blue, High
701-108	701-S31	701-S31	1.4	2.4	83.2	7.0	3.2	84.9	None
701-109	701-S17	701-S17	3.5	5.2	80.5	7.0	5.2	83.2	None
701-112	None	701-S25	2.0	2.9	80.3	3.0	2.1	81.6	Blue, Low
701-114	701-S30	701-S30	1.5	2.5	80.0	4.0	3.3	80.8	None
701-116	701-S34	701-S34	2.8	1.6	84.0	3.0	12.3	84.0	None(Lace-like pattern)

thicker primer coat. All panels which had been dried more than an hour before Marklad, were within the required limits of electrical and optical properties.

In this series, baking the primed panels did not show any advantage. However, Marklad panels had occasionally shown a faintly mottled appearance on close inspection. These panels had optical and electrical properties which fell within the required range but still it seemed desirable to eliminate this mottling if possible.

When mottling occurred it was found that it could be avoided by baking the primer at 70°C before Marklading. Since this difficulty did not occur in the above series of air dried panels, the results are inconclusive as to the advisability of baking the primer. Further study of this variable was set aside when favorable primer materials, having advantages in certain respects over S-25, were discovered.

Also having its effect on the uniformity and haze properties of primer and overcoat films is the method of application. As larger panels came into use with the advancement of the project, it became clear that atmospheric dust was giving rise to appreciable haze or speckling during hand spraying and that the hand spraying operation itself left something to be desired as regards uniformity.

An available lathe tool carriage was tried as one means to traversing a spray gun. The attainable speed was found to be so slow that the film laid down by one pass had partially dried before the next, overlapping pass could be made.

Flow coating was found to lay down a more optically perfect coating than spray coating and was used in the priming of 1 x 3 foot panels submitted in fulfillment of contract and all subsequent samples. This remark applies only to the undercoating operation.
Attempts to flow S-25 over Marklad panels undercoated with S-25 led to washing the Marklad coating from the

panels. Accordingly, it would be necessary to spray coat S-25 if it were to be finally chosen as an overcoat. It is considered that haze due to dust could be reduced to unobjectionable levels by operation in a properly conditioned room.

More critical test of the S-25 primer and overcoat system became possible and necessary with advancing development of Marklading methods and final availability of test equipment corresponding to all of the specification test methods.

Under the conditions of Fed. Spec. L-P-406b, Method 3053, the S-25 coating solution did not craze Plexiglas acrylic plastic. However, where some of the coating solution had wet the sawed edge of the acrylic plastic, crazing did occur on these edges. These results were obtained after 1/2 hour exposure of the acrylic plastic to our coating solution.

However, when test strips which had been flow coated and allowed to evaporate instead of being kept wet for 30 minutes were tested, no crazing occurred, whether or not the edges of the test strips had been wet with coating solution.

While these results showed no departure from specifications, some doubt was raised as to possible crazing of stressed surfaces such as may exist in canopies.

Panels undercoated with S-25 were subjected to various tests to evaluate S-25 in terms of abrasion resistance.

Undercoated panels which had been dried at room temperature for 48 hours or more were rubbed 50 times with dry cotton handkerchief cloth, with and without various washing and polishing agents, in the rubbing test equipment.

Tests in the abrasion machine, Fed. Spec. L-P-406b, Method 1093, in which abrasive powder is slowly rained over a circular area of the test specimen, were also performed. Results are shown in Table 4.

Indications were that S-25 had approximately the same resistance to abrasion as does Plexiglas.

Finally, panels which had been undercoated with S-25, Marklad and overcoated were subjected to rubbing tests. The conductivity, as measured by the application of two 1/2-inch diameter electrodes to the surface, was quickly destroyed. For example, a panel was Marklad to a resistance of 2.5 megs/sq. and was overcoated, bringing the resistance to 3 megs/sq. Five rubs with dry cotton handkerchief cloth raised the surface resistance to 100 megs/sq. and 10 rubs raised it to 10,000 megs/sq.

In applying an overcoat, the heavier the overcoat the greater the increase in resistance. In view of the rapid increase in resistance with rubbing, it seemed desirable to determine how much overcoat would be necessary to give reasonable protection to the Marklad. Then when this required thickness of overcoat was determined it might be possible to determine what initial conductivity of Marklad would be required so that the final resistance, after adequate overcoat had been applied, would fall within the limits of the specification.

Panels were overcoated to low resistance and overcoats were applied to bring them back into the 1 to 10 megs/sq. range. These panels were subjected to dry rub tests. Many of these panels showed rapid increase in resistance with comparatively mild rubbing. For example, panels were Marklad to resistances of 5, 1.4 and 0.1 megs/sq. range. The panels which had been coated to a resistance of 5 and 1.4 megs/sq. did not withstand the dry rub test, showing no conductivity by surface test after 100 rubs. The panel which had been Marklad to 0.1 meg/sq. and overcoated to 1 meg/sq. showed no increase in resistance after the dry rub test and only an increase to 4 megs/sq. after the Aerosol scrub. However, this panel did not survive the polish rub, using DuPont #7, which removed all the conductivity

Table 4

Rubbing and Abrasion Tests
Panels Undercoated with Formulation S-25

	Plexiglas		Undercoated Plexiglas	
	Trans. (%)	Haze (%)	Trans. (%)	Haze (%)
Before rub	91.5	0.17	92.7	0.38
After 50 rubs, dry	91.5	0.44	93.5	0.80
Before scrub	92.0	0.17	94.8	0.16
After 50 rubs, 3% Aerosol OT	91.5	0.16	94.5	0.37
Before polish	92.0	0.16	92.0	0.3
After polish with Simonize Kleener	91.0	0.27	91.5	0.4
Before polish	91.5	0.22	91.3	0.33
After polish with Noxon	91.0	1.10	91.2	1.43
Before polish	91.5	0.22	94.0	0.26
After polish with DuPont #7	91.5	0.22	94.0	0.26
After Abrasion Test				
Gms Abrasive				
100	85	12.6	88.0	9.3
200	83.2	18.9	82.5	16.0
300	84.5	20.4	79.0	19.9

as measured by the surface test. The appearance of the panels nevertheless indicated that much of the conductive coating was still present. It seemed possible that dry rubbing had removed some of the surface points which had made contacts with the electrodes which are used in the present tests. As a result, the electrodes were not making contact with the conductive layer which might still be available for the dissipation of static.

As a test of this possibility a panel was undercoated and heavily Marklad to a resistance of 0.04 megs/sq. Conductive strips were then painted onto the side areas of this panel and the panel was then overcoated so that by means of the conductive strips it would be possible to measure the resistance of the Marklad layer and compare it with the resistance as measured by surface contact. When this panel was subjected to 100 strokes with dry cotton cloth the resistance rose from .07 megs/sq. to 80 megs/sq., an increase of approximately 1000-fold but the resistance between the painted terminals increased only from an original value of 0.07 megs/sq. to 0.10 megs/sq.

These results indicated that the previous conventional surface contact measurement did not register accurately the conductivity of the film. The possibility remained that even though a good conductive layer remained after severe rubbing it might be so insulated by the overcoat that it was not available for dissipating static. If, on the other hand, these rubbed coatings were able to dissipate static even though the surface contact resistance were high, it might be advisable to reconsider the specified criterion of static dissipating ability.

In preparation for evaluating coatings in terms of their ability to dissipate static, equipment was built for generating static by rubbing, in a reproducible fashion and measuring the rate of static dissipation according to Fed. Spec. MIL-P-80A (Ships) except that the severity of the test was increased by using twice the specified rubbing force.

In this equipment Plexiglas II and Plexiglas acrylic sheet primed with the acrylic undercoat, S-25, developed 300 volts with 40 strokes and retained this charge for more than 10 minutes but Marklad panels, undercoated and overcoated with S-25, failed to develop any charge during 200 strokes with the weighted pad. This pad exerts twice as much pressure as does the pad in the rub test, paragraph F-5c, Army and Navy Aeronautical Spec. AN-C-154; 200 strokes with this pressure is a very severe test.

One of these panels showed a surface contact resistance of 600 megs/sq. after this rubbing but still dissipated static as rapidly as it was generated, developing no charge.

Another panel was dry rubbed until it showed no conductivity (over 10, 000 megs/sq. by contact test and 150 megs/sq. between coated terminals). When this panel was tested on the static generating equipment, it did not develop a measurable charge (60 volts) when rubbed for 5 minutes at 176 strokes/min. When rubbing was continued for 1/2 hour at this rate, the panel developed 170 volts. Acrylic plastic itself develops over 300 volts in 15 seconds under these conditions.

These results seem to indicate that resistance as measured by electrodes pressed against the surface is not a completely realistic measure of quality so far as static dissipating ability is concerned.

All things being equal, the use of heavier overcoats of the materials already considered would add to the durability of the conductive coatings. Such heavier overcoats can be used provided they do not interfere with the ability to dissipate static, even if their contact resistance is higher than called for by the existing specifications.

A panel was Marklad to a contact resistance of 0.8 megs/sq. and then was given a heavy overcoat which increased the contact resistance to 3.0 megs/sq. The resistance between coated terminals was 1.4 meg/sq. before and after overcoating. This panel was subjected to 200 strokes on the static generator. After this rubbing, the resistance measured between pressed-on contacts was 600 megs/sq. During this test static was dissipated as fast as it developed and no charge accumulated.

MISCELLANEOUS ANCHORING SYSTEMS

As noted above, it was found that an anchoring system based on acrylic solution S-25 would not craze Plexiglas acrylic plastic under the conditions of Fed. Spec. L-P-406b, Method 3053. Nevertheless, the presence of solvents made the system somewhat suspect, especially for the treatment of curved and possibly stressed shapes. Coating S-25 left something to be desired in resistance to dry rubbing, even though static dissipation took place under conditions of severe abrasion. These considerations, plus emphasis by the Contracting Agency on reduction of haze even below target specifications, led to the study of alternate anchoring systems.

Promising alternative undercoat and overcoat systems were investigated along the following lines:

1. Waxes which can be applied without spraying some of which have been shown to accept Marklad.

2. Systems such as polyvinyl acetate which offer possibilities of heat sealing the conductive material to the undercoat.

3. Latices of various plastics; these offer the possibility of dispensing entirely with solvents which can craze acrylic plastic.

4. Commercial coatings specifically designed for weather resistance, adhesion and non-crazing of molded acrylics.

Table 5 shows the optical properties of a variety of wax undercoats.

Three of the wax undercoats showed promise as regards lack of haze but they were unsatisfactory because of their very slow rate of Marklading. Measurable conductivities were not obtained during 40 minutes exposure to vibrating beds.

Table 6 shows the optical properties of various latex undercoats.

Of these only AA-40, a polyvinyl acetate emulsion, shows low haze coupled with lack of gross visual defects.

Two series of coatings for acrylics have been developed for commercial use -- Keystone Acrylics and Glidden Acrylics. These are said to have been carefully tested for weather resistance, adhesion and non-crazing of molded acrylics. Samples of these materials were included in the list of materials for preliminary test. These along with the AA-40 polyvinyl acetate emulsion primer were Marklad and checked for resistance and optical properties. Results are shown in Table 7. Again the polyvinyl acetate emulsion stood out as showing the least haze.

POLYVINYL ACETATE EMULSION ANCHORING SYSTEMS

Xyno Resin AA-40 is stated to be a very fine particle latex of polyvinyl acetate suspended in water. It contains 40% solids. It air dries to a transparent film which adheres well to acrylic plastics.

Undercoats which were applied by flow coating compared favorably with S-25 in optical properties giving 94.1% transmission and 0.5% haze on Plexiglas II which itself showed 93% transmission and 0.3% haze (cf. Table 8).

Table 5

Optical Properties of Wax Undercoats

Composition of Solid (%)			Waxed Panels	
Carnauba	Beeswax	Rosin	Transmission %	Haze %
100	-	-	92.1	0.33
95	5	-	92.3	0.16
-	-	100	91.4	6.25*
-	5	95	90.2	12.8 *
10	90	-	92.0	0.43
-	90	10	92.1	0.76
-	100	-	92.2	0.66

Waxes in Stoddard Solvent at 3% solids.
All applied, dried and polished except those marked (*) which were flow coated and not polished.

Table 6

Optical Properties of Latex Undercoats

Manufacturer	Type	Chemical Type	Undercoated Panel Transmission %	Undercoated Panel Haze %	Observations
Onyx Oil and Chemical Co.	AA-40	P.V. acetate	92.2	0.43	
	X-99	P.V. acetate	91.0	4.16	Poor adhesion
	S-69	Styrene-Etacrylate	90.2	1.77	
	362	P.V. acetate	89.0	1.24	Poor adhesion
National Resyns	11K01	P.V. acetate	78.7	29.3	
	10K25	P.V. acetate	90.5	14.2	Poor adhesion
Goodyear	Pliolite 170	Resin dispersion	89.7	2.8	Streaks
	Chemigum 101A	Buna-S	89.2	9.3	Streaks
	Chemigum 101E	Buna-S	90.4	10.0	Cloudy
Goodrich	552	P.V. chloride	90.6	6.95	

Table 7

Evaluation of Various Undercoats Marklad

Material	Resistance (Megs/sq.)	Transmission %	Haze %
Xyno Resin (AA-40) Latex	0.5	82	0.61
Polyvinyl acetate AYAF	4.0	85	1.59
Keystone acrylic 21-200	1.5	81	2.23
Keystone acrylic 20-200	10.0	83	1.33
Glidden acrylic 170-C-1	0.9	80	1.38

Table 8

Comparison of S-25 and AA-40 Undercoats

AA-40	Light Transmission %	Haze No.	Haze %
1	94.5	3.5	0.38
2	94.6	3.5	0.38
3	94.8	4.5	0.48
4	94.8	4.0	0.42
5	93.0	6.0	0.65
6	93.0	5.0	0.54
7	93.4	6.0	0.64
8	94.0	6.5	0.69
9	93.8	5.0	0.54
10	94.5	3.0	0.32
11	94.3	2.0	0.20
12	94.7	5.0	0.54
Average	94.1	4.4	0.47

S-25			
1	94.2	3.5	0.38
2	94.1	5.0	0.53
3	92.8	5.0	0.54
4	92.5	7.0	0.76
5	93.0	5.5	0.59
6	94.0	7.0	0.75
7	93.6	7.5	0.80
8	94.1	4.5	0.48
9	93.8	5.0	0.54
10	93.5	5.0	0.54
11	92.3	6.0	0.65
12	93.7	6.0	0.65
Average	93.4	5.6	0.60

Panels which had been undercoated with AA-40 were Marklad. They Marklad at approximately the same rate as panels which had been undercoated with S-25 and showed lower haze.

When Marklad panels, using AA-40 for undercoat, were overcoated with S-25 the resultant film was cloudy, due apparently to incompatability of S-25 acrylic with the AA-40 polyvinyl acetate.

Because of its freedom from solvents which tend to craze Plexiglas and its promising behavior as an undercoat, the work was continued in the direction of finding a suitable overcoat for AA-40 undercoated panels.

Dilute solutions of AA-40 did not spray satisfactorily, collecting into large droplets on the Marklad surface instead of forming a thin uniform film.

Since this latex was said to be polyvinyl acetate, a 0.6% solution of polyvinyl acetate, AYAF, in toluene was tried as an overcoat. This overcoat gave a cloudy film but baking at 85°C for 1 hour cleared the film.

Previous experience with S-25 had indicated that the overcoat must be kept very thin lest the conductive layer be insulated and not show surface conductivity. Good results had been obtained with S-25 as an overcoat over an S-25 undercoat if a light spray of 0.6% solids was used as an overcoat. While it seemed very probable that a flowed overcoat of a 40% solids suspension of AA-40 would completely insulate the conductive layer, such an overcoat was tried. Surprisingly enough, after drying, the contact resistance had only doubled, going from 2 megs/sq. to 4 megs/sq. Furthermore, there was no tendency to wash away the Marklad coating.

Repeated tests of this overcoat gave similar results. On the suspicion that the apparent conductivity of the film was due to retained water, overcoated panels were baked for 1 hour at 85°C without appreciably increasing the contact resistance.

That the overcoat is, however, a non-conductor is indicated by an experiment in which AA-40 was sprayed on a steel plate. A resistance greater than 1000 megohms was measured between the steel and the surface of the sprayed coating.

Since this overcoat is much thicker than an overcoat of S-25 with similar resistance, it might be expected to give much greater resistance to abrasion.

Panels which had been Marklad and overcoated with AA-40 were subjected to dry rub tests which were so severe that they raised the surface resistance of S-25 overcoated panels from two megs/sq. to several hundred megs/sq. This amount of rubbing did not cause any change in the surface resistance of panels which had been overcoated with AA-40.

Repeated tests, made on Marklad panels overcoated with AA-40, confirmed these results. Table 9 shows some typical results on panels overcoated with AA-40 and on panels overcoated with S-25. While the S-25 showed considerable durability in this test, AA-40 demonstrated even greater resistance to rubbing.

Tests of AA-40 undercoat on the static tester showed that AA-40 itself seems to have some inherent antistatic properties. It developed only one third as high voltage during rubbing, compared to S-25 undercoat, and the voltage which was developed leaked off more rapidly.

Panels which were Marklad and overcoated with either S-25 or AA-40 failed to develop any static charge during rubbing.

Table 9

Comparison of S-25 and AA-40 Anchoring Systems, Rub Tests

	Polyvinyl Acetate Emulsion	Acryloid Solution
Undercoat & Overcoat	AA-40	S-25
Before Dry Rub		
Resistance, megs/sq.	5.6	1.6
After Dry Rub (200 strokes)		
Resistance, megs/sq.	7.1	230.0
Before polishing		
Light Trans. %	81.5	83.3
Haze, %	1.0	1.4
Resistance, megs/sq.	7.5	2.4
After polishing (100 strokes)		
Light Trans. %	80.7	88.8
Haze, %	5.4	1.4
Resistance, megs/sq.	10.5	>10,000.
Before Wet Rub		
Light Trans., %	81.6	79.3
Haze, %	1.1	3.0
Resistance, megs/sq.	11.5	0.8
After Wet Rub (100 strokes)		
Light Trans., %	80.8	Marklad surface removed
Haze, %	5.5	
Resistance, megs/sq.	18.5	

Polishing and wet rub tests, while confirming the abrasion resistance noted above, revealed an objectionable sensitivity to water in that the haze of panels overcoated with AA-40 increased to 5.5% during the wet rub tests. These results are also collected in Table 9.

Since the particular polyvinyl acetate emulsion, AA-40, had failed only with respect to water sensitivity, other emulsions of the same family were given preliminary tests, water resistance being used as a screening test.

In this second series of alternate coatings, there were included:

Polyvinyl acetate emulsions

10K25	National Starch Products Co.
Darex Everflex A	Dewey & Almy Chemical Co.
Darex Everflex 6G	Dewey & Almy Chemical Co.

Polyvinyl acetate copolymer emulsion

Darex Copolymer Latex 3L	Dewey & Almy Chemical Co.

Used as received, with air drying, the 10K25 and Everflex A gave extremely hazy coatings. Panels representing the remaining coatings were tested by immersion in water for 5 minutes. Table 10 indicates that the Darex polyvinyl acetate emulsions showed water sensitivity similar to AA-40. Haze of the copolymer emulsion did not increase on immersion, but the copolymer films became tacky and lost adherence to the acrylic substrate.

None of the polyvinyl acetate emulsions tried had satisfactory water resistance. This may possibly be associated with the use of water sensitive emulsifying agents.

Table 10

Water Resistance of Polyvinyl Acetate Emulsion Undercoats

Undercoat	AA-40 (1)	Darex Everflex 6 (2)	Darex Copolymer Latex 3L (2)
Before Immersion			
Light Trans., %	92.6	91.3	91.0
Haze, %	0.9	2.6	1.9
1 Min. Immersion			
Light Trans., %	90.0	92.8	-
Haze, %	4.1	2.2	-
5 Mins. Immersion			
Light Trans., %	75.7	26.0	92.5*
Haze, %	42.5	88.5	4.2

*Coating tacky and non-adherent

POLYSTYRENE EMULSION ANCHORING SYSTEMS

Encouraged by the superior wear resistance of polyvinyl acetate emulsion and the fact that emulsions should be inherently free of crazing problems, a number of other emulsions were investigated.

Two grades of polystyrene emulsion designated Lustrex Medium Clear and Lustrex Short Clear (Monsanto Chemical Co.) were tested as undercoats and overcoats. As received and air dried these emulsions gave coatings which were too hazy to be useful.

Attempts were made to improve the transparency of films deposited from the polystyrene emulsions by baking. Preliminary tests indicated that the transparency of Lustrex Medium Clear could be improved by baking but that of Lustrex Short Clear (a harder grade) could not. A baking temperature of 80°C was selected as being high enough to coalesce the undercoat in a reasonable time without significantly affecting the substrate acrylic.

A series of experiments (Table 11) indicated that a baking time of about 3 hours would give a reasonably clear undercoat with improved resistance to water. The time of immersion was 1 hour.

Tests were made of Lustrex Medium Clear emulsion coatings baked at 80°C for 3 hours as undercoats to receive a Marklad coating. It was found that an undue amount of haze (5%) was created during the Marklading operation, possibly because the undercoat is softer than the beads used in the Marklading beds.

It was felt that the polystyrene emulsion might serve as a suitable overcoat for a Marklad AA-40 undercoat. Trials indicated that the two systems are optically compatible, giving adequately high light transmission and low haze. However, after the baking operation which

Table 11

Water Resistance of Baked Polystyrene Emulsion Primers

Lustrex Medium Clear Emulsion
Immersion Time - One Hour
Baking Temperature - 80°C

Baking Time, Hours	Before Immersion Light trans. %	Before Immersion Haze %	After Immersion Light trans. %	After Immersion Haze %
1	91.3	2.3	89.5	9.4
2	90.0	1.7	89.2	4.5
2 1/2	91.7	1.8	89.4	2.9
3	90.5	2.1	90.5	3.3
5	89.9	1.3	90.3	3.2

is needed to impart clarity to the overcoat. the surface resistance of the treated sheet (1 to 10 megohms per square) was found to have risen to above 10,000 megohms per square. Apparently baking had produced a continuous insulator film which prevented contact with the Marklad coating. A similar phenomenon was observed with AA-40 coatings which were baked along with the polystyrene materials.

Attempts to prevent the polystyrene emulsion overcoats from insulating the Marklad coating by diluting the emulsion or by modifying the baking conditions were unavailing.

SYNTHETIC RUBBER EMULSION ANCHORING SYSTEMS

Preliminary tests were made of two synthetic rubber emulsions, Hycar 4501 and Hycar 1561 (B. F. Goodrich Chemical Company). They were flow coated as supplied, air dried for 1/2 hour and baked at 80°C for 3 hours. As tested, Hycar 4501 gave slightly hazy undercoats. Hycar 1561 undercoats showed heavy streaks and flow marks with 1.4% haze. The latter could bear further investigation. It was set aside in favor of a particular acrylic emulsion (v.i.) which appeared to be even more promising.

ACRYLIC EMULSION ANCHORING SYSTEMS

Exploratory attempts were made to produce emulsions of Acryloid B-7 (Rohm & Haas Company), the resin which was the basis of the reasonably successful undercoat, S-25. Within the range of conditions and emulsifying agents which were tried, an emulsion which would lay down a smooth undercoat was not obtained. This approach was set aside in favor of using commercially available emulsions.

Commercial acrylic emulsions tested were Rhoplex WN-80 and Rhoplex AC-33 (Rohm & Haas Company). The former was used as supplied, 40% solids. The latter was used in the following formula, recommended by the supplier for use as a sealer:

Rhoplex AC-33 (46% solids)	45.3% by volume
Water	46.8
Ammonium Hydroxide (28%)	0.5
Tamol (6%)	6.8
Hexalin	0.2
Boric Acid	0.4

The two materials were initially tested by flow coating, air drying for 1/2 hour and baking at 80°C for 3 hours. Under these conditions Rhoplex AC-33 gave a slightly hazy and streaky coat whereas the Rhoplex WN-80 coating was clear, having 0.4% haze, undistinguishable from uncoated acrylic.

Exploratory tests showed that Rhoplex WN-80 would accept a Marklad coating without a great increase in haze, would overcoat that coating without great increase in resistance and would protect it against dry and wet rubbing.

Tests were performed to determine the proper concentration of emulsion for overcoat purposes. Whereas the solids concentration of Rhoplex WN-80 as delivered is 40%, a concentration of 35% was selected. The selected concentration is lower than the delivered concentration to minimize the increase of surface resistance on overcoating, but not low enough to introduce any interference colors due to thinness of the overcoat film.

A further series of experiments was performed to determine optimum baking conditions for Rhoplex WN-80 coatings. As indicated in Table 12, it was found that baking neither improved the light transmission or haze of Rhoplex WN-80 coatings nor improved the resistance of these coating to water. Accordingly baking was abandoned in further experiments.

Thereafter a group of 4 duplicate 3 1/2 x 3 1/2 x 1/16 inch panels was subjected to a rather rigorous series of tests. These panels were undercoated with Rhoplex WN-80 (35% solids), Marklad and overcoated with Rhoplex WN-80 (35% solids). The air dried panels were immersed in water for 24 hours, their optical properties being measured several times during and after this exposure.

Table 12

Water Resistance of Baked and Unbaked Acrylic Emulsion Primers

Baking Temperature - 80°C
Emulsion - Rhoplex - WN-80
Solids Concentration- 40%

Baking Time, Hours -	0	1/2	1	3	20
Before Water Immersion					
Light Trans., %	92.4	92.7	92.2	92.7	92.8
Haze, %	0.4	0.4	0.3	0.4	0.2
After 15 mins. Water Immersion					
Light Trans., %	92.2	92.0	92.2	92.5	93.0
Haze, %	0.8	1.0	1.8	1.6	3.2
After 30 mins. Water Immersion					
Light Trans., %	92.2	92.2	*	*	92.2
Haze, %	1.0	1.5	*	*	4.9

*Considerable haze, which disappeared in less than 2 minutes after withdrawal of samples from water.

The same panels were each subjected, sequentially, to 100 strokes with wet cotton cloth, 100 strokes with dry cotton cloth and 100 strokes with #7 polish (E. I. DuPont de Nemours & Co., Inc.) using apparatus according to Spec. MIL-C-5547. Thereafter the same panels were subjected to 200 rubs in static generating equipment designed according to Spec. MIL-P-80A except that the severity of the test was increased by doubling the pressure of the friction pad. Results of the test are shown in Table 13 along with corresponding data on coatings from emulsion AA-40. Note that in these tables resistances are given in terms of measurements with applied probes. While it was found in earlier work on solution type anchoring systems that resistance between painted on electrodes gives a more accurate indication of static dissipating properties, the test with probes is a more sensitive indication of wear.

The acrylic emulsion anchoring system showed at least the remarkable wear resistance which had been the favorable characteristic of the polyvinyl acetate emulsion but also showed much superior resistance to water immersion. Such increased haze as does form on water immersion disappears within a few minutes during simple air drying at room temperature.

The latter property is strikingly illustrated in the graphical presentation of the immersion data in Figure 6. After having passed all of the mentioned water immersion and rub tests, the same four panels developed no static charge when subjected to the intensified MIL-P-80A test of static charge dissipation.

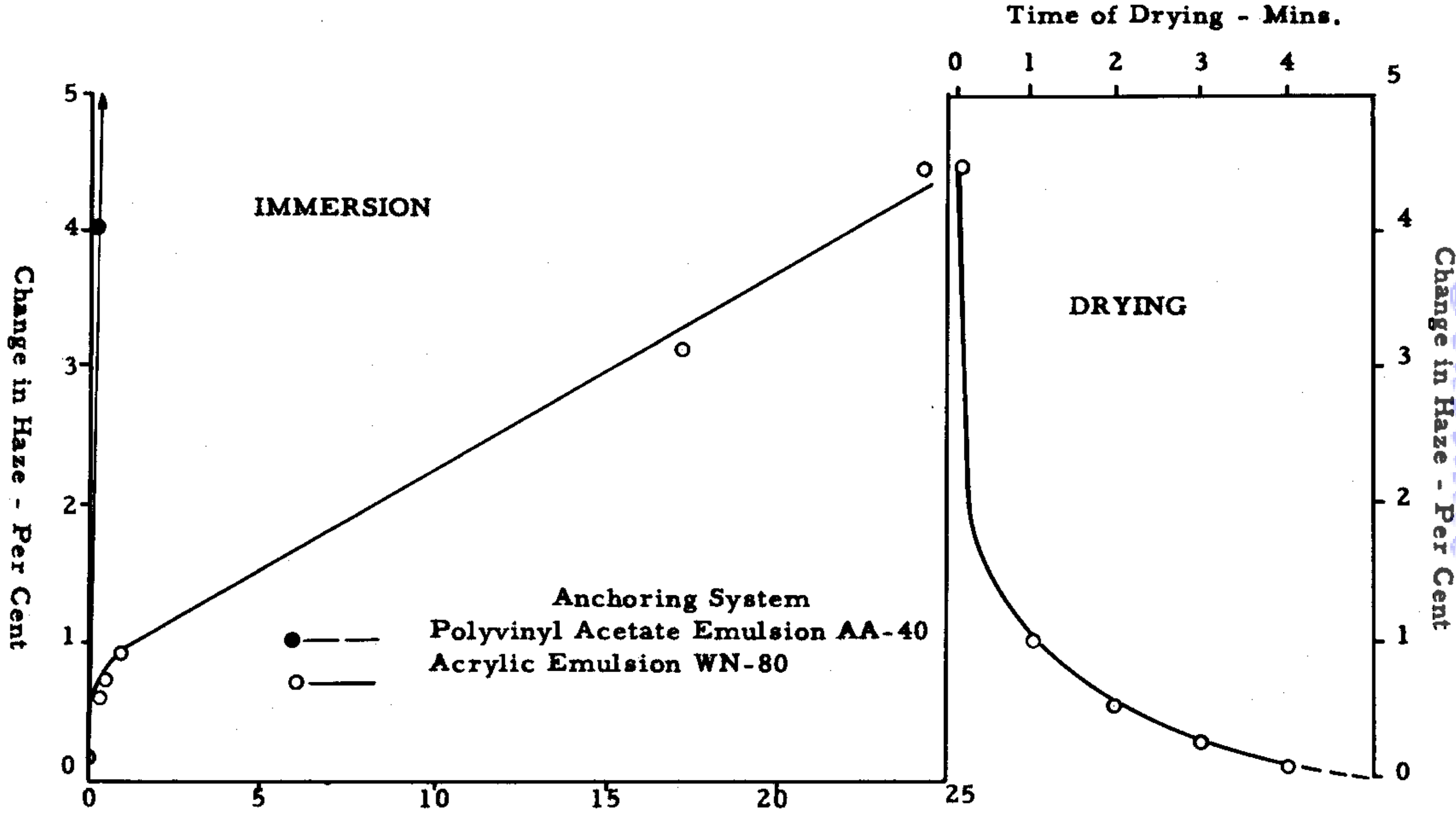
It was concluded that Rhoplex acrylic emulsion WN-80 which is a water emulsion and hence not suspect as far as crazing is concerned, provides a promising undercoat and overcoat for Marklad coatings. It has been used on flat sheet processed subsequent to the revision of contract aims.

Initially both under and overcoating with Rhoplex emulsions WN-80 was done by flow coating. That is, the emulsion was poured over the panel to be coated and the excess

Table 13

Resistance of Acrylic Emulsion Anchoring System to Combined Water Immersion and Wear Tests

Anchoring System	Rhoplex WN-80			Xyno Resin AA-40		
	Resistance Megs/sq.	Haze %	△ Haze %	Resistance Megs/sq.	Haze %	△ Haze %
Before Test	5.2	0.9	-	5.6	1.7	-
Water Immersion						
1 min.	-	1.1	0.2	-	5.8	4.1
15 mins.	-	1.6	0.7	-	76.7	75.0
45 mins.	-	1.7	0.8	-	-	-
75 mins.	-	1.8	0.9	-	-	-
17 hrs.	-	4.0	3.1	-	-	-
24 hrs.	-	5.3	4.4	-	-	-
Drying after Immersion						
1 min.	-	1.9	1.0	-	-	-
2 mins.	-	1.5	0.6	-	-	-
3 mins.	-	1.2	0.3	-	-	-
4 mins.	-	1.0	0.1	-	-	-
Rub Tests						
100 Strokes, Wet	-	1.4	0.4	-	6.2	4.5
100 Strokes, Dry	-	1.7	0.3	-	6.9	0.7
100 Strokes, Polish	4.1	1.7	0.0	5.8	7.9	1.0



(Note different time scales)

Figure 6

Effect of Water Immersion and Subsequent Drying on Acrylic Emulsion Anchoring System material drained off. It was observed that this type of coating, while satisfactory for small panels, on large panels yielded non-uniform coatings exhibiting excessive bubbles and drain patterns; therefore, equipment for dip coating both small and large panels was built.

The first tank for dip coating 4 ft. x 4 ft. x 1/4 in. acrylic sheet had inside dimensions closely fitting the sheet in length and height and 3/4 in. wide. The panel to be dip coated was immersed in emulsion which was then allowed to flow from the bottom of the tank to a reservoir. The height of the reservoir was controlled by a cable passing over a pulley to a wind-up drum driven by a 1/4 h.p. motor through a variable pitch pulley and gear reducer.

The panel could be coated by lowering the level of the emulsion at a controlled rate. Rate was controlled by the variable speed transmission connected to the wind-up drum governing the height of the reservoir.

Acrylic sheet has a strong tendency to bow. The width of the above tank would not readily accommodate a bowed acrylic sheet. Another feature of this first dip tank which required correction was the drain orifice which was found to be too small.

Taking advantage of knowledge gained by making the first dip tank, a galvanized steel tank was made with an inside width of 2 in. and other dimensions sized to closely fit a 4 ft. x 4 ft. panel. Panels were withdrawn from this tank by means of the variable speed windup. Satisfactory mechanical operation allowing dip coating of 4 ft. x 4 ft. panels at 2 in. per min. to 9 in. per min. was obtained with this set-up.

Since the large tank required about 30 gals. of liquid, a small tank for coating 12 in. x 3 in. x 1/4 in. test panels was made out of acrylic sheet. The same withdrawal mechanism was used with this tank as with the larger one described above.

Several Marklad panels having a resistance of 0.5 to 10 megohms per square were overcoated with 35% solids Rhoplex emulsion WN-80. Withdrawal rates of 2 to 9 inches per minute were used. It was found that at these withdrawal rates and this solids content the WN-80 completely insulated the Marklad coating from external surface probes. The conductivity between painted contacts applied prior to overcoating remained virtually unchanged, indicating that the 35% solids dip coating had sealed off the Marklad film. Inasmuch as flow coating at 35% solids increases the surface conductivity only three to four fold (cf. Table 14) it appears that flow coating and dip coating are not strictly comparable.

In an attempt to determine useful procedures, a brief study of the dip coating of Rhoplex emulsion WN-80 was carried out. These studies, using 3 x 12 x 1/4 in. acrylic panels indicated that Rhoplex emulsion WN-80 diluted to 20% solids and dip coated at from 2 in. to 9 in. per minute would overcoat the Marklading without sealing off the conductor. More extensive experiments conducted with 20% solids WN-80 are summarized in Table 15.

For the purposes of these experiments the small test panels were attached to the center of the Marklading template where bed action has been found to be quite uniform. Resistance measurements with probes applied at four positions along the test panel were averaged to yield the data shown in the table.

During the course of these experiments viscosity of the emulsions was measured with a Zahn Cup viscosimeter. Within the precision of measure of the method used no difference in viscosity could be measured between emulsions containing 20 and 35% solids. Results indicate the following trends:

a) For panels having essentially the same resistance before overcoating, the faster the withdrawal rate from a diluted acrylic emulsion bath the less the increase in surface resistance due to the overcoat.

Table 14

Effect of Flow Coating Overcoat of Acrylic Emulsion on Resistance

Panel	Average Resistance, Megs/sq. Before Coating	Average Resistance, Megs/sq. After Coating	Res. After / Res. Before	% Solids in Emulsion
723	0.6	2.0	3.3	35
726	1.1	4.0	3.6	35
727	1.1	3.0	2.7	35
728	1.0	3.5	3.5	35

Table 15

Influence of Withdrawal Rate on Resistance after Overcoating by Dip Coating

Acrylic Emulsion
20% Solids

	Panel	Average Resistance, Megs/sq. Before Coating	Average Resistance, Megs/sq. After Coating	Res. Before / Res. After
Withdrawal rate, 2 in. per min.	C1	0.8	3.0	3.7
	C2	0.8	3.0	3.7
	C3	0.8	3.0	3.7
	C4	0.8	2.4	3.0
	B4	1.0	10.0	10.0
	B1	1.5	8.0	5.3
	B2	6.0	40	6.6
	B3	6.0	40	6.6
Withdrawal rate, 5 in. per min.	E1	0.6	1.0	1.7
	D1	1.0	4.0	4.0
	E2	1.8	4.0	2.2
	D2	3.0	8.0	2.7
	E3	3.5	40	11.5
	D3	8.0	80	10.0
	E4	40	200	50
Withdrawal rate, 9 in. per min.	A1	0.8	1.2	1.5
	A2	1.0	2.0	2.0
	A3	4.0	10.0	2.5

b) For a given withdrawal rate, the ratio of surface resistance of an overcoated panel to that of a non-overcoated panel will increase as the non-overcoated surface resistance increases, i.e., the overcoating will tend to amplify non-uniformity of Markdading.

The data of Table 15 indicate that a 9 in. per min. withdrawal rate might be superior to a 2 in. per min. rate; however, the slower rate gives coatings which have fewer optical flaws. Panels coated at the faster rate show some drainage marks and "sag lines".

In both undercoating and overcoating with 20% solids WN-80 some difficulty in obtaining flawless coatings was encountered. Even when the diluted emulsion was filtered through filter paper just prior to use a few clots appear at intervals of about one inch. It is believed that these flaws are caused by aggregates formed in the latex due to the dilution of the protective colloid on addi tion of water.

The problem of clotting pointed out above is peculiar to emulsion coating systems as distinguished from systems discussed in the extensive literature on flow coating of resin solutions. The problems of immediate interest have been discussed with several manufacturers of resin emulsions. It is felt that clots might be eliminated by the addition of the proper protective colloid to the diluting water.

Several 3 1/2 x 3 1/2 x 1/4 in. panels under and overcoated by dip coating with 25% solids WN-80 at 2 in. per min. were sequentially subjected to 100 strokes with wet cotton cloth, 100 strokes with dry cotton cloth and 100 strokes with #7 polish (E. I. DuPont de Nemours & Co., Inc.) using apparatus according to Spec. MIL-C-5547.

In addition, the resistance of these panels to water immersion was tested. The results of the water and rub tests are summarized in Table 16 and the results compared to panels under and overcoated by flow coating with 35% solids WN-80. These data indicate that 20% solids WN-80 applied by dip coating is almost as resistant to these types of wear as 35% solids WN-80 applied by flow coating. At the same time the 20% solids WN-80 applied by dip coating permits the required degree of conductivity to appear on overcoated panels.

Although more work is needed to consistently produce flawless WN-80 anchoring and undercoat films, with particular reference to the occurrence of clots and intrusion of dust, it appears that 20% solids acrylic emulsion can supply effective priming and protection for the Marklading.

Table 16

Resistance of Dip Coated Acrylic Emulsion Panels to Combined Immersion and Wear Tests

Anchoring System	Rhoplex Emulsion WN-80 35% Solid Flow Coat			Rhoplex WN-80 20% Solid Dip Coat-2 in/min.		
	Res. Megs/sq.	Haze %	Δ Haze %	Res. Megs/sq.	Haze %	Δ Haze %
Before Test	5.2	0.9	-	6.1	0.9	-
Water Immersion						
1 min.		1.1	0.2		1.1	0.2
15 mins.		1.6	0.7		1.5	0.6
45 mins.		1.7	0.8		1.6	0.7
24 hrs.		5.3	4.4		4.9	4.0
Drying after Immersion						
1 min.		1.9	1.0		2.0	1.1
2 mins.		1.5	0.6		1.6	0.7
3 mins.		1.2	0.3		1.1	0.2
4 mins.		1.0	0.1		0.9	0.0
Rub Tests						
100 Strokes, Wet	-	1.4	0.4	6.6	1.0	0.1
100 Strokes, Dry	-	1.7	0.3	7.1	1.6	0.6
100 Strokes, Polish	4.1	1.7	0.0	8.0	2.8	1.2

SECTION IV

CLEANER FOR ACRYLIC PLASTIC

WADC technical personnel have stated as a secondary problem the need for a cleaner which would remove old Marklad coatings from canopies leaving them in suitable condition for recoating. There exists also the problem of removing traces of adhesive from Plexiglas which is to be coated.

When solvent cleaners are used there is the possibility of crazing acrylic plastic, particularly when strains are present as is likely to be the case in aircraft canopies. Another difficulty with solvent type cleaners is that unless very large amounts of solvent are used in repeated rinses there is always a small amount of the original coating redeposited. This has been confirmed with respect to the removal of small amounts of the adhesive which remained on panels after the protective paper was stripped off. When small spots of adhesive were sponged off with isopropyl alcohol the panel appeared to be perfectly clean. When these panels were primed they seemed to be uniform but when they were Marklad dark spots appeared where the panel had been washed. Apparently enough of the adhesive had remained to modify the primer.

A cleaner was formulated containing:

5% Neutronyx 600 (Onyx Oil and Chemical Co., Jersey City, N. J.)
45% Xylene
50% Stoddard Solvent

Marklad panels were washed with this cleaner on cotton swabs and before the cleaner dried the panels were flushed with water. The cleaner and old Marklad were immediately emulsified and washed away. The panels were dried, primed and Marklad. The coating was equal in all respects to that obtained with new panels. This cleaner was subsequently applied to all panels which were coated with S-25. The need for its use appeared to be obviated when emulsion type primers were introduced.

SECTION V

COLLECTOR ELECTRODES

As applied to canopies, Marklad coatings would need be provided with collector electrodes for draining off electric charges.

In the course of earlier work, the Markite Company has developed a proprietary conductive coating with a resistance of less than 2000 ohms per square which appears to adhere well to Plexiglas and to Marklad Plexiglas without causing cracking or crazing. This material, S8597, was sprayed on the opposite ends of several Marklad specimens. Surface resistance measurements made by means of such collector electrodes were in good agreement with values obtained by the technique described in Section II.

Contact to such electrodes can be achieved by any metal fastener which presents a metal face to the electrode. Roundhead screws, and rivets, nut bolt and washer assemblies, and standard peened lugs have been successfully used.

SECTION VI

APPLICATION OF MARKLAD COATING

GENERAL CONSIDERATIONS

In the Marklad process, objects receive a coating by repeated impact with small impactors which carry the coating material. Possible methods of providing the repeated impacts are many and varied.

Expecially during the first phases of the subject contract when the coating of large, complex shapes was being considered, vibration of either a bed of impactors or of an object in contact with a bed of impactors was considered to offer the most direct and prompt solution to coating problems. Specifically, polystyrene beads (XXX Grade, Koppers Co.) coated with graphite were used as impactors throughout this work. Electromagnetic vibrators (Syntron vibrators) were used as the source of vibration.

During many studies of the Marklad process variables, flat Plexiglas acrylic sheets were coated. As a measure of economy, three and one-half inch squares or other comparatively small pieces of acrylic sheet were attached to steel supports and substituted for the complete sheet. As a further refinement and to avoid edge effects on the small samples, templates were later cut from acrylic sheet with holes the size of the samples to be experimentally coated. Template and samples, when attached to a suitable backing, presented to the coating bed the equivalent of a single flat sheet of plastic.

BED CONDITIONING

In the operation of Marklading beds, it has been observed that "freshly" coated polystyrene beads transfer conductive material to acrylic plastic relatively rapidly but in an unsatisfactory manner, yielding dirty films with poor optical properties. Figure 7 is a photomicrograph of a Marklad coating made with "freshly" coated impactors.

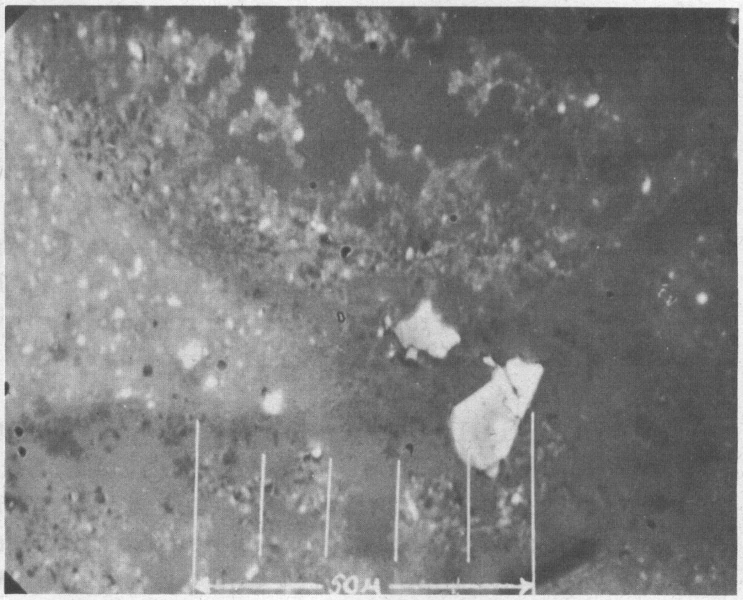


Figure 7

MARKLAD COATING
FROM FRESHLY COATED IMPACTORS

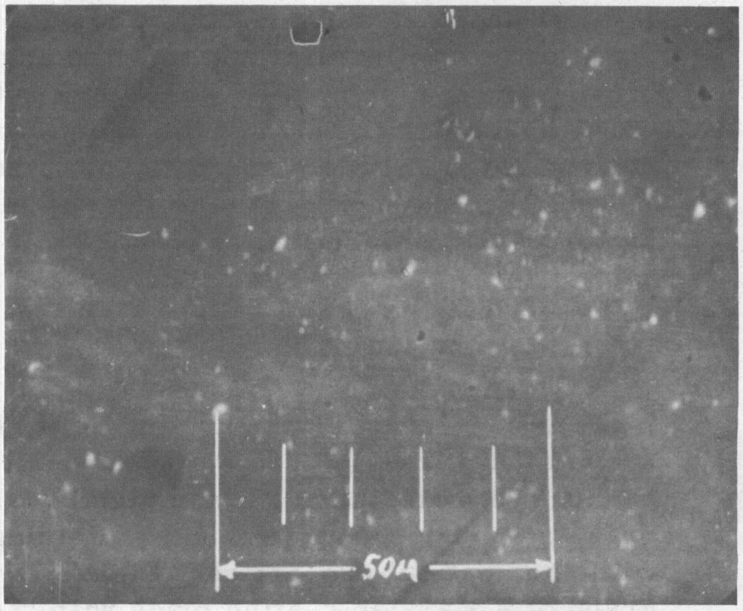


Figure 8

MARKLAD COATING
FROM CONDITIONED IMPACTORS

If, on the other hand, the impactors are subjected to mutual impacting for a sufficient period of time, Marklad coatings with satisfactory electrical and optical properties are obtained (cf. Figure 8). This conditioning operation may be performed by vibrating a bed of impactors or, more simply, by tumbling the impactors in a drum provided with baffles to lift and shower its contents. Tumbling for 4 hours appears to be an adequate conditioning procedure. In practice, tumbling over night has been found to be convenient.

VERTICAL PANEL, VIBRATING BED

This bed was designed to treat 1 x 3 ft. panels in a vertical position and was fitted with two Syntron vibrators to vibrate the bed vertically and horizontally. Marklading a number of panels in this vibrating bed showed that the rate of coating varied pronouncedly with bed depth. In the top few inches of bed coating was very slow, the top inch giving no measurable conductivity after coating for the same time that developed a resistance of 4 megs/sq. at a depth of 3 inches.

Coating speed was at a maximum at about 3 to 6 inches, decreasing at greater depths and reaching a minimum halfway down the bed. At lower levels coating occurred somewhat more rapidly giving a rate at 36 inches depth of bed equal to about 1/50 the maximum rate.

This work showed that Marklad coatings could be applied in a coating bed large enough to contain 1 x 3 ft. panels and that typical optical and electrical properties could be obtained. It also showed that a marked depth effect on rate of coating would have to be compensated for in coating large and complicated pieces and that large vibrators would have to be used to activate a bed sufficiently to get the desired amount of coating in a reasonable time.

VERTICAL, VIBRATING PANEL

For the purpose of making a comparison between coating in a vibrating bed and coating in a still bed with a vibrating panel, a 1 x 3 ft. panel of Plexiglas was mounted in an iron frame and a Syntron vibrator was attached to one of the short sides of the frame.

This panel was immersed vertically in a coating bed and was vibrated. In comparable 30 minute runs the vibrating bed activated by two type V-15 Syntron vibrators applied coatings having 20 to 200 times the resistance (depending on bed depth) of coatings which were applied in the same length of time on a vibrating panel which was activated by one type V-15 Syntron vibrator.

There was still an appreciable depth effect in coating a vibrating panel but it was less than that observed during coating in a vibrating bed.

Numerous coatings were made in a vertical still bed with vibrating panels to determine the length of run which would give the desired resistance, the optical properties of panels at different resistances, directional effects in coatings and the effect of the depth of bed.

The results showed that in a still bed with a vibrating panel:

1. Coating is comparatively slow in the upper 2 inches of bed.

2. Between 3 and 20 inches of bed depth there is considerable depth effect, faster coating occurring at greater depths.

3. Coatings with resistance between 1 and 10 megs/sq. were obtained in 10 minutes vibration.

4. Resistance of the coating is less in the direction of motion of the panel.

It was found that conductivity developed more rapidly parallel to the vibration of the panel than in the perpendicular direction. This directional effect was compensated for either by rotating the panels through 90° on their support at the middle of the run or by applying the vibrators for an equal length of time to two adjacent sides of the supporting panel. Figure 9 is a typical map which was obtained during such a test.

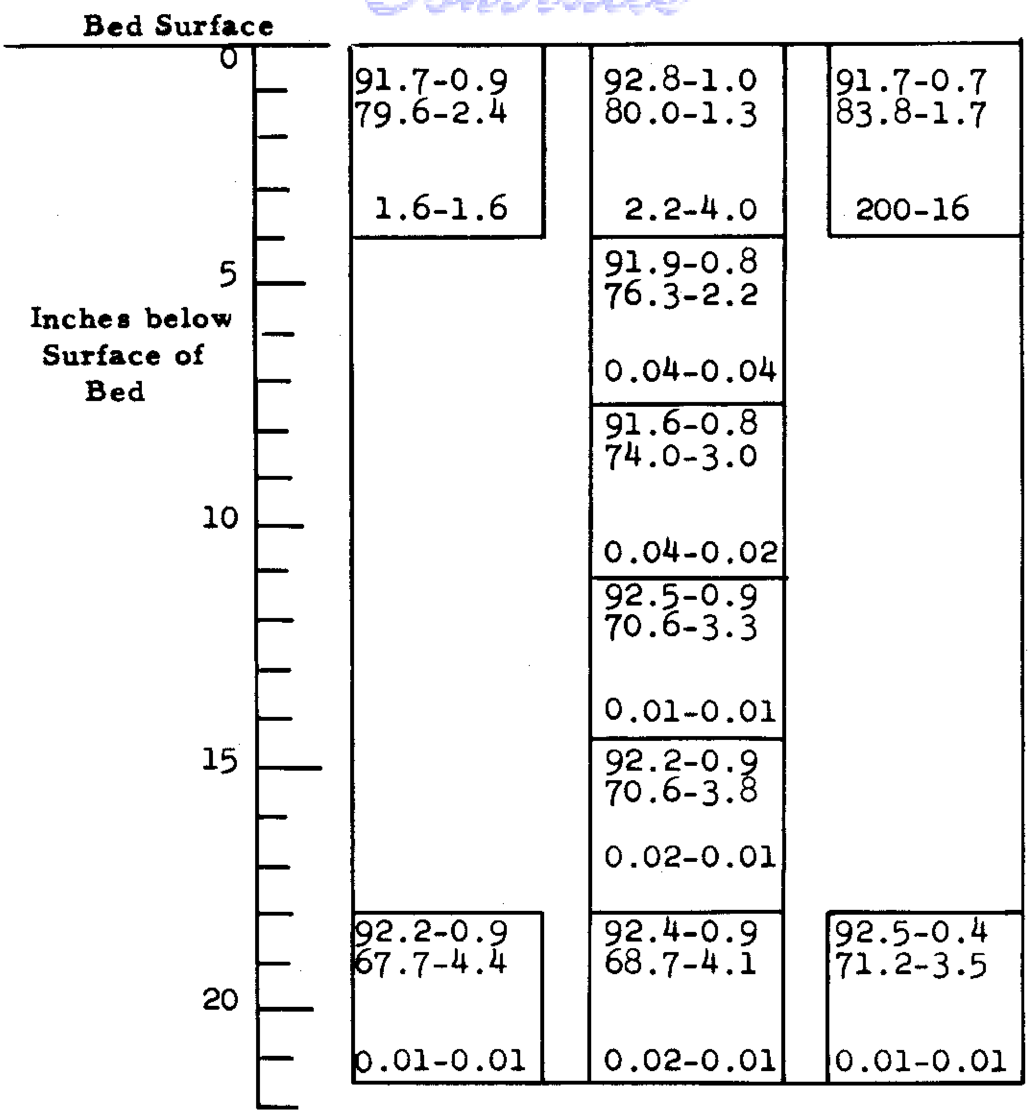
While the results at this stage of the work indicated that coatings with a resistance between 1 and 10 megs/sq. could be obtained on a panel immersed from 3 to 14 inches in the bed and that, considering the condition of the bed and the resistance of the panels, the optical properties were promising, it seemed that further immediate work on coating larger panels should be done in horizontal beds. This would eliminate the effects of bed depth and would make the interpretation of the results of coating a flat panel much clearer. These results would then be applied to the planning of a method for coating more complex shapes.

HORIZONTAL, VIBRATING PANEL

A shallow bed, 3 x 5 x 1 ft., was built to treat 1 x 3 ft. flat panels at bed depths up to 10 inches. An iron frame for a 1 x 3 ft. panel was built and was provided with places for attachment of Syntron Model V-15 vibrators on all four sides.

Three and one-half inch square acrylic panels were attached to a 1 x 3 ft. panel which was fastened in the vibrating frame. Coatings were made at various bed depths with this panel in the horizontal position, using different coating times and different locations for the vibrators. Uniformity of coating was dependent to some degree on the position of the vibrators. Rate of coating was dependent on bed depth. Panels were coated to within the range, 1 to 10 megs/sq., in 20 minutes at a bed depth of 5 inches, with the vibrators in the preferred position.

When a vibrating panel was immersed 5 inches deep in a coating bed there was very little motion in the bed except quite near the panel. Apparently the 5 inches of coating bed above the panel were acting only as a dead weight, providing pressure at the panel surface.



Key to Small Areas Above

Primer:
% Transmission - % Haze
Marklad:
% Transmission - % Haze

Marklad Resistance (megs/sq.)
Lengthwise - Crosswise

Figure 9

Map of Panel Marklad by Vibrating in Vertical Bed

It seemed that it would be more economical to obtain this pressure by other means, thus reducing the amount of bed which would be needed.

A preliminary test was made by attaching a 3 1/2 in. square acrylic panel to the large steel panel, laying the latter face down on the surface of the coating bed and applying to the back of the assembly a weight which exerted a pressure equivalent to a bed 8 1/2 in. deep. The coating bed weighs approximately 40 lbs. per cubic foot and exerts a pressure of about 0.023 lbs. per square inch per inch depth of bed. The results were sufficiently promising so that this method of coating was explored further, determining the evenness of coating, coating time and best location for the vibrators.

The best results obtained in this series of coatings were obtained by weighting the vibrating panel so that a pressure of 0.25 lbs. per sq. in. was obtained; by attaching two vibrators, one on each of two opposite sides of the panel and in the middle of the run, changing the position of the vibrators to the other two opposite sides of the panel to give vibration in a direction perpendicular to that used during the first half of the coating.

Based on the foregoing exploratory work, a base for the panels which were to be coated was prepared from 1/4 inch iron plate with suitable points of attachment for the Syntrons and the panel. This plate measures 18 x 42 inches. Two smaller iron plates, 1/4 x 16 x 40 inches, were used as weights to be placed on top of the vibrating panel to give different pressures which would be evenly distributed.

The weights of the mounting panel with two Syntrons attached and of the weighting panels were such that they exerted pressures on the Plexiglas as follows:

Supporting panel and Syntrons	1.01 psi
Same + 1 weighting panel	1.56 psi
Same + 2 weighting panels	2.19 psi

Figure 10 shows the Markladíng bed ready for operation with panel holder and Syntron vibrators in place.

A 16 x 40 inch panel, No. 701-146, was coated face down on the coating bed with one weighting panel on top of the mounting panel to provide additional pressure. This weight, added to the weight of the mounting panel and two Syntrons, gave a pressure on the panel of 1.56 psi.

The vibrators were operated for 5 minutes, one at each end of the panel. They were then removed and attached on the sides of the panel. They were run for 5 minutes in this position, vibrating the panel in a direction at right angles to that of the first 5 minutes vibration. The whole operation was repeated, giving a total coating time of 20 minutes.

The surface of the panel was explored with the contacts described in Section II, above, to determine the resistances of 22 areas as shown in the map, Figure 12. Since coating by this method is somewhat directional, depending on the direction of vibration, the resistances were measured lengthwise and crosswise on the panel and averages of three or four readings in each direction were recorded on the map.

The results showed that the desired range of resistance had been approached, 98% of the area having a resistance less than 10 megs/sq.

Optical properties of each of the areas were determined in the modified hazemeter (cf. Section II, above). The results are also entered in Figure 12.

The panel was overcoated with formulation S-25 (cf., Section III, above) and again explored for resistance. The results are shown in Figure 12. A portion of the haze was due to the conditions under which the undercoat was applied. Panel 701-146, after priming and before Marklading had average haze of 0.4% and in some areas the haze was as high as 1,10%, apparently due in part to dust which had collected in the primer during spraying. The average transmission was 92.5%.

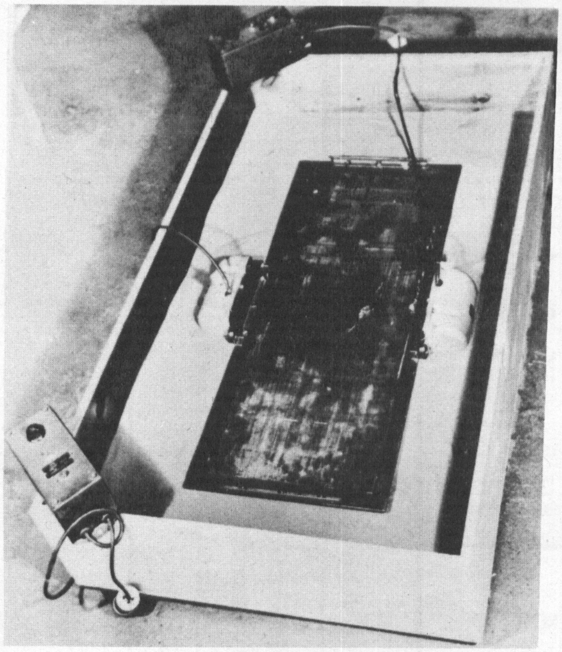


Figure 10

HORIZONTAL MARKLADING BED, VIBRATING PANEL

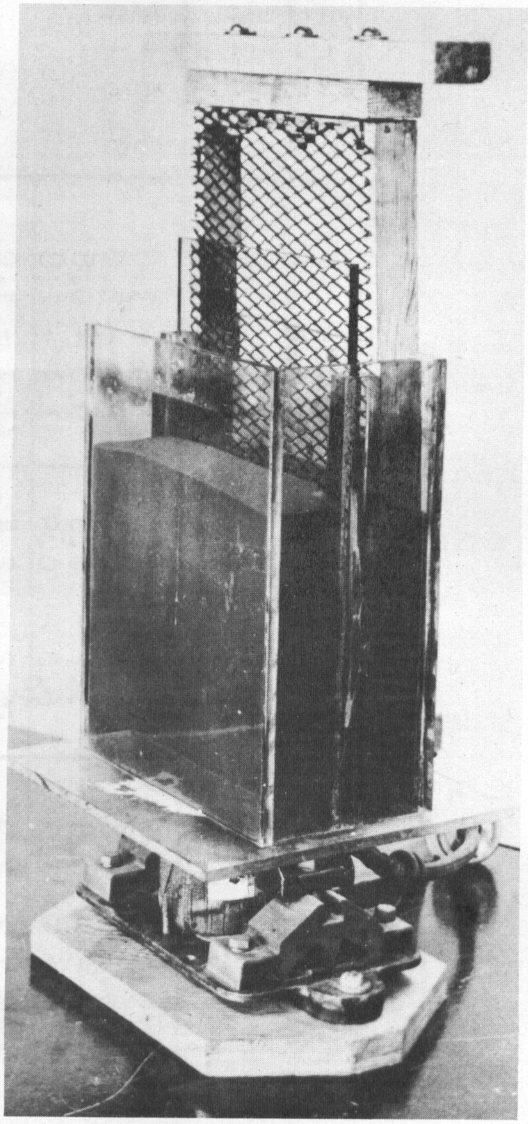


Figure 11

SMALL COATING BED WITH BAFFLE SCREEN

76.5 - 3.4 81.0 - 2.4 1.2 - 3.0 6.0 - 1.5	82.2 - 2.7 87.0 - 2.3 1.2 - 1.2 1.8 - 1.3	82.3 - 1.5 87.0 - 1.5 40.0 - 4.0 30.0 - 40.0	82.3 - 2.1 85.3 - 5.8 6.0 - 6.0 800 - Inf.	81.7 - 1.8 82.2 - 2.6 0.9 - 1.6 6.0 - 6.0	81.0 - 1.6 82.5 - 1.3 1.6 - 1.2 6.0 - 6.0
76.0 - 1.7 84.0 - 2.0	74.0 - 2.3 77.0 - 4.6 0.4 - 0.4 0.7 - 0.7	75.3 - 3.1 78.2 - 3.8 0.5 - 0.8 1.0 - 1.2	60.4 - 4.1 74.2 - 5.0 1.2 - 0.8 6.0 - 0.9	77.6 - 3.0 76.7 - 3.0 0.6 - 0.6 1.4 - 1.8	80.6 - 1.4 84.6 - 2.2
1.0 - 0.6 1.0 - 0.9	77.5 - 2.3 80.9 - 2.2 0.5 - 0.6 0.9 - 1.0	76.3 - 2.9 81.0 - 3.8 1.2 - 1.0 2.0 - 3.0	76.2 - 2.4 83.9 - 2.9 0.9 - 0.9 5.0 - 5.0	71.1 - 4.0 74.7 - 3.9 0.8 - 0.9 2.0 - 3.0	1.2 - 1.0 3.0 - 5.0
76.1 - 2.6 82.5 - 2.8 0.5 - 0.5 0.9 - 0.9	79.0 - 2.5 82.2 - 2.7 1.4 - 1.5 1.6 - 1.4	79.0 - 3.0 83.0 - 3.6 4.0 - 6.0 3.0 - 4.0	80.7 - 2.2 85.6 - 2.9 6.0 - 2.0 20.0 - 30.0	80.0 - 3.1 82.5 - 2.5 1.2 - 1.6 4.0 - 6.0	80.6 - 1.3 84.1 - 1.8 1.8 - 2.0 4.0 - 6.0

Key to Above Areas

% Transmission - % Haze - Marklad
% Transmission - % Haze - Overcoated
Resistance (megs/sq.) 1. Crosswise 2. Lengthwise - Marklad
Resistance (megs/sq.) 1. Crosswise 2. Lengthwise - Overcoated

Figure 12

Map of Panel No. 701-146

After this panel was Marklad, large areas appeared which were darker than the surrounding areas, having accepted the Marklad coating more rapidly than other portions. These areas had been washed with alcohol before priming to remove traces of adhesive which had separated from the protective paper which had covered the panel.

Another panel, No. 701-147, was coated in a similar way without the added weight on the back of the mounting panel. The weight of the mounting panel and the Syntrons exerted a pressure of 1.01 psi.

After 40 minutes coating, the average resistance was greater (6.8 megs/sq.) than that of Panel No. 701-146 after coating 20 minutes (2.5 megs/sq.) with one weighting panel on top of the mounting panel.

This panel was overcoated and the electrical and optical properties were determined.

Great increases in resistance in portions of the panel after overcoating indicated that the overcoat had been applied unevenly and much too heavily in some areas. 58% of the area of the panel had a resistance greater than 10 megs/sq.; whereas, before overcoating 82% of the area had a resistance below 10 megs/sq.

Another panel, No. 701-148, was coated for 20 minutes without any additional weight and then one weighting panel was applied for 10 more minutes. This gave a coating with an average resistance of 2.0 megs/sq. and a more uniform coating than had previously been obtained. After overcoating, the average resistance was 8.0 megs/sq. and 79% of the area had resistances in the range of 1 to 10 megs/sq.

Two more panels were coated using one weighting panel. Panel 701-149 was coated in 30 minutes and Panel 701-150 in 40 minutes. After overcoating, these panels had more than 80% of their area within the 1 to 10 megs/sq. range of resistance. A summary of Panel 701-149 is shown in Figure 13. This may be taken as representative of

78.5 - 1.9 82.8 - 1.7 3.0 - 3.0 3.0 - 3.0	78.6 - 1.9 83.9 - 1.8 0.9 - 1.0 3.0 - 2.0	86.2 - 1.6 86.7 - 1.3 2.0 - 2.0 9.0 - 7.0	81.1 - 1.5 85.2 - 1.4 1.4 - 2.0 24.0 - 6.0	79.1 - 1.6 83.7 - 1.8 1.2 - 1.0 4.0 - 2.5	79.6 - 1.6 83.7 - 1.4 1.8 - 2.0 4.0 - 4.0
79.0 - 2.2 83.5 - 2.2	79.7 - 2.4 83.9 - 1.7 0,8 - 0.7 2.0 - 2.0	85.0 - 1.3 88.9 - 1.5 1.4 - 1.6 6.0 - 5.0	81.7 - 1.2 86.2 - 1.2 1.0 - 1.4 20.0 - 6.0	78.5 - 1.5 83.2 - 1.4 0.6 - 0.6 1.8 - 1.8	78.9 - 1.9 84.2 - 1.7
3.0 - 3.0 4.0 - 5.0	79.2 - 1.9 83.4 - 1.8 0.8 - 0.8 3.0 - 3.0	79.0 - 1.8 84.6 - 1.5 0.8 - 0.8 2.0 - 2.0	77.1 - 1.7 83.7 - 1.4 0.6 - 0.6 5.0 - 4.0	76.8 - 1.5 82.5 - 1.6 0.7 - 0.6 1.4 - 1.2	0.6 - 0.6 3.0 - 2.0
80.8 - 2.0 84.1 - 2.2 2.5 - 3.0 5.0 - 5.0	81.0 - 1.1 84.7 - 1.3 1.2 - 1.2 4.0 - 5.0	80.8 - 1.4 84.2 - 1.w 0.8 - 0.9 4.0 - 4.0	77.5 - 1.7 83.7 - 1.4 0.9 - 0.6 3.5 - 4.0	78.9 - 1.9 84.2 - 1.7 0.6 - 0.6 3.0 - 2.0	78.0 - 1.5 83.1 - 1.6 1.4 - 1.2 4.0 - 5.0

Key to Above Areas

% Transmission - % Haze - Marklad
% Transmission - % Haze - Overcoated
Resistance (megs/sq.) 1. Crosswise 2. Lengthwise - Marklad
Resistance (megs/sq.) 1. Crosswise 2. Lengthwise - Overcoated

Figure 13

Map of Panel No. 701-149

the resistance uniformity obtainable with the particular Marklading method here described. The four panels coated (Nos. 701-147 through 701-150) after the preliminary panel (701-146) had between 1.2 and 6.8 megs/sq. average resistance, between 81.9 and 83.0% average light transmission and between 1.5 and 1.9% haze.

BAFFLE SCREEN

While working with vibrated coating beds it had been observed that there was considerably more movement of the particles next to any stationary object which was inserted in the bed, such as small rods or supports, than there was in the major portion of the bed. This effect was especially strong next to the edges of such objects. Examination of small panels which had been coated in vibrating beds showed that there was a border around the panel near the edges which was much more conductive than the center of the panel, indicating that the edges of the panel had increased the motion of the bed. It seemed possible that if a large number of "edges" could be placed near the panel the activity of the bed might be increased, thus hastening the coating and possibly increasing the uniformity.

A piece of heavy, 1/8 in. mesh wire screen (hardware cloth) was mounted on a frame and was placed in a vibrating bed 1/4 inch away from a primed panel and parallel to the surface which was to be coated. Figure 11 shows a baffle screen and a small coating bed. It was found that the presence of the screen increased the coating rate by a factor of as much as 40 in extreme cases where only a light coat was applied. The coating was more uniformly applied over the surface of the panel and the coating was less directional, that is, considerably less dependent on the direction of vibration.

For example, when a 3 1/2 x 3 1/2 in. panel was coated in a vibrating bed for 10 minutes, the resistance measured in the direction of vibration was 19 megs/sq., while a panel similarly treated with a baffle screen 1/4 in. from the panel coated to 1.1 megs/sq. The resistance perpendicular to the direction of vibration was 460 megs/sq. when the baffle screen was not used and only 2.0 megs/sq. when the baffle screen was used.

Especially important in the coating of curved shapes was the fact that the presence of a baffle screen made possible the coating of panels when the direction of vibration was perpendicular to the surface of the panel. Heretofore panels had been coated with one axis of the surface parallel to the direction of vibration. When vibration had been in a direction perpendicular to the surface, coating did not occur at anything approaching a practical rate. With a baffle screen placed 1/4 in. from a panel and the panel placed in a vibrating bed perpendicular to the direction of vibration the panel coated to a resistance of 14 megs/sq. in 12 minutes.

Studies of the effect of the distance of the baffle screen from the surface which was being coated showed that the screen was effective in the range of 1/4 to 1 3/4 in. from the panel. At the greater separations within this range the accelerating effect of the screen was decreased and the uniformity of coating was increased. However, the differences were small enough to indicate that the adjustment of separation of panel and baffle screen would not be so critical as to be impractical. Later experience with curved panels confirmed this indication.

Metal lath, such as is used as a foundation in plastered walls, gave better results than did hardware cloth both in rate and in evenness of coating.

A metal lath baffle was installed in equipment for coating curved panels.

MARKLADING CURVED PANELS

It had been found that the rate of transfer of the conductive Marklad coat from the bed of impactors to the acrylic panel depends on a number of variables, among them, pressure between coating bed and panel, condition of the coating bed and the direction of vibration. A number of these variables seemed especially important in developing a method for applying a uniform Marklad coat to a complex and large form such as that of a canopy.

The rate of coating is dependent on the pressure between the coating bed and the panel. Whether this pressure is due to the depth of the bed, in a manner analagous to hydrostatic pressure, or to pressure applied mechanically to the back of the panel and through the panel to the bed, does not seem to matter.

This relation may be complicated by proximity to sources of vibration, to edges of the piece being coated or to mechanical parts of the bed container. No definite evidence of the existence of vibration nodes in the bed had been obtained but the possibility was kept in mind. In examining bed depth experimentally, it had been found that at depths of the order of 2 inches, the rate of coating was very slow. A comparatively small increase in depth caused a big increase in rate of coating, further increase in depth decreased the rate and further increase in depth then increased the rate.

As a first approach to the solution of this problem of non-uniformity due to bed depth, it was proposed that the canopy be rotated while it was being coated. Thus each area would be subjected in turn to all different bed depths and each area would receive the same total treatment. Since, in the equipment for coating canopies, vibrating beds would probably be used and since it seemed improbable that perfect uniformity in the intensity of vibration delivered to different parts of the bed or canopy could be accomplished without unreasonably complicated construction, it seemed advisable to get some quantitative idea about the relation between the rate of coating and the energy of vibration. For preliminary tests a small coating bed weighing approximately 6 lbs. was mounted on a V-15 Syntron vibrator. The energy of vibration was controlled by the Syntron control box. Panels were coated in the bed with the control set at maximum, at minimum and at a point midway between these two. At the maximum setting, the vibrator drew 1.84 amps., at the mid-point it drew 1.36 amps. and at the minimum setting 0.9 amps. With the control set at the midpoint where the vibrator drew 74% as much current as at the maximum setting, the rate of coating (Δ conductance/time) was 70%

of that at the maximum vibration, roughly proportional. But at the minimum setting which drew 49% as much current as the maximum the coating rate was only 0.3% of that at the maximum setting. These figures indicate that there is a critical energy of vibration below which practically no coating occurs. In coating canopies, it would be necessary to keep all portions of the bed in contact with the canopy vibrating above this critical point or dead spots would result. On the other hand the relation between rate of coating and energy of vibration above this critical point seemed to be such that reasonable care in the distribution of vibrational energy should result in coatings having resistances within the specified range.

A rectangular bed large enough to permit rotating a complete canopy would have to contain at least 1500 lbs. of coating material. This would present the problem of preparing large amounts of conditioned coating material and would also present a problem in effectively vibrating such a heavy bed, especially since it had been found that in a vibrating bed there is a critical energy of vibration below which coating occurs at an impractically slow rate.

It was proposed that the size of the coating bed be reduced by building a shell which would be similar in shape to a canopy and which, when joined to a canopy frame, would form a surrounding space a few inches thick which would be filled with coating material. This whole assembly, canopy, shell and coating bed would be rotated while it was being vibrated to provide uniform coating.

To test the action of thin beds, flat panels were coated in a vibrating bed which was 1/2 in. thick. Coating occurred at a practical rate.

Equipment was built which would coat curved, 1 x 3 ft. or smaller panels. This equipment consists of a steel box with a curved side conforming approximately to the shape of the curved panels which were used. A baffle screen was mounted parallel to the curved wall. The lid of this box was curved to provide an annular space for a coating bed between 1 and 2 inches in thickness. A suspension frame was built and was fitted with suitable hoists so that this box could be suspended and rotated through 360° about any axis while it was being vibrated.

Figure 14 shows the open coating box with baffle screen in place. Figure 15 shows the lid of the box with a curved panel attached.

Panels were softened on a large hot plate and molded on the curved lid of the coating box. Transverse curvature was obtained by fitting a pack of Dynel fleece to the lid. The pad was shaped so that a curve approximating an 18 in. spherical radius was obtained across the panel. After a panel was softened by heating, it was laid over this mold. Metal straps pulled the edges of the panel down to the surface of the box and held it in position until it cooled. Molded panels were then drilled for mounting in the coating equipment, wereprimed and coated.

The first exploratory 1 x 3 ft. curved panel, No. 701-224, was coated for 10 minutes with the convex side down and the top of the coating box at 30° from the horizontal.

For one half of this period, a Syntron vibrator was applied to the bottom of the box and for the other half, the vibrator was applied to one end of the box.

The box was then placed in a horizontal position and a Syntron vibrator was applied to the bottom for 5 minutes and then to each end for 5 minutes. The box was then tilted to 30° from the horizontal with the end which had been elevated during the first period now in the lower position. In this position a vibrator was applied to the bottom for 5 minutes and to the end for 5 minutes. Examination of the panel showed that the coating was thinner on the ends than in the center, so

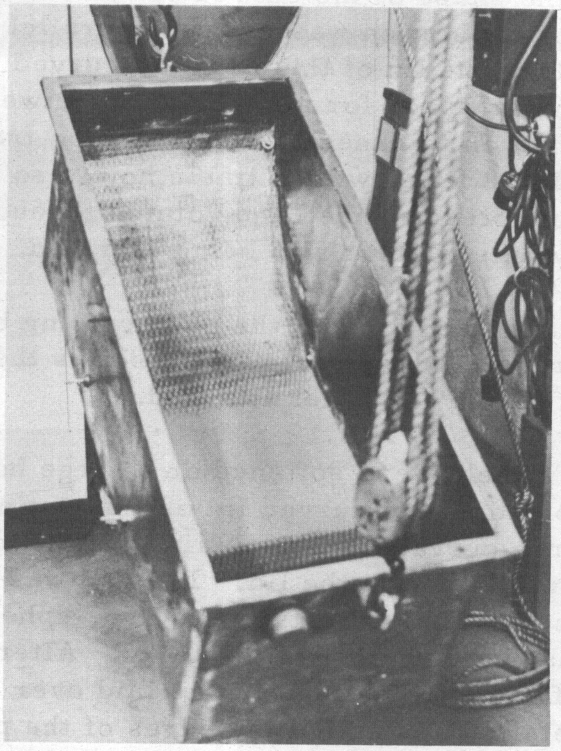


Figure 14

BOX FOR COATING CURVED PANELS

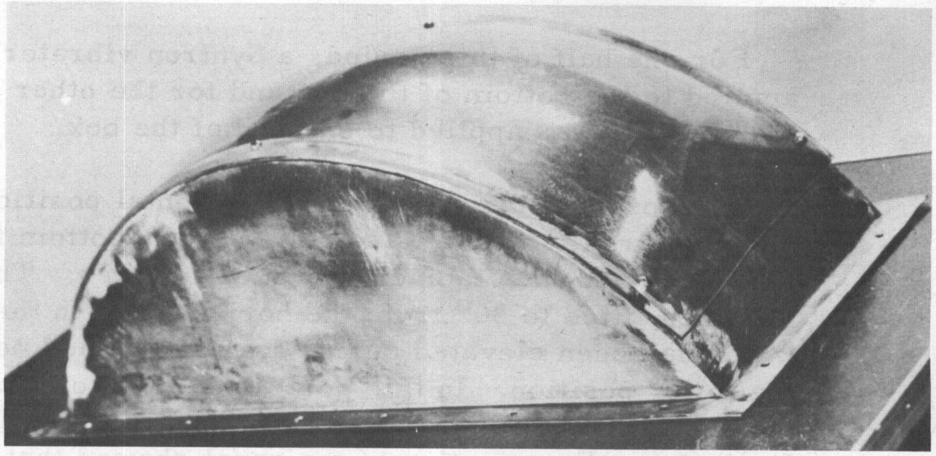


Figure 15

CURVED PANEL MOUNTED FOR COATING

the panel was returned to the box and coating was continued. Until this stage of the procedure the convex side of the panel had been on the bottom. The whole coating assembly was now turned over and held in a horizontal position, and the Syntron vibrator was applied to the upper surface of the box for 25 minutes.

The resistance of 55 areas of the panel was determined. The results showed that 93% of the areas were within the range 0.3 to 10 megs/sq. These results are shown in the map, Figure 16.

The results showed very little directional variation in resistance even though no vibration had been applied crosswise to the panel. This uniformity is probably due to the use of the baffle screen as described above.

Two more curved panels were Marklad by vibrating in a vertical direction with the vibrator applied on the outside of the coating bed at the center of the convex side of the panel and with the bed in a horizontal position. During the first half of the coating period the convex side of the panel faced down. The entire coating assembly was then turned over so that the convex side of the panel was up and vibration was continued through the second half of the coating period. This reversal of position was for the purpose of averaging out the depth effect by having the center of the panel at the greatest depth during half the time and the ends of the panel at the greatest depth during the rest of the time. Panel 701-225 was coated for 30 minutes in each position, 701-226 for 25 minutes in each position.

Resistances across the panels and lengthwise were measured in 55 areas.

Areas of Panel 701-225 showed average resistances between 0.1 and 2.1 megs/sq. with 89% of the area within the range 0.1 to 1.0 megs/sq.

Areas of Panel 701-226 showed average resistances between 0.2 and 10.2 megs/sq. with 73% of the areas within the range 0.2 to 2.0 megs/sq.

0.8 0.6	1.6 0.7	1.4 1.4	4.0 4.0	6.0 3.0
0.8 1.0	1.4 2.0	0.4 0.5	0.3 0.3	0.3 0.3
1.0 1.4	0.6 0.5	0.6 0.5	0.6 0.5	0.6 0.6
0.4 0.4	0.4 0.4	0.4 0.7	0.4 0.5	0.4 1.4
0.6 0.4	60.0 1.4	INF 8.8	0.4 0.4	0.8 1.5
3.0 1.8	INF INF	INF INF	16.0 0.5	1.6 2.0
1.0 0.7	INF 4.0	INF 2.0	0.3 0.6	1.8 1.6
0.4 0.7	20.0 3.0	20.0 1.2	0.5 0.3	0.4 0.6
1.3 4.0	1.8 4.0	1.4 4.0	0.6 1.6	1.0 1.2
6.0 3.0	40.0 20.0	120.0 40.0	8.0 4.0	2.0 1.0
0.9 0.4	0.8 0.6	0.3 0.2	0.2 0.4	0.2 0.2

← **Resistance Crosswise**
← **Resistance Lengthwise**

Figure 16

Map of Panel No. 701-224

Results for Panel 701-225 are mapped in Figure 17.

The above method of molding curved panels roughened the panel on the side next to the mold (not the side to be coated) so that the optical properties of the panel itself are poor. Molding equipment and techniques to produce panels having good optical properties would have been much more expensive and time consuming than the rough methods used. It therefore seemed advisable to disregard the optical properties at this stage.

Marklad coatings with reasonable optical and electrical properties have been applied repeatedly to flat panels. Presumably coatings which are applied to curved panels should be no poorer in optical properties.

Preliminary consideration was given to the appropriate design for equipment to Marklad canopies. This was to take the form of a conforming shell, approximately two inches larger than the acrylic canopy. Framed canopies were to be clamped into this shell against a rubber gasket and conditioned coating bed material was to be poured into the annular space between the shell and the canopy. Vibrators were to be attached to the shell and the shell was to be suspended on a frame by means of a rubber suspension which would permit vibration of the shell and canopy. This frame, carrying the shell and canopy, was to be mounted on a support which would permit rotation about the long axis of the canopy and rocking motion thru 90° on the short axis of the canopy. The purpose of rotation during coating was to even out depth effects over the canopy and thus equalize the thickness of conductive coats.

Revision of contract aims caused this work to be dropped while still in the planning stages.

0.6 0.8	0.8 2.0	0.8 2.0	1.6 2.0	1.4 4.0
0.6 0.5	0.6 0.4	0.3 0.3	0.2 0.2	0.2 0.2
0.7 0.6	0.4 0.3	0.4 0.5	0.3 0.5	0.6 0.6
0.3 0.3	0.2 0.2	0.3 0.2	0.2 0.1	0.1 0.1
1.2 1.0	0.1 0.7	0.2 0.1	0.2 0.1	0.2 0.2
0.3 0.9	0.2 0.1	0.2 0.2	0.2 0.1	0.5 0.2
1.0 1.2	0.2 1.2	0.1 0.3	0.2 0.3	1.2 0.7
0.4 0.2	0.3 0.2	0.3 0.2	0.3 0.5	0.4 0.4
0.2 0.4	0.2 0.4	0.3 0.3	0.4 0.2	0.4 0.2
0.3 0.6	0.3 0.6	0.2 0.5	0.2 0.2	0.1 0.2
0.3 0.2	0.3 0.2	0.2 0.2	0.2 0.1	0.1 0.1

← **Resistance Crosswise**
← **Resistance Lengthwise**

Figure 17

Map of Panel No. 701-225 (Megs/Sq.)

RECIPROCATING BEDS

With the change in contract emphasis from canopies to large flat sheets, a reconsideration of the Marklading procedure was called for. In connection with the coating of large, complex shapes, the design of coating equipment had included features calculated to minimize directional effects in the coating bed. These included the use of two or more vibrators attached to the piece being treated and vibrating screens located close to the surface of the piece. These latter served to give a uniform bed action despite the various orientations of parts of the surface.

It seemed that with only plane surfaces to be treated, the equipment could be simplified considerably and coating accomplished with less expenditure for vibrational energy.

Prior to the inception of this contract it had been found that Marklad coatings could be applied to flat sheet by relative rectilinear motion between the bed and piece over rather large amplitudes. This observation was checked by exploratory experiments in which a 1 ft. x 3 ft. sheet was moved by hand in available coating equipment.

When these experiments yielded fairly uniformly conductive sheets, a coating device for 3 ft. x 3 1/2 ft. pieces was designed and built.

The device consisted essentially of a flat plywood tray 6 feet square and 6 inches deep mounted so as to roll on tracks. The tray was connected to a double action Mead air cylinder, Type H-18-8 (Mead Specialties Company) having a stroke of 6 inches. The tray was loaded with conditioned polystyrene beads. A sheet of acrylic plastic was hung face down in the bed on a mounting board whose edges were beveled to minimize ploughing action.

A photograph of the device with a sheet of plastic in position for Marklading is shown in Figure 18.

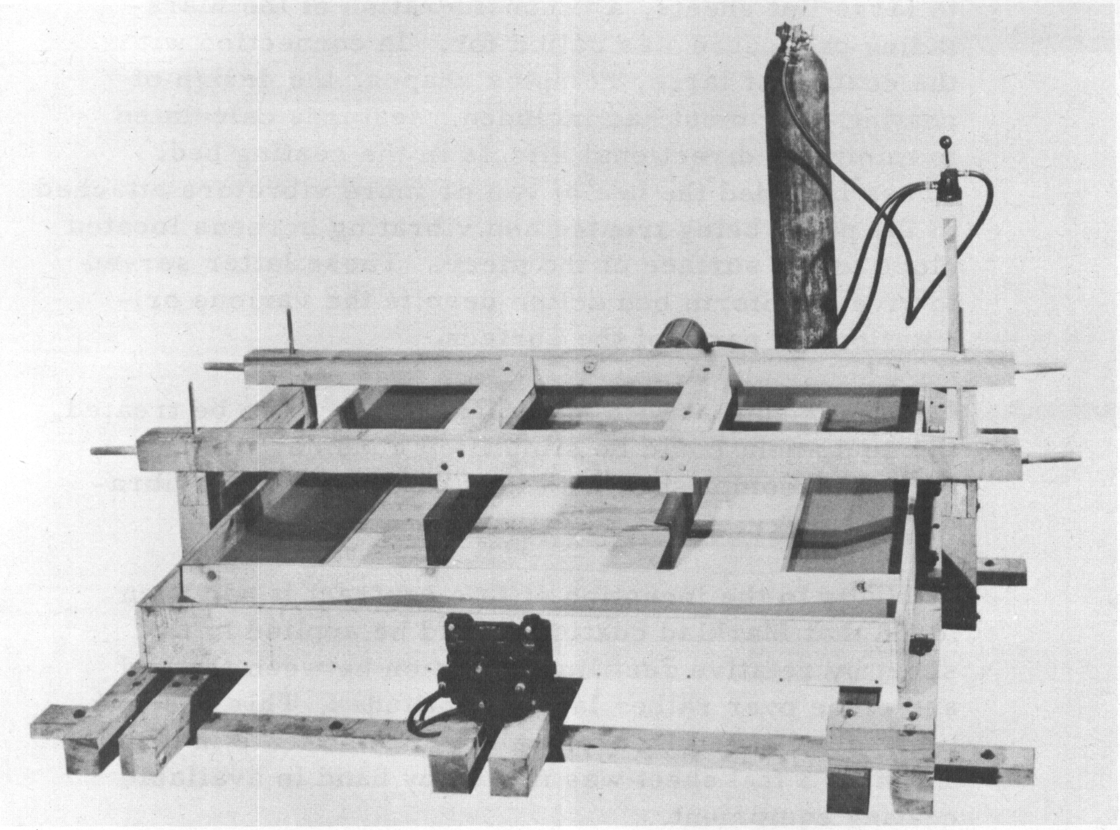


Figure 18

RECIPROCATING MARKLADING BED

To economize material in experimental runs, an acrylic plastic template was made and attached to the mounting board. This receives 11 smaller pieces of acrylic plastic which mount flush with the template and provide an indication of the degree of coating being secured in various parts of the bed.

When runs were made, about 2 1/2 inches of conditioned bed material were placed in the tray and the panel to be coated was immersed to a depth of about 1/4 to 1/2 in. The pressure to the air cylinder was adjusted so that the bed moved through a 6 inch stroke in 1 1/2 to 2 seconds. The bed was moved through a selected number of cycles, usually 20 or 25. The panel was moved through a 90° angle on the mounting board. These operations were repeated four times so that the panel was treated in each of four possible positions.

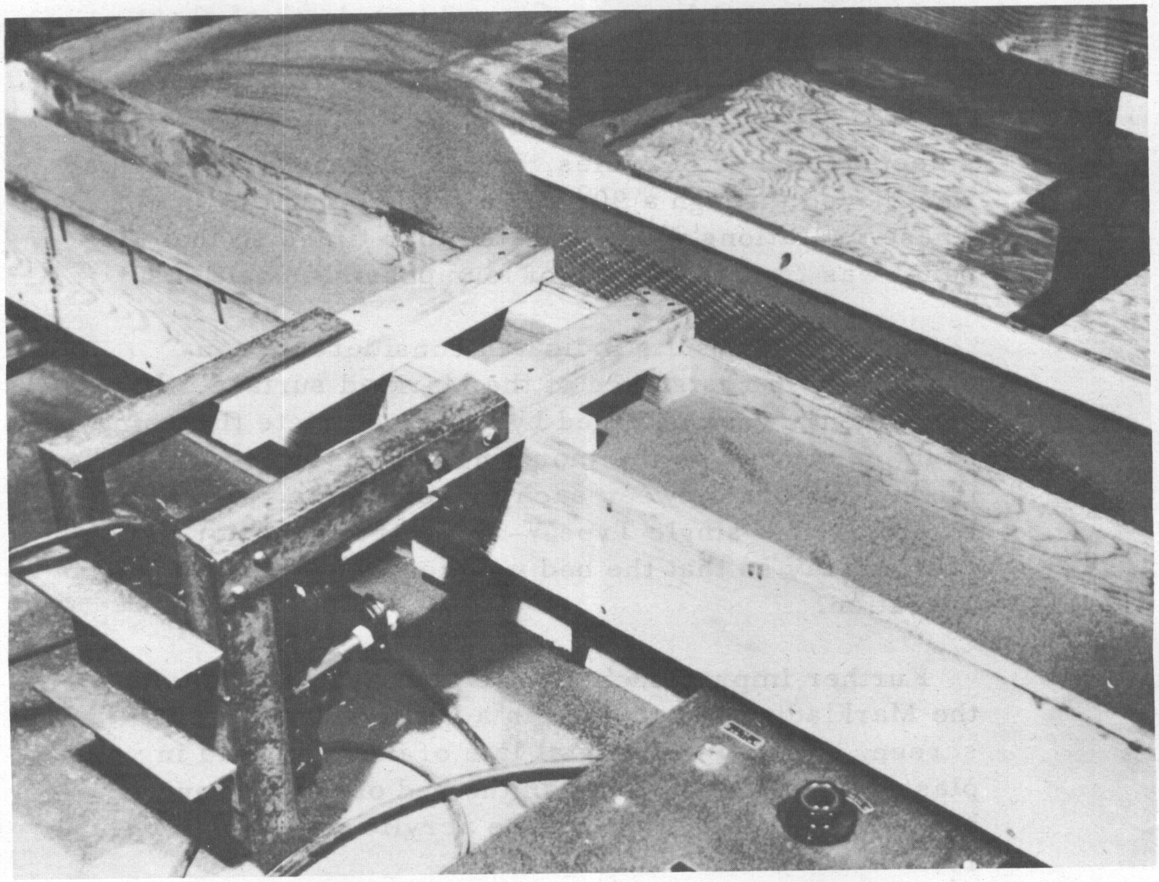
Initial test results indicated considerable non-uniformity in resistance of the Marklad surface. Improvements were obtained by more complete flattening of the test panel on the mounting board, by leveling the coating bed between each turning of the panel and by attaching a single Type V-60 Syntron vibrator to the coating tray so that the bed was kept more level during operation.

Further improvements were obtained by modifying the Marklading bed to contain a baffle screen. This screen, consisting of metal lath of the type used in plaster walls, was placed in the bed of polystyrene beads about 1/2 inch below the acrylic panel (cf., Figure 19).

An initial series of test runs was made with a Syntron vibrator rigidly attached to the stationary portion of the Marklading bed. During these runs, 3 x 12 x 1/4 in. panels were distributed over a larger template. The vibrator transmitted motion to a 4 x 4 ft. screen by means of a 1 inch shaft extending from the vibrator to the screen through a cloth seal in the container for the bed. In this set up there was no gross movement of the screen in relation to the panel; there was, however, a six inch motion of the bed relative to the screen. The

Figure 19

BAFFLE SCREEN IN RECIPROCATING
MARKLADING BED

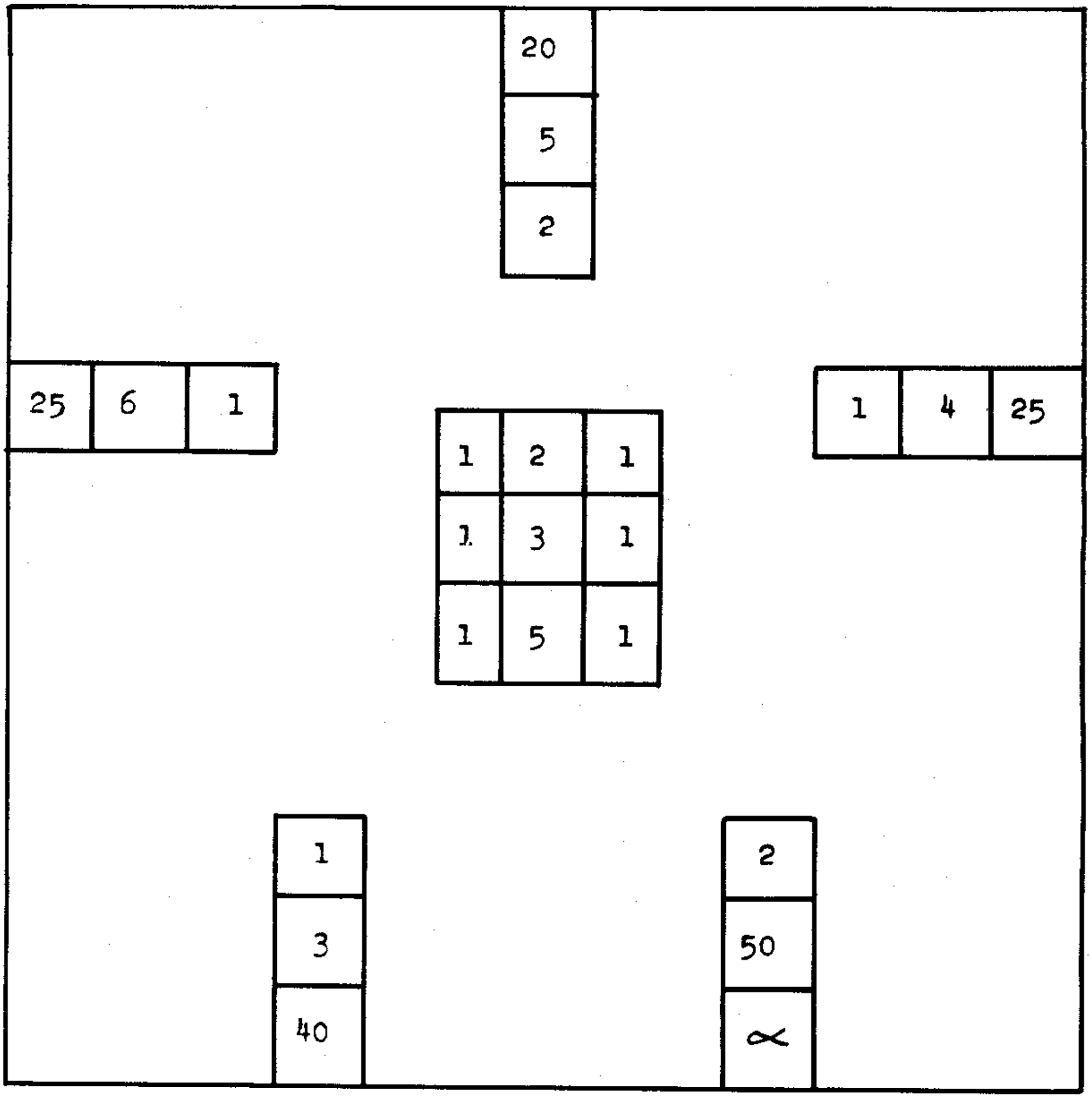


combination of a fixed screen and a moving bed caused the polystyrene beads to be "snow plowed" up on the forward stroke and to fall away from the edge of the acrylic panel holder on the return stroke. This action prevented the ends of the panel perpendicular to the direction of motion from being clad; therefore this procedure was abandoned.

The set-up was modified so that the vibrator was mounted on the container for the moving bed (cf. Figure 19). Motion of the Syntron vibrator was transmitted to the screen by means of a 1 in. steel shaft fastened rigidly between the vibrator and the frame holding the screen. The screen consequently moved with the Marklading bed relative to the test template. At the same time the dimensions of the screen were increased to 5 x 5 ft. so that even at the extremes of the 6 in. air ram stroke the screen extended beyond the panel by 6 in. With this physical set-up several test runs employing 3 x 12 x 1/4 in. panels in the 4 x 4 ft. template were made. These panels were undercoated with Rhoplex emulsion WN-80. It was observed that twenty-five 6 in. strokes in each direction with maximum energy input to Syntron vibrator produced Marklading with resistance in the range of interest. Figure 20 shows a map of the resistance distribution of a typical test run on a four foot panel (Panel 701-802B) made under these conditions.

It had been the practice to rotate the template through 90° at equal intervals during the Marklading in order to minimize directional effects in the bed. It had also been observed earlier that a decrease in resistance (and presumably deposition of conductive material) took place more rapidly as Marklading proceeded. It was therefore believed that if the template were rotated 90° more frequently as the Marklading progressed, a more uniform conductive coating would be obtained. This presumption is confirmed by a comparison of Figures 20 and 21. A panel which took 100 strokes to clad at 25 strokes per rotation was found to be somewhat

Resistance in Megohms per square

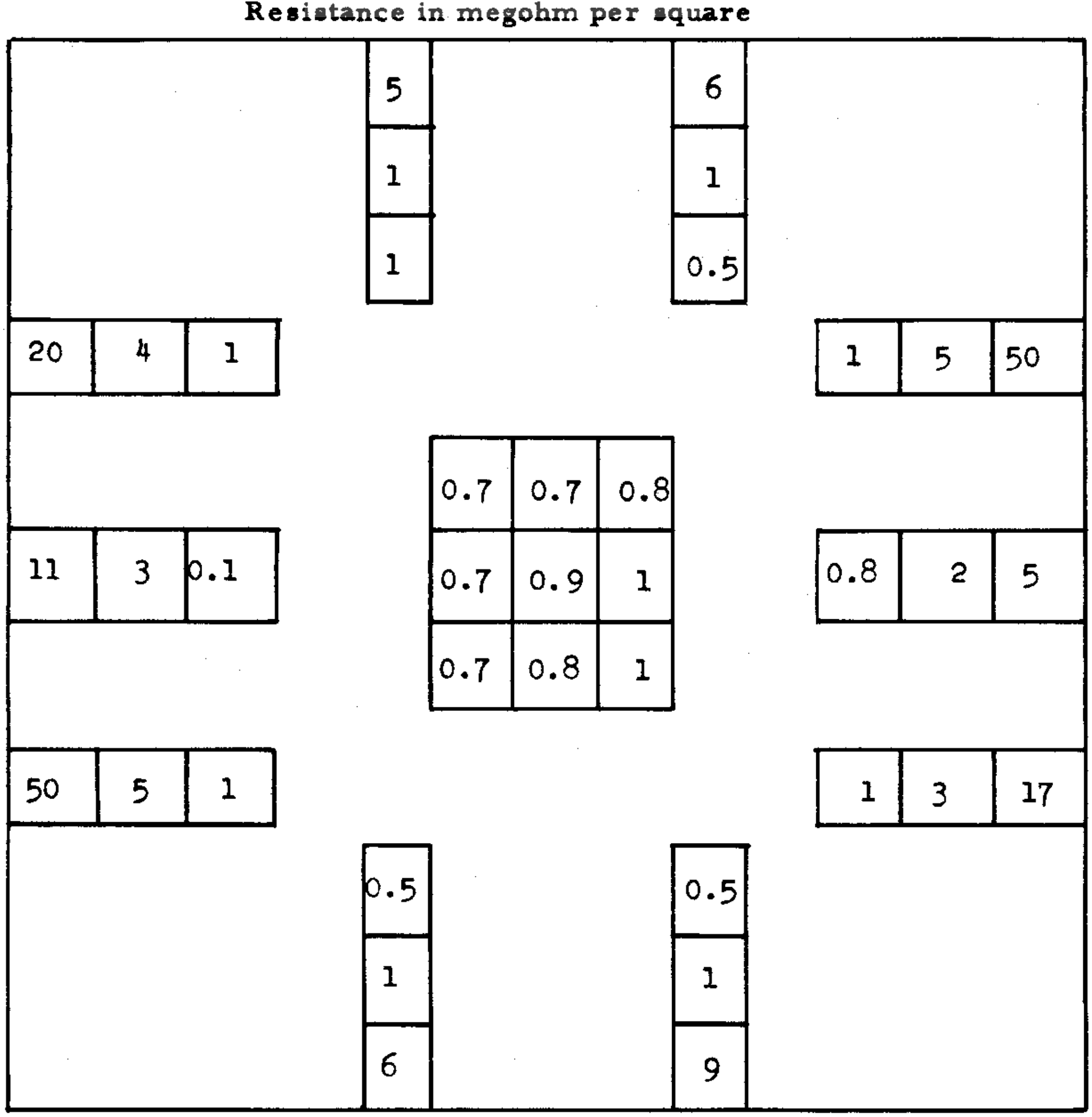


Conditions:

1. Cylinder air pressure, 30 psi.
2. Stroking schedule: 25 strokes in each of 4 directions.

Figure 20

Map of Panel No. 701-802B



Conditions:

1. Cylinder air pressure, 30 psi.
2. Stroking schedule:
    - a. 15 strokes in each of 4 directions.
    - b. 7 strokes in each of 4 directions.
    - c. 3 strokes in each of 4 directions.

Figure 21

Map of Panel No. 701-806

less uniform than panels done according to the following schedule (cf. Figure 21):

a) 15 strokes in each of 4 possible positions, or 60 strokes;

b) 7 ~~strokes~~ in each of 4 possible positions, or 28 strokes;

c) 3 strokes in each of 4 possible positions, or 12 strokes;

Total, 100 strokes.

The air pressure on the stroking air cylinder was reduced on the next series of runs from 30 psi to 6 psi. By so doing the time for 100 strokes and therefore the amount of vibrational Marklading received by a panel was increased. This increase in the proportion of low amplitude to high amplitude oscillation appeared to yield slightly more even Marklading.

Several large panels (4 ft. x 4 ft. x 1/4 in.) were Marklad as follows:

Undercoat: Rhoplex Emulsion WN-80, 20% solids.
Vibrator Setting: Maximum.
Air Pressure on 6 in. Stroke Cylinder: 6 psi.
Stroking Schedule:
a) 13 strokes in each of 4 directions, or 52 strokes;
b) 7 strokes in each of 4 directions, or 28 strokes;
c) 4 strokes in each of 4 directions, or 16 strokes;
Total, 96 strokes.

A map of the surface resistance of a typical panel is shown in Figure 22.

It should be noted that the panel, with the exception of the corners, is fairly evenly coated in the range of interest. It appears that more even Marklading on the corners of a 3 x 3 1/2 ft. panel might be obtained by increasing the size of the panel from which the 3 x 3 1/2 ft. panel is made.

Resistance in Megohms per square

∝	∝	∝	100 140	12 12	4 4	2 2	3 3	12 30	200 300	∝	∝
∝	∝	∝	20 16	3 3	1 1	0.7 0.8	0.9 1	3 3	50 50	∝	∝
2000 2000	∝	60 50	5 4	1 1	0.6 0.6	0.5 0.5	0.8 0.8	2 2	7 5	200 200	∝
100 100	50 50	3 4	1 1	0.6 0.6	0.3 0.3	0.3 0.3	0.5 0.4	0.8 0.7	2 2	10 6	350 200
10 10	2 2	1 1	0.6 0.6	0.4 0.4	0.3 0.3	0.3 0.3	0.3 0.3	0.4 0.4	0.9 0.8	5 4	40 30
4 3	1 1	0.6 0.5	0.4 0.3	0.4 0.4	0.5 0.5	0.4 0.4	0.4 0.3	0.4 0.3	0.5 0.5	1 0.8	25 13
3 2	0.9 0.8	0.4 0.3	0.2 0.2	0.3 0.3	0.6 0.7	0.5 0.5	0.4 0.3	0.5 0.4	0.9 0.8	1 0.8	20 6
9 6	1 1	0.4 0.3	0.2 0.2	0.3 0.3	0.3 0.3	0.4 0.4	0.4 0.4	0.7 0.7	2 2	3 3	30 12
86 40	3 3	0.7 0.7	0.3 0.4	0.3 0.3	0.2 0.2	0.3 0.3	0.6 0.8	0.9 1	3 3	7 7	30 30
∝	20 20	4 5	1 1	0.4 0.4	0.2 0.3	0.4 0.5	2 2	2 2	40 40	300 300	∝
∝	∝	80 50	2 3	0.4 0.5	0.4 0.5	0.8 1	4 4	15 14	200 250	∝	∝
∝	∝	∝	10 12	2 4	2 2	3 4	16 30	400 500	∝	∝	∝

4'

4'

Figure 22

Map of Panel No. 701-811

The preferred equivalent of this procedure, not involving wastage of material, is to provide a large permanent template shaped like a picture frame. The surface of this template should be flush with the surface of the panel being Marklad. As measured by comparison with small samples of known light transmission and haze it is estimated that panels made as described above and exemplified by Figure 22 have light transmission between 75 and 85% and haze between 1 and 3%. The properties of the comparison standards had been measured according to Fed. Spec. L-P-406b, Amendment 1, 25 September 1952, Method 3022.

SECTION VII

METER FACE PLATES

In many military applications it is advantageous for meter cases to have transparent plastic face plates rather than glass ones. In the case of meters which are sensitive to neighboring charges of static electricity, such as microammeters, this gives rise to serious problems. Cleaning of plastic windows, chance brushing with clothing of the operator, accumulation of charges by induction and many other incidents connected with the operation of equipment on which a meter may be a part can cause charges to appear on a plastic meter face plate. These charges can cause serious errors in the readings of the meters. Use of Marklad acrylic sheet as dial covers for sensitive meters is an answer to this problem. Questions have been raised as to the necessary conductivity of Marklad sheet for face plates, as to the necessity for Markladding both surfaces of the sheet, as to which side of the sheet should be Marklad if only one is treated and as to the necessity for grounding the face plate.

In order to make an exploratory investigation of these questions an available microammeter was selected. The instrument in question was made by Hickok Electrical Instrument Company, Cleveland, Ohio for use with a photoelectric colorimeter manufactured by E. Leitz, Inc. It has a resistance of 1380 ohms and a full scale deflection of 91 microamperes. Its rest point is at the 50 unit point of an arbitrary scale having 100 divisions.

A slot was cut in the case so that a 1/16 inch Marklad acrylic panel could be slipped between an outer, untreated acrylic plastic face plate and the meter pointer. It was found that by rubbing the face plate a few times with a cotton cloth a charge would be developed which would deflect the meter indicator through full scale. If, then, a Marklad acrylic sheet was inserted between the face plate and the movement, the meter indicator would return to its rest point immediately. This proved to be true for Marklad sheet having the following range of surface resistance:

Resistance megs/sq.	Light Transmission %	Haze %
6	85	0.6
15	85	1.0
1500	86	1.0
6000	90	1.0
15000	88	0.6

Figure 23 shows the meter movement deflected by a charge induced on the acrylic face plate. A Marklad panel is about to be inserted. It also shows the meter with its indicator returned to its rest point after insertion of the Marklad panel.

After a Marklad panel had been inserted between the face plate and instrument movement it was not found possible to deflect the movement by rubbing the face plate. When the insulator face **plate** was replaced with an acrylic face plate Marklad on its inner surface only, the movement could likewise not be deflected by rubbing the face plate. During these experiments the inserted Marklad sheets were insulated from the meter case.

Apparently grounding of the Marklad face plates is not necessary to protect a microammeter of the above indicated design against static charges generated by friction.

It is concluded that Marklad dial covers of a wide range of easily attainable resistances will protect meter movement from accumulation of localized static charges on the covers, that a single Marklad surface is adequate and that this surface will give the needed protection when it is located on the inside of the meter case away from all chance of wear or other abuse.

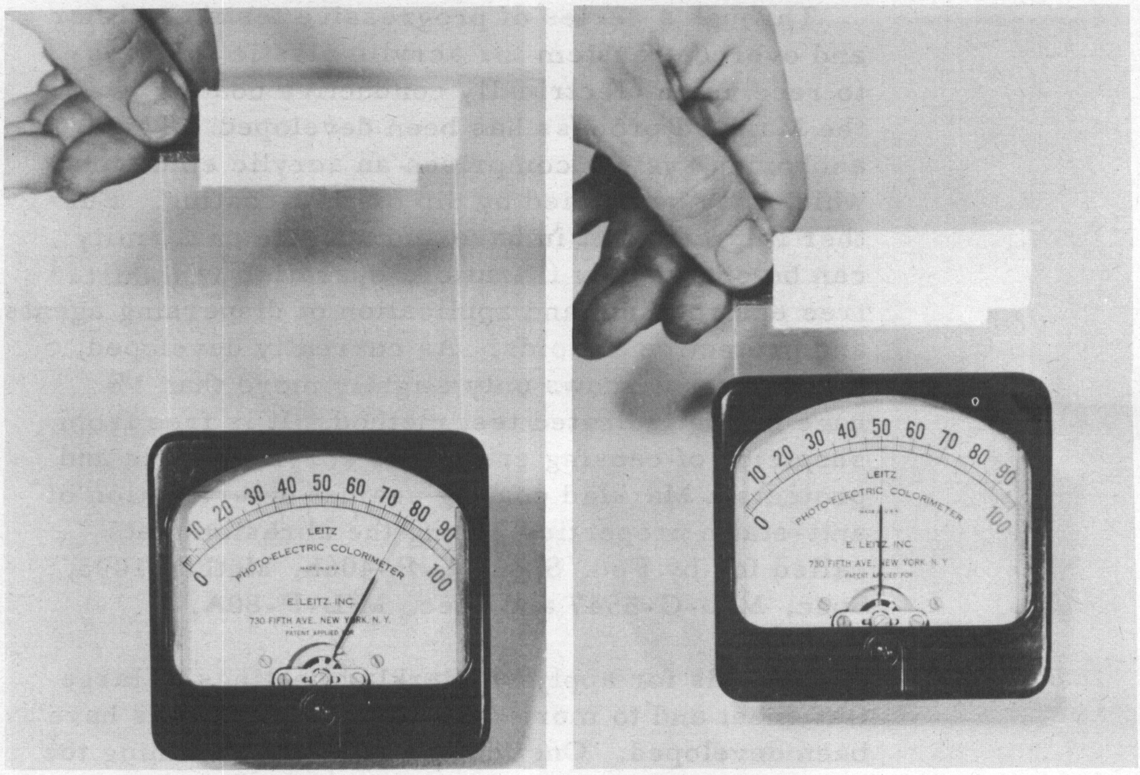


Figure 23

METER CASE PROTECTED WITH
MARKLAD PANEL

SECTION VIII

SUMMARY

Through a series of progressive tests a primer and overcoat system for acrylic plastic which is to receive an electrically conductive coating by the Marklad process has been developed. This anchoring system comprises an acrylic emulsion which may be applied by dip or flow coating. Further improvement in haze and surface uniformity can be obtained by filtration, operation in a dust-free environment and application of dispersing agents and protective colloids. As currently developed, the undercoat shows only slightly more than 1% haze by the indicated test method. It is free from suspicion of causing crazing of acrylic plastic and protects a Marklad coating against deterioration of anti-static properties during the abrasion tests called for by Fed. Spec. L-P-406b, Method 1093, Spec. MIL-C-5547 and Spec. MIL-P-80A.

Methods for applying Marklad coatings to large flat sheet and to more complex curved shapes have been developed. One method involves retaining the Marklad impactors (graphite coated polystyrene beads) in a shell shaped to conform roughly to the article being coated and spaced about one to two inches from it, and vibrating the entire assembly. This procedure is favored for complex shapes. It requires a comparatively large expenditure of vibrational energy.

Large flat sheet may be more conveniently coated by mounting on a weighted vibrating frame and resting face down on a bed of impactors or by reciprocating in a bed of impactors. The last mentioned procedure calls for the least energy consumption.

Uniformity of resistance of coatings resulting from any of the above procedures can be improved by locating a vibrating baffle consisting of such material as metal lath in the coating bed about one inch from the surface to be coated.

Sensitive meter movements are protected against external static charges or the accumulation of charges on windows by use of Marklad acrylic sheet for windows. The coated face may be turned to the inside of the case.

Flat sheets have been coated so as to have resistance in the range of 1 to 10 megohms per square, light transmission of 75 to 85% and haze of 1.0 to 2.5%. 90% of the area of 3 foot square sheet has a surface resistance encompassed within one order of magnitude. Methods for having all areas within such limits are indicated.