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NATIONAL BUREAU OF STANDARDS REPORT

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Protection of Glass and Metal Surfaces From Wind-Blown Sand

By

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and
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Report to
Materials Division
U. S. Naval Civil Engineering Research & Development Laboratory
Construction Battalion Center
Port Hueneme, California

NBS

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- Office of Basic Instrumentation
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PROTECTION OF GLASS AND METAL SURFACES FROM WIND-BLOWN SAND

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Abstract

An abrasion apparatus, employing an unsupported abrasive, is described. By using the apparatus described, 41 commercially available protective coatings for glass and metal were evaluated for their abrasion resistance. Specimens of 18 of the materials submitted were evaluated for their probable durability by exposing them to both out-door and accelerated tests. Data are also presented on the formulation, method of application, and spreading rates of a number of the coatings.

1. INTRODUCTION

In March 1952, the Department of the Navy discussed with representatives of the National Bureau of Standards two problems encountered in desert area operations. They were as follows: (1) the protection of glass and metal surfaces from the abrasive action of wind-blown sand and (2) the protection of tools and other metal objects to permit comfortable handling when they are subjected to intense heating upon exposure to direct sunlight.

The solution to the first problem, namely, the protection of glass and metal surfaces from abrasion, was the primary objective of the investigation. Of lesser importance was the reduction of the searing effect caused by solar heated tools. Consequently, the experimental work was directed toward the assembly of equipment to simulate and measure abrasion of the type encountered in desert areas, and the evaluation of coated glass panels in this equipment. Incidental to the abrasion studies were the evaluation of weathering and adhesion of the materials.

The First and Second Progress reports and this final report are confined to the abrasion problem. In regards to the solar heating problem, a theoretical analysis will be furnished in a supplementary report.

2. REVIEW OF LITERATURE

A comprehensive study was made of the abstracted literature on abrasion resistance from 1907 to 1950. The most important publications pertaining to this subject are listed in Appendix 1. A brief statement of their scope, presented categorically, follows:

2.1 Theory of Abrasion

Kuroda (1)* in discussing the mechanism of the abrasion of metals proposes the following system of classification:

I. Pure dynamic abrasion

A. Abrasion between solids

(1) Elastic abrasion
(2) Scratching abrasion

The author theorized that abrasion between solids is the result of fatigue failure. He calculated the pressure at the contact surface between two abrading bodies followed Heitz's formula. This pressure becomes quite large and as it is added to every point on the surface successively, the material receives a severe repeated load. The result is that the sustained fatigue failure causes the abrasion.

The relationship between hardness and abrasion resistance of plastics is discussed by Boor, Ryan, Marks, and Bartoe (2). The authors define the "hardness" of plastics as resistance to indentation and observed that this hardness is not necessarily a measure of mar, scratch or wear resistance.

*Figures in parenthesis indicate literature references in Appendix 1.

F. Campus, R. Dantinne, and R. Jacquemin (3) reported that a linear relationship exists between the quantity of abrasive used and the thickness of the specimen. They also observed that the base to which the coating is applied has an influence on the quantity of abrasive used. For example, the quantity of sand for the same wear is much greater for a steel base than for a bright iron base, and yet greater for a bright iron base than for a glass base. The authors also reported that if the quantity of abrasive (ordinate) is plotted as a function of film thickness (abscissa), the line (for the same base) intersects the abscissa axis at a value which can be considered as an expression of abrasion.

In a paper published in 1936, Milligan (4) demonstrated a relationship between crystallographic orientation and abrasion hardness in the case of feldspar and quartz crystals by producing impact abrasion by an accurately controlled blast of "Standard Ottawa quartz sand" (24-30 mesh, round-grain, silica-quartz sand). In his experiments with abrading grains other than quartz sand, he showed that corresponding hardness values for such hard materials as crystalline x-alumina and silicon carbide came much closer together when hard artificial abrasive grains are used for blasting.

2.2 Test Methods Utilizing Unsupported Abrasives

The results of work done by the Bell Telephone Laboratories were reported by A. E. Schuh and Z. W. Kern (5) in March 1931. The measurement of abrasion resistance of paints, varnishes and lacquers was determined by the employment of the following test method: Carborundum powder of uniform particle size was admitted at a constant rate to a directed stream of air under constant pressure. The resulting blast was allowed to impinge upon a film of the test material at a fixed angle. The abrasion resistance was evaluated in terms of the weight of carborundum required to wear through a unit thickness of the material. For the testing of paints, varnishes and lacquers, the authors observed that the following conditions of operation were well adapted:

1. Position of Test Specimen - Flush against the edge of nozzle at an angle of 45° inclination.
2. Air Pressure - 6 cm. of mercury.
3. Rate of Flow of Carborundum - 24 g per minute.
4. Particle Size - 170-200 mesh.

Spencer-Strong (6) described a method in which he employed a simple inexpensive apparatus for determining relative abrasion resistance of enamels. He obtained abrasion by fixing the specimen in the path of a stream of sand, propelled by a rapidly-revolving disc. He reports that the severity of the abrasive action is dependent upon the particle size of the abrasive.

In June 1939, the Scientific Section, National Paint, Varnish and Lacquer Assiciation, Inc., issued a circular covering an improved abrasion apparatus. Sward (7) described improvements in the operation of the falling sand abrasion apparatus and outlines an indirect method of indicating abrasion resistance by means of gloss measurements.

Marks and Conrad (8) described an abrasion tester utilizing an emery blast as the abrasive. The abrasive action was evaluated in terms of scattered light. The authors observed that the amount of light scattered was proportional to the abrading action on the specimen.

2.3 Results of Abrasion Tests by Others

In a memorandum report issued in August 1944 by Materiel Command, Army Air Forces (9), it was reported that of 15 transparent plastics tested by a modified test procedure of A.S.T.M. D673-42T, only three indicated good mar resistance. They are (1) an allyl base plastic, (2) methyl methacrylate coated with an abrasive resistant material manufactured by du Pone and (3) plate glass. The remaining materials gave results which indicated poor to fair abrasion resistance. It was further reported that in field tests (one year outdoor exposure in Mojove Desert, Blythe Field, California), not one of a variety of plastic specimens exposed showed any but minor abrasion caused by sand. However, in actual service tests (windows installed on a C-40 airplane), polished plate glass was about four times as abrasion resistant as any plastic used.

Preliminary results reported by Robertson, Libisser and Stein (10) showed that rubber-coated glass cloth laminates give complete protection when they are used for air-borne radar antenna housings flown at high speeds through rain.

After subjecting twenty-nine coatings, spun on glass, to various mar and abrasion tests, Coles, Schulz, Levy and Wheatley (11) concluded that Allymer C-39 (Columbia Chem. Div., Pittsburgh Plate Glass Co.) was most resistant to marring. An alkyd modified melamine (Strathmore Products) was second best, followed by Vibrin 1305 (Naugatuck Chem. Co.), diallyl Phtholate (Shell Development Co.) and a combination of CR-39 (Dd) and diallyl phtholate.

Marks and Conrad (8), using an emery blast method, reported that CR-39 showed the best results of some 18 plastics tested.

3. MATERIALS

3.1 Types of Coatings

The discovery of an easily applied, inexpensive material of Mohr hardness 6 or above did not seem likely at the inception of this work; consequently, the search was narrowed to organic coatings. In the hopes of discovering a film of sufficient resiliency to withstand abrasion, the types of materials employed were confined largely to organic polymers.

Two means of application of polymers were considered: a) As preformed films, in which case an adhesive would be required; and b) From solution or suspension, in which case the preparation could be sprayed, brushed, printed, or applied by immersion. Considerable practical difficulty was envisioned in the mounting of preformed films, with the result that the bulk of the work was done with fluid preparations.

3.2 Procurement and Identification of Materials

Unless otherwise indicated, materials were obtained directly from manufacturers in response to a National Bureau of Standards letter. A copy of the letter was included in the First Progress Report.

Table 1.* lists the materials, together with their manufacturers, brand names, formulation, recommended application, and code numbers. The numbers were assigned in the order of the receipt of the materials. Formulations were obtained either directly from the manufacturer or taken from the labels of the containers.

3.3 Classification of Materials

The following classification was made of the materials submitted in this investigation:

1) Transparent
2) Translucent or opaque

All materials, except NBS numbers 31 to 36 inclusive, fall in classification 1.

4. ABRASION

4.1 Test Surfaces

The test surfaces used in the abrasion tests were 5- x 2-3/4- x 1/8-in. panels of double-thickness window glass.

4.2 Preparation of Test Specimens

The coating materials were applied to the test surfaces by one of the following methods:

1) Brush application
2) Spray application
3) Dip coating employing the Fisher-Payne Dip Coater (12)

*All tables and figures are attached to this report as Appendix 2.

In the case of 17 materials, including the 6 opaque coatings, duplicate specimens were prepared by the manufacturer.

Tables 2 and 3 list the method of application as well as the thickness of the dried film for the abrasion resistance tests.

4.3 Abrasion Apparatus

The abrasion apparatus employed in the investigation consisted of three parts as follows: 1) the air supply system, 2) the abrasive supply system, and 3) the specimen chamber. The apparatus is pictured in Figure 1.

The air, taken from a high-pressure air line, was reduced to the desired pressure by means of a valve and introduced through the pressure gauge [1] into a 1/8 in. brass tube fitted with a tee (not shown in photograph), which serves as a chamber for mixing air with the abradant. The mixture of air and abradant was then passed out through a 1/8 in. brass nozzle into the specimen chamber [2] where it impinged upon the test specimen.

The abrasive supply system consisted of a sand reservoir [3], constructed from a one-pint oil can inverted over a tee in the air line. The downstream section of this line served as a mixing chamber. The sand, thoroughly dried, was fed by gravity from the reservoir through a glass tube [4] having an orifice of approximately 1/32 in. diameter into this tee. The rubber tubing [5] extending from the air supply system to the sand reservoir equalized the pressure on both sides of the 1/32 in. orifice so that the rate of sand feed was independent of the pressure in the mixing chamber.

The specimen chamber (see Figure 2) consisted of an electrical junction box 12 x 10 x 6 in., in which the sand blast nozzle recess [6] was centrally located on the 12 x 6 in. dimension. The test specimen was mounted on a stage of a 1/8 in. brass plate on the opposite side of the test chamber and at a distance of ten inches from the sand blast nozzle recess. The specimen was masked by a rubber-coated, 1/16 in. brass plate, having an aperture [7] of one inch in diameter, which sharply defined the abrasion pattern on the test specimen. This is shown in Figures 3 and 4.

The specimen chamber was equipped with a shutter-like arrangement constructed of a rubber-coated, 1/16 in. brass plate [8], actuated by a control lever [9] located on the outside of the chamber. The exposure time of the specimen to the sand blast was accurately controlled by this arrangement.

4.4 Evaluation of Abrasion

In order to obtain a quantitative measurement of abrasion, two methods were adopted to determine the extent of attrition: 1) Haze determinations, and 2) Gloss determinations. The six opaque materials were rated by visual examination in addition to the gloss determination.

4.4.1 Haze

The fraction of the total transmitted light from a normally incident beam, which is not transmitted in a straight line, is defined as the haze of a sample. It was calculated as follows (13):

$$\text{Haze } \% = \frac{Ts}{Td + Ts} \times 100$$

where Ts = amount of light transmitted in all directions except rectilinearly

Td = amount of light transmitted in a straight line.

For the determination of the extent of haze due to abrasion on the specimen, the integrating sphere method for photometric measurements was adopted. The abraded surface was evaluated in terms of the transmitted light scattered, i.e., the amount of diffusion of the parallel light incident on the specimen.

The Pivotable-Sphere Hazemeter, manufactured by the H. A. Gardner Laboratories, Bethesda, Maryland, was used for the haze determinations.

4.4.2 Gloss

Since haze is a measurement which is dependent upon light transmission, it was necessary to employ another means of evaluation for surfaces which are translucent or opaque. The method selected was the determination of gloss which was described by Sward (7) in 1939. This method was employed also with the transparent specimens.

Gloss is defined as one thousand times the ratio of brightness of the sample when illuminated unidirectionally and viewed in the direction of the specular reflection less the brightness of the sample when illuminated in the same direction and viewed normally, to the brightness of the ideal, completely reflecting, perfect mirror, similarly illuminated and viewed in the direction of specular reflection (14).

Gloss measurements were made with a Photovolt Photoelectric Glossmeter, Model 66, manufactured by The Photovolt Corporation, using the 60° gloss attachment.

4.5 Test Conditions

The following conditions were determined experimentally to give the most uniform abrasion:

a) Abradant -- 60-100 mesh, Ottawa silica sand.
b) Rate of sand feed -- 6.9 grams per minute (gravity).
c) Air pressure -- 6 psi.
d) Distance from nozzle to specimens -- 10 inches.
e) Exposure times -- 10, 20, and 40 seconds.
f) Size of abraded area -- 1 inch in diameter.

4.6 Test Procedures for Abrasion

Duplicate test specimens of each material were prepared by methods described in Section 4.2. They were allowed to age at room temperature for a period of at least twenty days before testing. One specimen of each sample was subjected to abrasion by exposing three separate areas of each specimen to the sand blast for periods of 10, 20, and 40 seconds respectively. A control specimen, consisting of an uncoated panel of double-thickness window glass, was exposed to the blast for similar periods at the start and at the completion of each series of tests to indicate any variable present in the abrasion apparatus. Four abrasion patterns resulting from the exposure of uncoated glass for periods of 10, 20, 40, and 80 seconds, respectively, were magnified 30 times and photographed with the results shown in Figures 5 to 8. Figure 9 shows quantitatively the effect of exposure time and resulted in the decision to employ 10, 20, and 40 second exposure times as standards. By averaging the results obtained at each of the exposure times, the performance of the test specimen under optimum working conditions was rated.

The selection of 6 psi as the standard pressure was based on the findings displayed in Figure 10, in which the optimum pressure for haze readings near the center of the scale was found to lie between 6 and 8 psi. The lower value was selected because the conditions of abrasion were realized at the outset to be too rigorous for plastic materials if based indiscriminately upon the performance of glass.

Table 4 illustrates typical haze values obtained upon exposing the working standard to the selected conditions. The determinations were made at different times by different operators. The data obtained show the abrasion apparatus gives reproducible results.

After abrasion, the specimens were wiped free of loose abradant, and gloss and haze determinations were made on each of the exposed areas as well as on the unabraded portion of the surface. At a later date, duplicate specimens of each sample were subjected to the abrasion tests in order to determine the effect of aging on the specimen.

Tables 2 and 3 list method of preparation, age at test, film thickness, gloss and haze test results for each specimen.

4.7 Abrasion Results

4.7.1 Haze

The results of abrasion in terms of haze are given in Table 2. The values in the table are uncorrected for the original haze of the material, which was sufficiently low to be neglected in all but three cases.

The results are also presented graphically, for the first 19 materials submitted, in Figure 29.

Also listed in Table 2 are the comparisons of haze readings with the glass standard, whose performance was arbitrarily assigned the value of 100. Materials rated above 100 are more resistant to abrasion than the glass standard.

Figures 11 to 28, inclusive, are photomicrographs of the abraded areas of glass and typical plastic films after exposures of 10, 20 and 40 seconds duration.

4.7.2 Gloss

The results of abrasion on the transparent specimens, in terms of gloss, are described in Table 2. The original gloss of each material is taken as 100 and each area of exposure is rated in terms of percent of original gloss retained. These results are presented graphically in Figure 30.

Ratings comparing each transparent material to the standard were made as described in Section 4.7.1 above.

No standard was employed in rating the opaque coatings. The ratings were made both in terms of gloss and by visual inspection. A rating of 1 indicates the best performance to abrasion resistance. The ratings are presented in Table 2.

5. WEATHERING

5.1 Outdoor Exposure Tests

5.1.1 Test Surfaces

The test surfaces employed in outdoor exposure tests were 6 x 2-3/4 x 1/8 in. panels of double-thickness window glass.

5.1.2 Preparation of Test Specimens

The coating materials were applied as described in Section 4.2.

Table 5 lists the method of application as well as film thickness for the specimens exposed in the outdoor weathering tests.

5.1.3 Exposure Conditions

The coated specimens were exposed on elevated racks from 4 to 5 feet above the roof deck of the Industrial Building, National Bureau of Standards, Washington, D. C. The coated surfaces of the specimens faced south at an angle of inclination of approximately 45°.

5.1.4 Results of Outdoor Exposure

The results of outdoor exposure on the transparency (in terms of haze) before and after exposure, together with the time and type of initial and final failures are described in Table 5.

5.2 Accelerated Weathering Tests

5.2.1 Test Surfaces

The test surfaces used in the accelerated weathering test were similar to those described in Section 5.1.1 above.

5.2.2 Preparation of Test Specimens

The test specimens were prepared by one of the methods described in 4.2. Table 6 lists the method of application and thickness of the dried film of the specimens used in the accelerated exposure tests.

5.2.3 Exposure Conditions

The accelerated exposure tests were made in a low-intensity, enclosed carbon arc unit, "Weather-ometer, Type HVKL-X", manufactured by the Atlas Electric Devices Company, Chicago, Illinois. Only one arc lamp, centrally located, was used as a source of radiation. The power consumption of the arc was approximately 1.8 kw. per hour.

The unit was operated five days per week, 22-1/2 hours per day. Each daily run was started with a nine-minute water spray period, which was repeated every hour. The water was introduced through four spray nozzles at a line pressure of twenty pounds. The volume of water was such that the specimens were thoroughly washed by flowing water during each pass under the spray unit. The water temperature at the spray unit was approximately 77°F and was essentially metal and mineral free (total solids were less than 0.2 grains per gallon).

All piping, valves and spray jets were constructed of aluminum. The position of the test specimens was changed daily to insure uniform weathering and washing.

Specimens were exposed in duplicate for a maximum exposure period of 1000 hours.

5.2.4 Results of Exposure

Table 6 lists the haze of the original coating as well as after periods of 250, 500, 750, and 1000 hours of exposure. The table also includes the time and type of initial and final failure.

6. DISCUSSION OF RESULTS

6.1 Abrasion Resistance

A number of materials indicated either that abrasion resistance varies with the age of the set film or that reproducibility of abrasion was poor. Other materials gave virtually constant test results regardless of the time of aging. The coating that indicated the greatest change was coating No. 1, a polymerized acrylic type resin. The changes that occurred are shown in Table 7.

During the test, control specimens were abraded at intervals to demonstrate that variables were not present in the apparatus or in the test procedure.

6.1.1 Transparent Materials

The abrasion tests gave a wide range of values for the transparent materials. There was no general trend as to which resin base was the best or which formulation produced the most resistant coating. This information was not available for the majority of the materials as shown in Table 1. Coatings Nos. 1, 2, 3, 5, 14, and 40 indicated the best resistance, while coatings Nos. 7, 11, 12, 15, 17, 23, and 24 fell in the lower ranges of abrasion resistance. The remaining coatings were approximately equal to the glass standard. In the case of nine samples, Nos. 10, 12, 20, 21, 24, 25, 26, 28, and 30, sand etched completely through the coating to the glass base. It is believed that this type of failure can be attributed to the thinness of the protecting film, which was 0.001 in. or less in thickness in eight of the nine cases.

6.1.2 Opaque Materials

The opaque coatings were subjected to the abrasion test procedure, after which they were rated both by visual inspection and in terms of percentage of gloss retained after abrasion. Coating No. 36 had excellent abrasion resistance when compared to other materials tested. The abrasion pattern was barely visible to the naked eye even after 40 seconds of abrasion. Coatings Nos. 34 and 35 followed in abrasion resistance, while Nos. 31, 32, and 33 were the least resistant of the opaque coatings. Gloss determinations were not possible on coating No. 31 since its original gloss was 0.

6.2 Weathering

6.2.1 Outdoor Exposure

The following discussion is limited to coatings Nos. 1 to 19, inclusive, since samples Nos. 20 to 41, inclusive, were submitted too late for the exposure tests.

Evaluation of weatherability in terms of haze was impossible in many cases, owing to failure of the films. Instead, ratings were made in terms of initial and final failure. The former was selected as the point at which irregularities appeared in the film, which could serve as nuclei for complete removal or breakdown of the film; the latter was construed as the time at which a significant area of glass was exposed. The interpretation of what constituted a significant area was subjective in a few cases, but, in general, was not subject to serious doubt.

The materials were exposed for 80 days, during which time various criteria of failure were observed. Loss of adhesion was most common, followed in frequency by discoloration and clouding of the film. Spalling of the film was observed in a few instances.

Table 5 lists the type of failures encountered and, in general, may be taken as a log of the happenings on outdoor exposure of the films.

6.2.2 Accelerated Weathering Exposure

The following discussion is limited to coatings Nos. 1 to 19, inclusive, for reasons stated in Section 6.2.1 above.

All materials indicated initial failure in this series of tests, in periods of exposure ranging from 30 hours in the case of coating No. 17, to 600 hours for coating No. 8. Final failures were evident in 12 of the coatings while only 6 survived the maximum of 1000 hours exposure.

Loss of adhesion was the most common reason for failure, followed by discoloration and clouding of the film.

7. CONCLUSIONS

7.1 Transparent Materials

a) None of the 35 transparent materials tested was perfectly resistant to abrasion by wind-blown sand. However, a number of those tested were superior to window glass (standard), when evaluated in terms of haze and gloss.

b) Materials that were applied in thicknesses of 0.003 in. or more protected glass from abrasion by wind-blown sand.

c) A thin film of oil or glycerol applied to a glass panel reduced abrasion appreciably, especially after long periods of exposure.

7.2 Opaque Materials

a) All materials tested protected glass from abrasion by sand.

b) One coating was far superior to the other five tested as the abrasion pattern was barely evident after as much as 40 seconds abrasion.

8. RECOMMENDATIONS

8.1 Glass Surfaces

8.1.1 Permanent Type Coating

To qualify as a permanent coating, the material must possess the following requirements:

a) good weatherability
b) good adhesion
c) good transparency
d) an abrasion resistance superior to plate glass.

None of the materials tested in this study fulfils all the above requirements.

8.1.2 Semi-Permanent Type Coating

In lieu of a permanent type coating, there are a number of possibilities for protecting windshields and other glass surface from attrition by employing a semi-permanent film. In utilizing such a protecting film, the material could be removed and reapplied when it became marred or unserviceable due to abrasion, weather, etc., thus eliminating the replacement of the glass unit. Semi-permanent protection may be attained by the following methods:

1) A preformed sheet of plastic material of high abrasion resistance (vinyl, polyethylene, etc.) may be applied using a suitable adhesive. The plastic film should have a minimum thickness of 0.003 in. and should be capable of being removed easily. Materials similar to this type are available commercially for interior application to automotive glazing, for example, sun visors, anti-fog films, etc.

2) A protecting film, in solution or dispersion form, may be applied by brush or spray to a thickness of at least 0.003 in. (dry film thickness). The film should be capable of being removed easily. This can be accomplished either by the use of a solvent or by stripping of the film, depending upon the nature of the material. The latter method is preferred since it eliminates the hazard of employing a volatile solvent and provides a cleaner operation. A number of materials, or variations thereof, tested in the investigation would meet the requirements. For convenience, Table 2 classifies the materials as strippable, non-strippable or strippable with difficulty.

In general, any material used for the protection of a glass surface should be clear and transparent when applied, i.e., the haze of the combination (glass + coating) should be less than 5% and preferably less than 1%. The thickness of the film in place should be a minimum of 0.003 in. In addition, it should have a reasonable resistance to abrasion and weathering.

8.1.3 Field Expedient

In the event of an emergency, the application of a thin film of oil, glycerol, or similar substance will reduce abrasion appreciably, although it will not prevent it entirely. The disadvantages of this procedure are: 1) abrasive particles adhere to the oil, glycerol, etc., and 2) difficulty of applying to obtain good visibility.

8.2 Metal Surfaces

Metal surfaces or glass surfaces where transparency is not a requirement, may be protected by applying a coating similar to NBS No. 36, by brush or spray application, to a thickness of approximately 0.010 in.

In the event that protection is required for articles in storage, it is recommended a strippable material be used.

APPENDIX 1.

LITERATURE REFERENCES

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LITERATURE REFERENCES

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(d) Bell Labs. Record, 14, 210, (1936).

(13) 1946 Book of A.S.T.M. Standards, Part III B, p. 870.

(14) Federal Specification TT-P-141b, Method 610.1.

APPENDIX 2.

TABLES AND FIGURES

TABLE 1. MATERIALS TESTED

NBS NO.	MANUFACTURER	BRAND NAME	FORMULATION	RECOMMENDED APPLICATION	REMARKS	DATE RECEIVED
1	ROHM AND HAAS COMPANY	ACRYLOID B-72	POLYMERIZED ACRYLIC ESTER-TYPE RESIN. SOLIDS 40%. SOLVENT-TOLUOL.	SPRAY, DIP, BRUSH OR MACHINE COATING.	RECOMMEND REDUCING SOLIDS TO 20% FOR APPLICATION.	10-14-52
2	REICHHOLD CHEMICALS CO.	NO. 447 PLYOPHEN	PHENOLIC BAKING LACQUER. SOLIDS 50%. SOLVENT - METHYL ISOBUTYL KETONE.	SPRAY OR DIP, BAKE AT 325°F FOR 30-35 MINS.	RECOMMENDED FORMULA: NO. 447 PLYOPHEN - 150 LBS. BUTYL ALCOHOL - 16 LBS. BUTYL ACETATE - 16 LBS.	10-14-52
3	REICHHOLD CHEMICALS CO.	NO. 1307 BECKOSOL + NO. 3520 BECKAMINE	PURE DRYING ALKYD. NON-VOL. - 49-51%. SOLVENT - XYLOL. UREA - FORMALDEHYDE. NON-VOL. - 48-52%. SOLVENT - XYLOL-BUTANOL.	SPRAY OR DIP, BAKE AT 300°F FOR 30 MINS.	TWO COMPONENT SYSTEM. RECOMMENDED FORMULA: NO. 1307 BECKOSOL - 75 LBS. NO. 3520 BECKAMINE - 75 LBS. XYLOL - 75 LBS.	10-14-52
4	PITTSBURGH PLATE GLASS COMPANY	VD 4949-(SOL. A) + VD 4950-(SOL. B) + ML 29665 - (SPECIAL REDUCER)	TWO COMPONENT SYNTHETIC RESIN SOLUTION. RESIN NOT IDENTIFIED.	BRUSH OR SPRAY. APPLY 24 TO 36 HRS. AFTER COMPONENTS ARE MIXED.	RECOMMENDED FORMULA: 3 PARTS SOL. A. 2 PARTS SOL. B. REDUCE WITH SPECIAL REDUCER.	10-21-52
5	BETTER FINISHES & COATINGS, INC.	TRANSPARENT GREEN NO. 3198	TOTAL SOLIDS: 19.63%. VINYL COPOLYMER RESIN: 11.25%. VINYL RESIN PLASTICIZER: 7.99%. STABILIZER: .33%. PIGMENT: .06%. SOLVENTS: 54.0%. DILUENTS: 26.37%.	SPRAY	NONE	10-21-52
6	BETTER FINISHES & COATINGS, INC.	TRANSPARENT CLEAR NO. 2422	VINYL COPOLYMER RESINS: 17.62%. VINYL RESIN PLASTICIZERS: 2.38%. VOLATILE: SOLVENT - 52.8%. DILUENTS - 25.2%.	NONE RECOMMENDED.	LABEL ATTACHED TO CONTAINER STATED THAT THIS FORMULATION WAS NOT TO BE USED FOR EXTERIOR APPLICATION.	10-29-52
7	B. F. GOODRICH	NO. 0300-BF-97	NOT GIVEN.	NOT GIVEN.	NONE	11-12-52

TABLE 1. MATERIALS TESTED (CONTINUED) - 2

NBS NO.	MANUFACTURER	BRAND NAME	FORMULATION	RECOMMENDED APPLICATION	REMARKS	DATE RECEIVED
8	STONER-MUDGE INC.	CLEAR LACQUER #X9-231	VINYL COMPOSITION.	SPRAY, FILM THICKNESS 40 MILS.	SHOULD BE IN PLACE AT LEAST A WEEK BEFORE ABRASION TESTS ARE MADE.	11-17-52
9	MOBILE PAINT MFG. CO.	BLP VARNISH, ABRASION-RESISTANT, CLEAR LS 96, BATCH 96105	NOT GIVEN.	NOT GIVEN.	NONE.	11-28-52
10	MOBILE PAINT MFG. CO.	BLP VARNISH, ABRASION RESISTANT, CLEAR LS 97, BATCH 96104.	NOT GIVEN.	NOT GIVEN.	NONE.	11-28-52
11	MOBILE PAINT MFG. CO.	BLP VARNISH, ABRASION-RESISTANT, CLEAR LS98, BATCH 96106.	NOT GIVEN.	NOT GIVEN.	NONE.	11-28-52
12	KRYLON, INC. (NOTE: PURCHASED FROM FISHER SCIENTIFIC CO.)	KRYLON ACRYLIC SPRAY.	ACRYLIC RESIN.	SPRAY.	NONE.	11-28-52
13	NAUGATUCK CHEMICAL CO.	KOTOL 7210-C-1, CONTROL A-3417.	NOT GIVEN.	NOT GIVEN.	NONE.	12-2-52
14	MINNESOTA MINING & MFG. COMPANY.	EXP 2864-22, LOT 1124.	NOT GIVEN.	NOT GIVEN.	NONE.	12-4-52
15	DO.	EXP 2864-12, LOT 1022.	NOT GIVEN.	NOT GIVEN.	NONE.	12-4-52
16	PROCURED AT NBS STOREROOM.	SODIUM SILICATE	-----------	NOT GIVEN.	NOT SUITABLE AS COATING FOR GLASS.	12-11-52
17	DO.	DU PONT DUCO CEMENT.	CELLULOSE ACETATE.	NOT GIVEN.	DISSOLVED IN METHYL ETHYL KETONE.	12-11-52
18	DO.	SARAN LATEX.	NOT GIVEN.	NOT GIVEN.	NONE.	1-28-53
19	WILBUR & WILLIAMS COMPANY.	SHATTERBOND.	NOT GIVEN.	BRUSH, SPRAY, OR DIP.	NONE.	2-10-53
20	MINNESOTA MINING & MFG. COMPANY.	286412-B	NOT GIVEN.	NOT GIVEN.	NONE.	2-11-53
21	DO.	286416	NOT GIVEN.	NOT GIVEN.	NONE.	2-11-53
22	DO.	259639-D	NOT GIVEN.	NOT GIVEN.	NONE	2-11-53

TABLE 1. MATERIALS TESTED (CONTINUED) - 3

NBS NO.	MANUFACTURER	BRAND NAME	FORMULATION	RECOMMENDED APPLICATION	REMARKS	DATE RECEIVED
23	MINNESOTA MINING & MFG. COMPANY.	EC-880	NOT GIVEN.	NOT GIVEN.	NONE.	2-11-53
24	DO.	259618	NOT GIVEN.	NOT GIVEN.	NONE.	2-11-53
25	DO.	EC-1139	NOT GIVEN.	NOT GIVEN.	NONE.	2-17-53
26	DO.	EC-1111	NOT GIVEN.	NOT GIVEN.	NONE.	2-17-53
27	DO.	EXP-1234	NOT GIVEN.	NOT GIVEN.	NONE.	2-17-53
28	DO.	EXP-259611	NOT GIVEN.	NOT GIVEN.	NONE.	2-17-53
29	DO.	EXP-259618	NOT GIVEN.	NOT GIVEN.	NONE.	2-17-53
30	DO.	EXP-286410-B	NOT GIVEN.	NOT GIVEN.	NONE.	2-17-53
31	DO.	COROGARD #22 OVER #14 PRIME COAT.	NOT GIVEN.	NOT GIVEN.	OPAQUE COATING.	2-17-53
32	DO.	COROGARD #14	NOT GIVEN.	NOT GIVEN.	OPAQUE COATING.	2-17-53
33	DO.	EXP-287127-A	NOT GIVEN.	NOT GIVEN.	OPAQUE COATING.	2-17-53
34	DO.	EXP-259624 OVER COROGARD #14	NOT GIVEN.	NOT GIVEN.	OPAQUE COATING.	2-17-53
35	DO.	EXP-287129-B	NOT GIVEN.	NOT GIVEN.	OPAQUE COATING.	2-17-53
36	DO.	EXP-287116-A	NOT GIVEN.	NOT GIVEN.	OPAQUE COATING.	2-17-53
37	DO.	EXP-286422-C	NOT GIVEN.	NOT GIVEN.	TRANSPARENT.	6-2-53
38	DO.	313539-A	NOT GIVEN.	NOT GIVEN.	SOFTER VARIATION OF 286422-C.	6-2-53
39	DO.	313539-B	NOT GIVEN.	NOT GIVEN.	SOFTER VARIATION OF 286422-C.	6-2-53
40	DO.	313540	NOT GIVEN.	NOT GIVEN.	TRANSPARENT.	6-2-53
41	DO.	71946	NOT GIVEN.	NOT GIVEN.	TRANSPARENT	6-2-53

TABLE 2. ABRASION AND TESTING OF TRANSPARENT COATINGS

NBS NO.	SPEC. NO.	METHOD OF APPLICATION	THICK., IN.	ADHESION[1]	AGE AT TEST, DAYS	HAZE, PER CENT[2] 0 SEC.	10 SEC.	20 SEC.	40 SEC.	RATING COMPARED TO GLASS[3]	GLOSS RETAINED, PER CENT 0 SEC.	10 SEC.	20 SEC.	40 SEC.	RATING COMPARED TO GLASS[3]
	GLASS	----	--	--	--	0.3	20.5	41.2	71.8	100	100	58	33	12	100
1	S-1	DIP	0.003	NS	42	1.3	23.0	34.7	67.6	100	100	56	37	11	100
	S-3	DIP	0.003	NS	40	0.8	21.0	39.1	66.6	100	100	56	33	11	100
	S-2	DIP	0.003	NS	57	2.1	11.9	21.5	38.8	180	100	73	52	29	180
	S-4	DIP	0.003	NS	55	0.8	11.1	19.8	39.2	190	100	72	52	28	170
2	S-93	SPRAY	0.001	NS	21	0.7	21.5	38.3	63.3	110	100	58	37	15	110
	S-94	SPRAY	0.001	NS	36	0.9	12.1	23.9	44.2	170	100	73	53	29	180
3	S-5	DIP	0.002	NS	40	0.8	12.7	26.0	49.1	160	100	68	46	21	140
	S-6	DIP	0.002	NS	55	0.6	8.4	17.3	33.9	230	100	75	61	36	200
4	S-14	BRUSH	0.003	NS	35	1.9	22.3	41.1	67.8	100	100	53	28	10	90
	S-15	BRUSH	0.003	NS	50	2.1	19.9	40.2	63.9	110	100	56	32	11	100
5	S-7	DIP	0.002	S	37	2.0	16.2	26.5	46.5	150	100	63	47	21	140
	S-8	DIP	0.002	S	52	1.3	16.2	24.6	47.9	150	100	64	47	20	140
6	S-9	DIP	0.002	SD	37	2.7	24.0	42.7	55.6	100	100	55	30	9	90
	S-11	DIP	0.002	SD	52	1.7	19.7	36.5	62.5	110	100	55	32	11	90
7	S-12	DIP	0.003	S	36	8.3	38.1	58.0	81.5	70	100	52	31	19	110
	S-13	DIP	0.003	S	51	7.6	38.3	58.1	80.7	70	100	49	25	11	80
8	S-16	DIP	0.003	S	34	6.0	18.5	29.4	52.8	130	100	65	48	19	140
	S-17	DIP	0.003	S	49	8.1	23.2	44.2	64.1	100	100	61	30	12	100
9	S-18	DIP	0.002	S	30	1.7	17.5	29.7	53.2	130	100	59	40	16	120
	S-19	DIP	0.002	S	45	1.4	14.1	27.9	50.8	140	100	65	41	17	130
10	S-20	DIP	0.003	NS	30	1.1	21.5	26.6[4]	64.4	[4]	100	62	38[4]	12	[4]
	S-21	DIP	0.003	NS	45	1.4	18.2	35.3	61.5	120	100	61	33	13	100
11	S-22	DIP	0.003	NS	30	3.1	36.3	60.0	83.4	70	100	41	19	6	60
	S-23	DIP	0.003	NS	45	9.2	36.9	56.4	78.5	70	100	56	24	8	80
12	S-24	SPRAY	0.001	NS	21	2.6	30.0	50.8	77.0	80	100	49	26[4]	7[4]	70
	S-25	SPRAY	0.001	NS	36	1.2	24.4	[4]	[4]	[4]	100	48	42[4]	23[4]	[4]
13	S-96	DIP	0.003	S	27	1.1	21.7	40.4	66.8	100	100	55	33	10	90
	S-97	DIP	0.003	S	42	1.3	18.3	36.5	62.6	110	100	53	28	10	90
14	S-89	DIP	0.003	S	20	3.2	14.8	25.6	44.1	150	100	65	49	24	150
	S-90	DIP	0.003	S	35	2.3	14.2	28.4	45.9	150	100	66	39	20	130

(CONTINUED ON NEXT PAGE)

TABLE 2. ABRASION AND TESTING OF TRANSPARENT COATINGS (CONTINUED) - 2

NBS NO.	SPEC. NO.	METHOD OF APPLICATION	THICK., IN.	ADHESION[1]	AGE AT TEST, DAYS	HAZE, PER CENT[2] 0 SEC.	10 SEC.	20 SEC.	40 SEC.	RATING COMPARED TO GLASS[3]	GLOSS RETAINED, PER CENT 0 SEC.	10 SEC.	20 SEC.	40 SEC.	RATING COMPARED TO GLASS[3]
15	S-87	BRUSH	0.001	NS	19	2.7	28.5	47.9	71.5	90	100	48	24	9	80
	S-88	BRUSH	0.001	NS	19	2.7	26.3	46.1	71.8	90	100	52	27	10	80
17	S-27	DIP	0.002	SD	6	2.2	27.3	63.1	77.7	80	100	52	26	8	80
	S-28	DIP	0.002	SD	6	1.8	31.1	54.2	79.2	80	100	46	23	7	70
18	S-180	BRUSH	0.001	NS	42	22.2	34.0	47.7	66.8	80	100	46	28	14	90
	S-181	BRUSH	0.001	NS	54	4.7	19.1	34.6	57.1	120					
	S-29	DIP	0.002	NS	34	31.2	47.8	66.1	80.9	60	100	48	19	10	70
	S-30	DIP	0.002	NS	46	35.4	45.6	64.9	81.9	70					
19	F-10	DIP	0.002	S	13	1.5	24.6	52.9	78.5	80	100	48	24	7	
	F-11	DIP	0.002	S	22	1.2	25.3	57.7	83.8	80	100	45	22	5	
20	A	BRUSH OR	0.0005	NS		8.2	33.8[4]	38.4[4]	36.2[4]	[4]	100	47[4]	25[4]	39[4]	[4]
	B	SPRAY	0.0009	NS		3.5	30.3	51.4	30.8[4]	[4]	100	49	29	56[4]	[4]
21	A	BRUSH OR	0.0008	S		2.8	26.6	40.7	59.5[4]	[4]	100	46	19	17[4]	[4]
	B	SPRAY	0.0008	S		4.0	20.9	40.2	58.1[4]	[4]	100	36	28	19[4]	[4]
22	A	BRUSH OR	0.0015	S		3.7	21.7	40.2	64.1	110	100	46	31	9	80
	B	SPRAY	0.0015	S		4.6	21.3	31.7	61.9	120	100	35	20	7	60
23	A	BRUSH	0.006	NS		19.7	54.0	69.2	85.0	70	100	29	16	6	50
	B	BRUSH	0.006	NS		17.1	49.8	64.8	82.5	70	100	21	11	5	40
24	A	BRUSH OR	0.0020	NS		10.5	45.5	63.6	84.3	[4]	100	31	14	5[4]	[4]
	B	SPRAY	0.0020	NS		7.1	41.4	62.1	85.6	70	100	37	18	5	40
25	A	SPRAY	0.0006	NS		4.0	[4]	[4]	[4]	[4]	100	[4]	[4]	[4]	[4]
	B	SPRAY	0.0006	NS		3.8	[4]	[4]	[4]	[4]	100	[4]	[4]	[4]	[4]
26	A	BRUSH	0.0008	NS		3.5	[4]	[4]	[4]	[4]	100	[4]	[4]	[4]	[4]
	B	BRUSH	0.0008	NS		3.2	[4]	[4]	[4]	[4]	100	[4]	[4]	[4]	[4]
27	A	SPRAY	0.0017	SD							100	51	27	9	[4]
	B	SPRAY	0.0017	SD							100	52	27	9	[4]
28	A	SPRAY OR	0.0006	NS		--	--	[4]	[4]	[4]	100	38	16[4]	21[4]	[4]
	B	BRUSH	0.0006	NS		--	--	[4]	[4]	[4]	100	39	16[4]	7[4]	[4]
29	A	SPRAY OR	0.0013	NS							100	41	18	6	60
	B	BRUSH	0.0013	NS							100	39	18	6	60

(CONTINUED ON NEXT PAGE)

TABLE 2. ABRASION AND TESTING OF TRANSPARENT COATINGS (CONTINUED) - 3

NBS NO.	SPEC. NO.	METHOD OF APPLICATION	THICK., IN.	ADHESION[1]	AGE AT TEST, DAYS	HAZE, PER CENT[2] 0 SEC.	10 SEC.	20 SEC.	40 SEC.	RATING COMPARED TO GLASS[3]	GLOSS RETAINED, PER CENT 0 SEC.	10 SEC.	20 SEC.	40 SEC.	RATING COMPARED TO GLASS[3]
30	A	SPRAY OR	0.0008	NS		--	[4]	[4]	[4]	[4]	100	[4]	[4]	[4]	[4]
	B	BRUSH	0.0008	NS		--	[4]	[4]	[4]	[4]	100	[4]	[4]	[4]	[4]
37	A	BRUSH	0.0008	S	9						100	58	39	10	100
38	A	BRUSH	0.0010	S	9						100	53	32	10	90
39	A	BRUSH	0.0007	S	9						100	49	37	11	90
40	A	BRUSH	0.0008	S	9						100	62	42	19	130
41	A	BRUSH	0.0008	S	9						100	49	27	8	80
OIL COATED PANEL											100	65	66	46	230
GLYCEROL COATED PANEL											100	84	76	74	330

[1] S = STRIPPABLE, NS = NOT STRIPPABLE, SD = STRIPPABLE WITH DIFFICULTY.

[2] TIME INDICATES LENGTH OF EXPOSURE TO SAND.

[3] AVERAGED, GLASS = 100.

[4] SAND ETCHED THROUGH COATING.

TABLE 3. ABRASION RESISTANCE OF OPAQUE COATINGS

NBS NO.	SPEC. NO.	METHOD OF APPLICATION[1]	THICKNESS IN.	ADHESION[2]	AGE AT TEST DAYS	GLOSS, % RETAINED 0	10	20	40	RATING[4] GLOSS	VISUAL
31	A	SPRAY	0.0045	NS	35	[3]	[3]	[3]	[3]	[3]	5
	B	"	0.0045	NS	35	[3]	[3]	[3]	[3]		
32	A	"	0.0010	NS	35	100	60	40	20	4	6
	B	"	0.0010	NS	35	100	60	40	20		
33	A	"	0.0100	NS	35	100	55	50	20	5	4
	B	"	0.0100	NS	35	100	59	33	18		
34	A	"	0.0018	SD	35	100	71	59	32	2	3
	B	"	0.0018	SD	35	100	63	49	35		
35	A	"	0.0030	NS	35	100	69	52	22	3	2
	B	"	0.0030	NS	35	100	64	45	18		
36	A	"	0.0120	S	35	100	89	63	41	1	1
	B	"	0.0120	S	35	100	93	67	41		

[1] ALL SPECIMENS PREPARED BY MANUFACTURER.

[2] S = STRIPPABLE. NS = NOT STRIPPABLE. SD = STRIPPABLE WITH DIFFICULTY.

[3] GLOSS DETERMINATION NOT POSSIBLE.

[4] RATING OF 1 INDICATES BEST ABRASION RESISTANCE.

TABLE 4. TYPICAL HAZE VALUES OBTAINED ON GLASS

Date Abraded	Operator	Haze 10 Sec.	% Dev.	Haze 20 Sec.	% Dev.	Haze 40 Sec.	% Dev.
12-15-52	1	21.5	2.4	40.4	3.6	74.7	2.2
"	2	22.3	6.2	44.3	5.7	73.8	1.0
"	2	21.7	3.3	43.9	4.8	76.0	5.0
1-7-53	1	19.5	7.1	39.1	6.4	70.4	3.7
"	2	21.1	0.5	41.6	0.7	73.3	0.3
1-22-53	1	21.6	2.9	43.3	3.3	71.3	2.5
"	2	19.8	5.7	40.9	2.4	72.5	0.8
2-20-53	1	20.7	0.6	41.7	0.8	71.6	2.1
Average		21.0		41.9		73.1	

TABLE 5. OUTDOOR WEATHERING OF PROTECTIVE COATINGS

NBS NO.	SPEC. NO.	PREPARATION		HAZE, PER CENT			INITIAL FAILURE		FINAL FAILURE	
		METHOD	THICK., IN.	BEFORE EXP.	AFTER EXP.	Δ HAZE	TIME, DAYS	TYPE	TIME, DAYS	TYPE
1	S-63	DIP 3 COATS	0.003	2.0	1.1	-0.9	15 72	LOST ADHESION. FLAKED OFF.		NO FINAL FAILURE.
2	S-73	SPRAY 2 COATS	0.001	0.6	---	---	15	WATER UNDER FILM.	49	FILM OFF PANEL.
3	S-62	DIP 3 COATS	0.002	1.0	---	---			15	FILM OFF PANEL.
4	S-45	BRUSH 1 COAT	0.003	1.4	1.0					NO VISIBLE CHANGE IN FILM.
5	S-54	BRUSH 1 COAT	0.002	4.5	8.6	4.1	79	LOST ADHESION IN 1 SPOT.		NO FINAL FAILURE TO DATE.
6	S-51	DIP 2 COATS	0.002	2.5	---	---	8	FILM LOOSE.	27	FILM OFF PANEL.
7	S-47	DIP 1 COAT	0.003	7.3	---	---			8	FILM OFF PANEL.
8	S-42	DIP 3 COATS	0.003	8.5	12.9	4.4				NO VISIBLE CHANGE IN FILM.
9	S-38	DIP 3 COATS	0.002	1.4	1.8	0.4	49	WATER UNDER FILM.		NO FINAL FAILURE.
10	S-35	DO.	0.003	0.8	3.4	2.6	27 72	LOST ADHESION. FLAKED OFF.		NO FINAL FAILURE.
11	S-67	DO.	0.003	3.3	---	---	27	LOST ADHESION AND FLAKED OFF.	72	1/3 OF FILM OFF.
12	S-79	SPRAY 1 COAT	0.001	0.9	2.4	1.5	27 58	SMALL PART FLAKED OFF. FILM SLIPPED OFF.		NO FINAL FAILURE.
13	S-70	DIP 3 COATS	0.003	1.5	1.4		8	FILM SLIPPED OFF PANEL.		NO FINAL FAILURE.

(CONTINUED ON NEXT PAGE)

TABLE 5. OUTDOOR WEATHERING OF PROTECTIVE COATINGS (CONTINUED) - 2

NBS NO.	SPEC. NO.	PREPARATION		HEZE, PERCENT			INITIAL FAILURE		FINAL FAILURE	
		METHOD	THICK., IN.	BEFORE EXP.	AFTER EXP.	Δ HAZE	TIME, DAYS	TYPE	TIME, DAYS	TYPE
14	S-82	DIP 6 COATS	0.003	1.6	2.1	0.5				NO VISIBLE CHANGE IN FILM.
15	S-76	DIP 7 COATS	0.001	1.5	---	---	12	1/3 FILM GONE.	50	3/4 FILM GONE.
16	NOT EXPOSED.									
17	S-104	DIP 3 COATS	0.002	1.1	---	---	22	WATER UNDER FILM.	31	FILM OFF.
18	F-25	BRUSH 1 COAT	0.001	9.3	13.1	3.8	22	FLAKED OFF.	45	STRIPPED FROM GLASS.
19	F-19	DIP 3 COATS	0.002	0.9	---	---	22		7	FILM OFF.

TABLE 6. ACCELERATED WEATHERING OF PROTECTIVE COATINGS

NBS NO.	SPEC. NO.	PREPARATION METHOD	PREPARATION THICK., IN.	HAZE, PER CENT 0 HRS.	250 HRS.	500 HRS.	750 HRS.	1000 HRS.	Δ HAZE	INITIAL FAILURE TIME, HRS.	INITIAL FAILURE TYPE	FINAL FAILURE TIME, HRS.	FINAL FAILURE TYPE
1	S-58	BRUSH 1 COAT	0.003	1.0	9.1	13.9	14.2	14.7	13.7	233 300	SMALL ERUPTIONS. SMALL BLISTERS.		
	S-64	DIP 3 COATS	0.003	0.9	6.8	11.8	13.4	13.4	12.5	233 300	SMALL ERUPTIONS. SMALL BLISTERS.		
2	S-71	SPRAY 2 COATS	0.001	0.7	7.8	--	--	--	7.1	220 308	SMALL CRACKS. LOOSENING & WASHING OFF.	472	FILM OFF.
	S-72	DO.	0.001	0.8	7.5	--	--	--	6.7	220 308	SMALL CRACKS. LOOSENING & WASHING OFF.	425	FILM OFF.
3	S-60	DIP 3 COATS	0.002	1.1	--	--	--	--	--	---		67	FILM OFF.
	S-61	DO.	0.002	0.9	--	--	--	--	--	43	LOOSE FROM GLASS.	90	FILM OFF.
	S-100	DO.	0.002	0.6	--	--	--	--	--	67	FILM LOOSE.	279	FILM OFF.
	S-101	DO.	0.002	0.5	--	--	--	--	--	67	FILM LOOSE.	279	FILM OFF.
4	S-43	BRUSH 1 COAT	0.003	1.8	1.8	3.4	5.5	7.0	5.2	233	SMALL ERUPTIONS.		
	S-44	DO.	0.003	1.5	1.6	3.4	5.8	6.9	5.4	233	SMALL ERUPTIONS.		
5	S-55	DIP 5 COATS	0.002	3.0	4.6	7.4	10.3	12.2	9.2	233	SMALL ERUPTIONS.		
	S-56	DO.	0.002	2.0	3.7	6.6	9.4	10.6	8.6	233	SMALL ERUPTIONS.		
6	S-49	BRUSH 2 COATS	0.002	2.2	10.5	--	--	--	8.3	299	BLISTERING & TURNING BROWN.	507	VERY DARK BROWN, ALMOST OPAQUE.
	S-52	DIP 2 COATS	0.002	2.4	7.7	18.8	--	--	16.4	299	SMALL BLISTERS.	507	BROWN IN COLOR & BLISTERED.
7	S-46	DIP 1 COAT	0.003	9.1	6.9	--	--	--	2.2	44	WATER UNDER FILM.	460	FILM OFF.
	S-48	DO.	0.003	8.7	9.2	12.8	--	--	4.1	117	WATER UNDER FILM.	507	FILM OFF.
8	S-39	DIP 3 COATS	0.003	7.0	9.6	13.6	22.3	24.6	17.6	600	TURNING BROWN.		
	S-40	DO.	0.003	8.6	9.4	13.8	21.0	25.5	16.9	600	TURNING BROWN.		
	S-36	DIP 3 COATS	0.002	0.8	1.2	3.7	6.0	14.8	14.0	762	LOSING ADHESION IN ONE CORNER.		
	S-37	DO.	0.002	0.6	1.2	3.2	5.9	13.5	12.9	478	LOOSE ON BOTTOM EDGE.		

(CONTINUED ON NEXT PAGE)

TABLE 6. ACCELERATED WEATHERING OF PROTECTIVE COATINGS (CONTINUED) - 2

NBS NO.	SPEC. NO.	PREPARATION METHOD	PREPARATION THICK., IN.	HAZE, PER CENT 0 HRS.	250 HRS.	500 HRS.	750 HRS.	1000 HRS.	Δ HAZE	INITIAL FAILURE TIME, HRS.	INITIAL FAILURE TYPE	FINAL FAILURE TIME, HRS.	FINAL FAILURE TYPE
10	S-33	DIP 3 COATS	0.003	0.7	1.0	3.2	3.0	--	2.3	525	LOSING ADHESION.	954	FILM 1/2 OFF.
	S-34	DO.	0.003	0.9	1.4	3.3	3.4	--	2.5	525	LOSING ADHESION.	954	FILM 1/3 OFF.
11	S-65	DO.	0.003	2.6	1.7	--	--	--	--	226	LOSING ADHESION.	526	FILM OFF.
	S-66	DO.	0.003	3.7	1.7	--	--	--	--	226	LOSING ADHESION.	526	FILM OFF.
12	S-77	SPRAY 1 COAT	0.001	0.7	5.5	10.2	11.4	12.3	11.6	220	SMALL ERUPTIONS & BLISTERS.		
	S-78	DO.	0.001	0.7	5.3	10.2	11.2	12.3	11.6	220	SMALL ERUPTIONS & BLISTERS.		
13	S-68	DIP 3 COATS	0.003	0.9	1.3	3.7	--	--	2.8	478	BROWN SPECKS.	762	DARK BROWN. ALMOST OPAQUE.
	S-69	DO.	0.003	0.9	2.7	6.0	--	--	5.1	478	BROWN SPECKS.	762	DARK BROWN. ALMOST OPAQUE.
14	S-80	DIP 6 COATS	0.003	2.6	9.2	14.3	--	--	11.7	279	SMALL ERUPTIONS & TURNING BROWN.	731	FILM OPAQUE.
	S-81	DO.	0.003	3.5	7.6	10.9	--	--	7.4	279	SMALL ERUPTIONS & TURNING BROWN.	731	
15	S-32	BRUSH 3 COATS	0.001	0.8	5.0	10.6	11.5	13.8	13.0	220	SMALL ERUPTIONS & BLISTERS.		
	S-83	DO.	0.001	1.5	6.3	10.4	11.4	--	9.9	472	BLISTERS.	853	FILM OFF.
16	NOT EXPOSED.												
17	S-102	DIP 3 COATS	0.002	1.0	1.2	--	--	--	0.2	24	LOSING ADHESION.	497	FILM OFF.
	S-103	DO.	0.002	1.1	1.3	--	--	--	0.2	24	LOSING ADHESION.	497	FILM OFF.
18	F-20	BRUSH 1 COAT	0.001	7.6	--	--	--	--	--			L1	FILM OFF.
	F-21	DO.	0.001	8.6	--	--	--	--	--			L1	FILM OFF.
	F-18	DIP 3 COATS	0.002	12.4	--	--	--	--	--			24	FILM OFF.
	F-16	DO.	0.002	15.1	5.9	--	--	--	--	141	TURNING BROWN.	452	OPAQUE & CRACKED.
19	F-12	DIP 3 COATS	0.002	0.9	--	--	--	--	--	95	ERUPTIONS & LOOSENING OF EDGES.	98	FILM OFF.
	F-28	DO.	0.002	1.0	--	--	--	--	--	95	ERUPTIONS & LOOSENING OF EDGES.	216	MOST OF FILM OFF.

TABLE 7. APPARENT EFFECT OF AGING ON ABRASION RESISTANCE OF COATING NO. 1

Specimen No.	Age at Abrasion	Haze 10 Sec.	Haze 20 Sec.	Rating Glass as 100	% Gloss Retained 10 Sec.	% Gloss Retained 20 Sec.	Rating Glass as 100
S-3	40 days	21.0	39.1	100	56	37	100
S-1	42 days	23.0	40.9	100	56	33	100
S-4	55 days	11.1	19.8	190	72	52	170
S-2	57 days	11.9	21.5	180	73	52	180

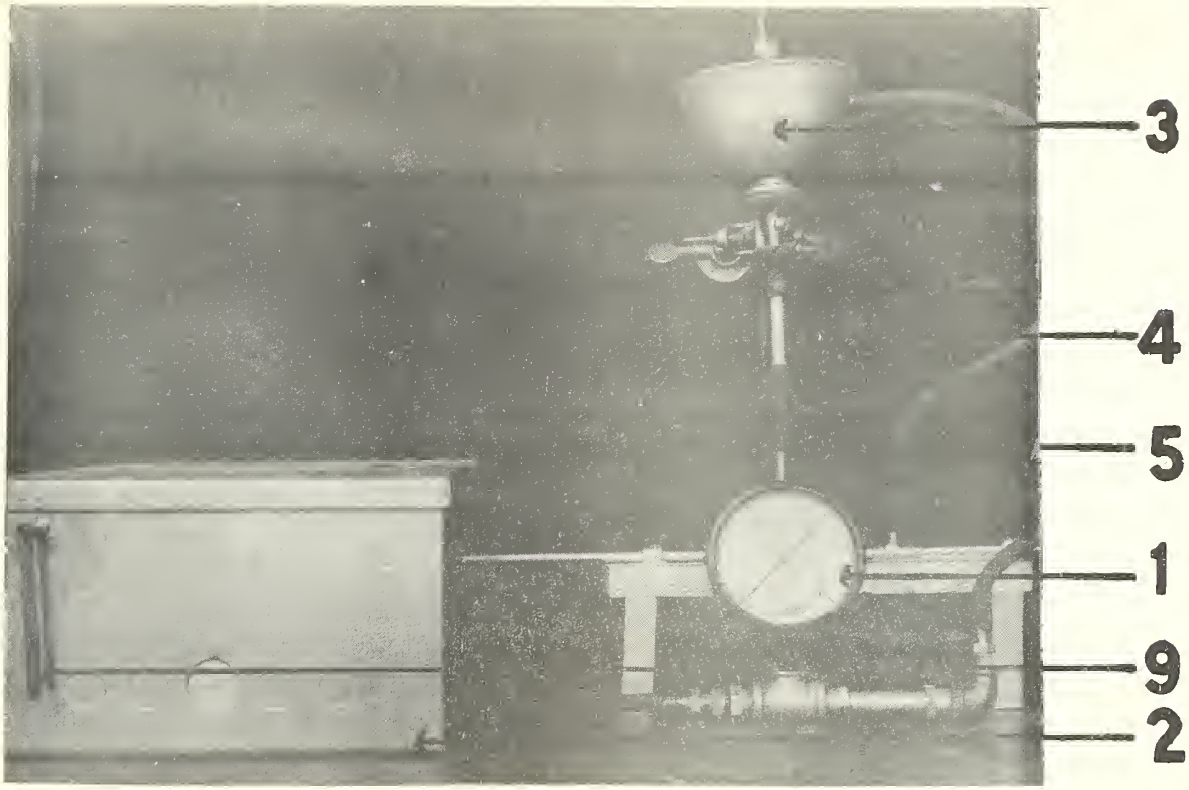

Figure 1. Abrasion Apparatus.

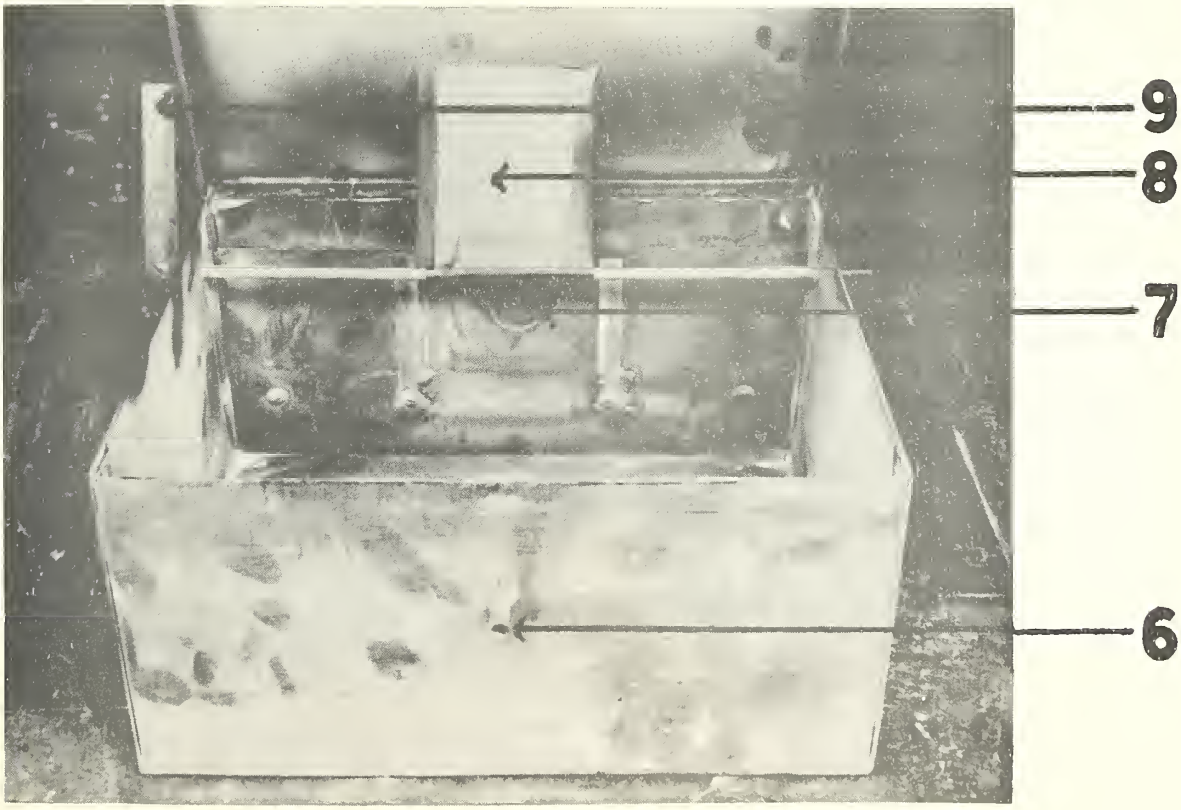

Figure 2. Specimen Chamber.

Figure 3.
Specimen Before Abrasion.

Figure 4.
Specimen After Abrasion.

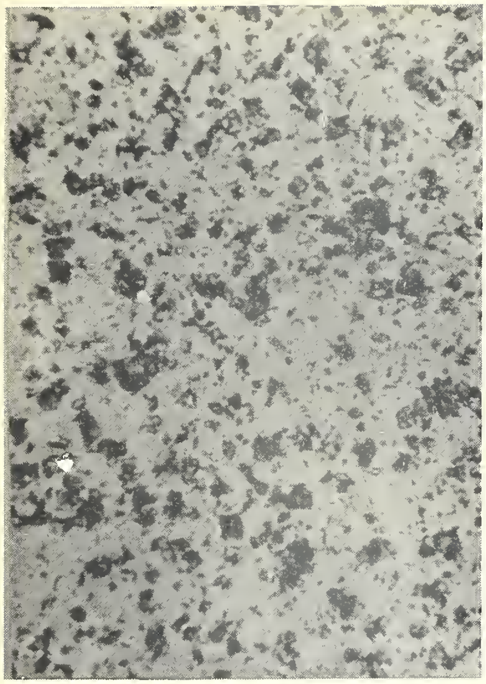

Figure 5.
10 Seconds
Haze - 21.5%

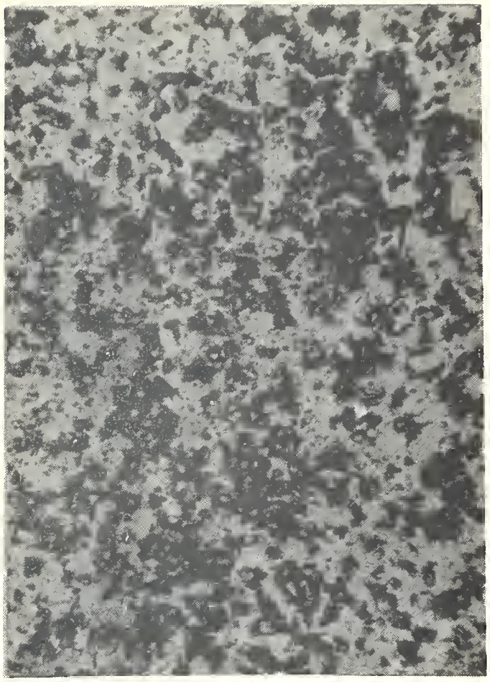

Figure 6.
20 Seconds
Haze - 40.4%

Figure 7.
40 Seconds
Haze 73.8%

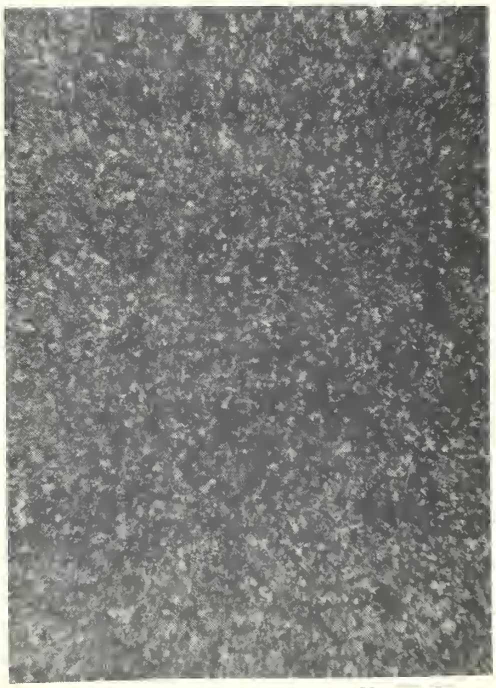

Figure 8.
80 Seconds
Haze 93.0%

Figures 5 - 8. Photomicrographs of Abrasion Patterns of Glass at 10, 20, 40, and 80 Seconds Exposure.

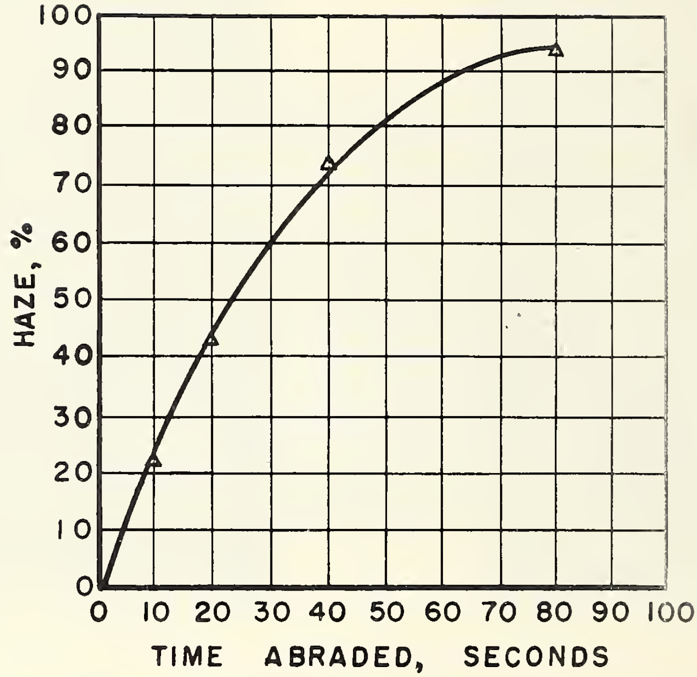

FIGURE 9. HAZE VS. EXPOSURE TIME

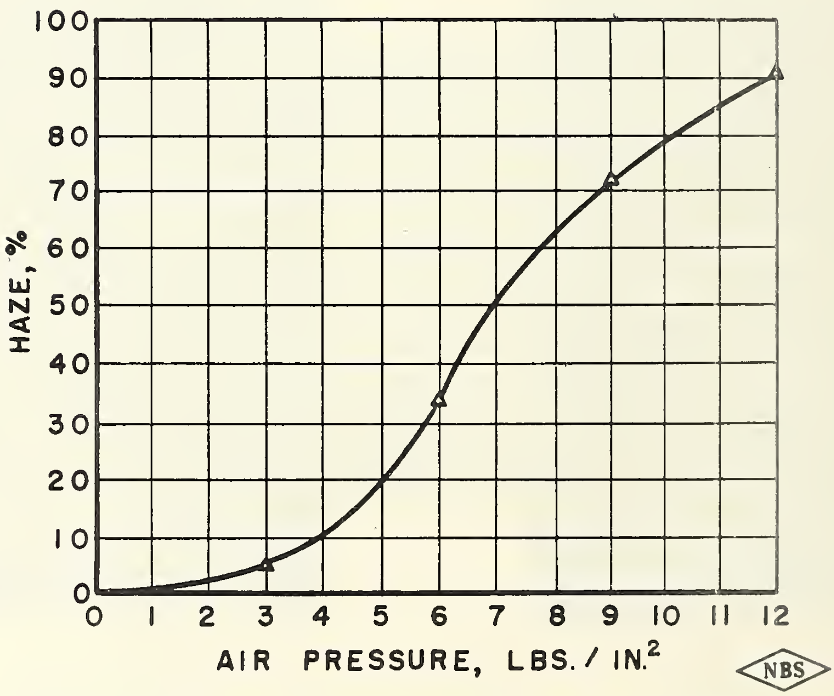

FIGURE 10. HAZE VS. AIR PRESSURE

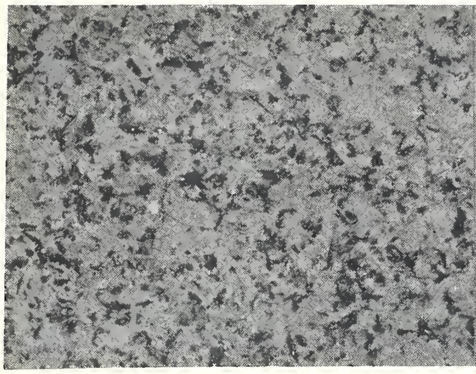

Figure 11.
Coating No. 7
Haze 38.3%

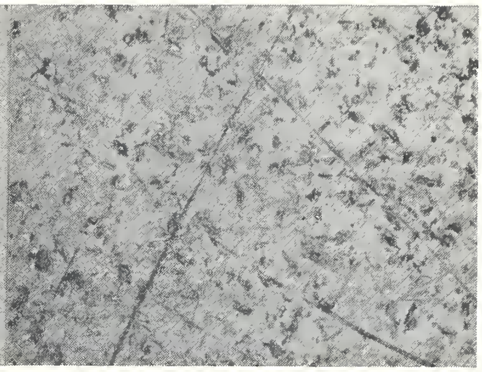

Figure 12.
Coating No. 11
Haze 36.9%

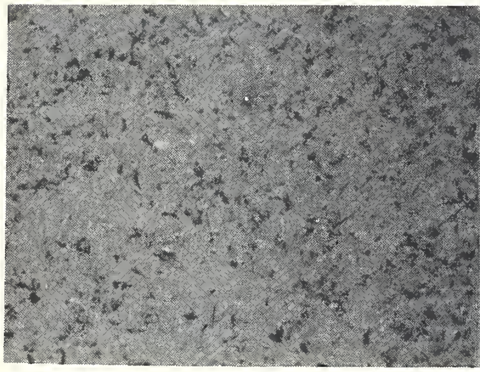

Figure 13.
Coating No. 4
Haze 22.3%

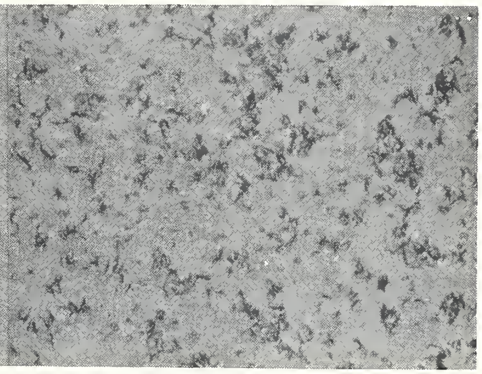

Figure 14.
Glass
Haze 19.8%

Figure 15.
Coating No. 5
Haze 16.2%

Figure 16.
Coating No. 3
Haze 12.7%

Figures 11 - 16.
Abrasion Patterns of Glass and Five Coatings at 10 Seconds Exposure.

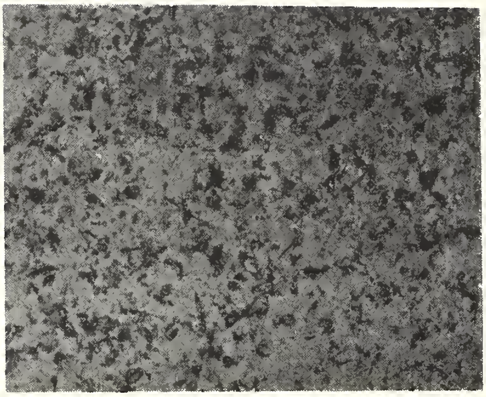

Figure 17.
Coating No. 7
Haze - 58.1%

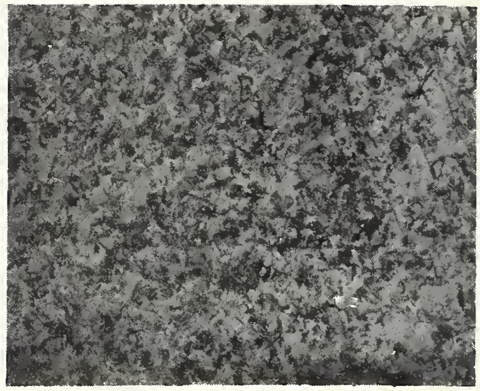

Figure 18.
Coating No. 11
Haze - 56.4%

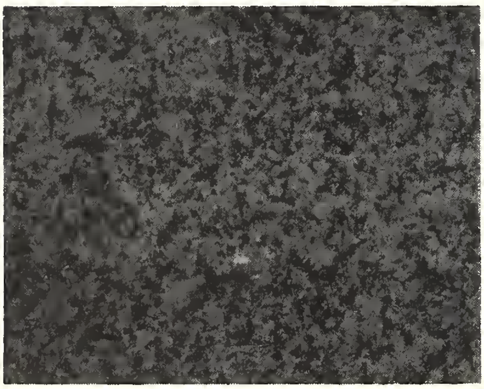

Figure 19.
Coating No. 4
Haze - 41.1%

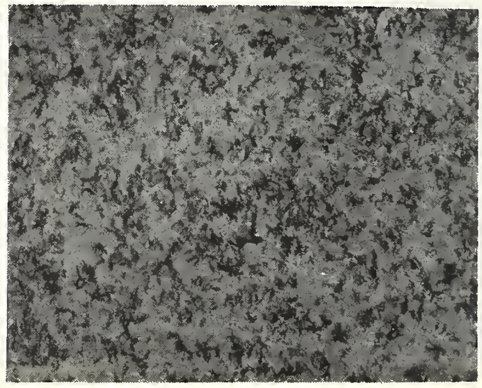

Figure 20.
Glass
Haze - 40.9%

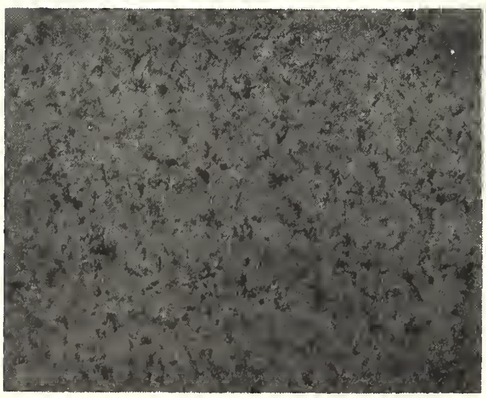

Figure 21.
Coating No. 5
Haze - 26.5%

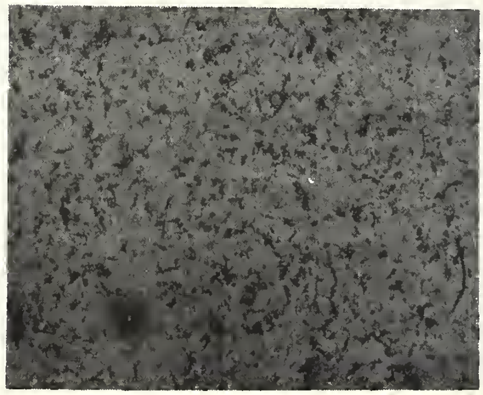

Figure 22.
Coating No. 3
Haze - 26.0%

Figures 17 - 22. Abrasion Patterns of Glass and Five Coatings at 20 Seconds Exposure.

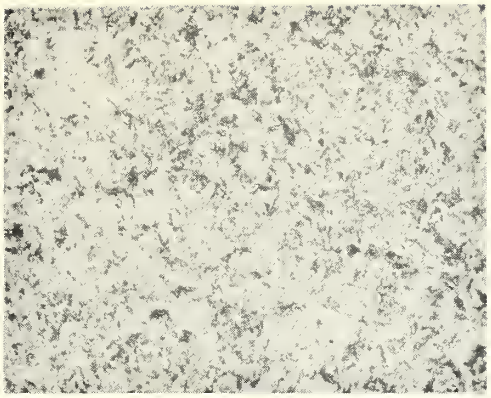

Figure 23.
Coating No. 7
Haze - 80.7%

Figure 24.
Coating No. 11
Haze - 78.5%

Figure 25.
Coating No. 4
Haze - 67.8%

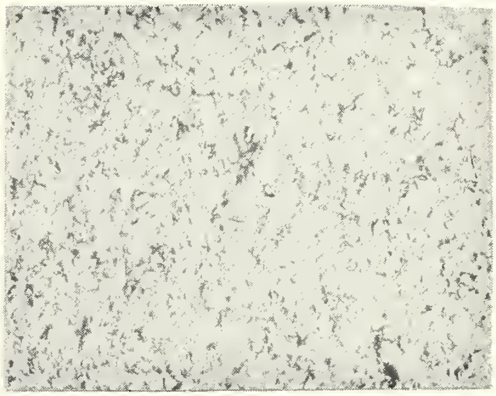

Figure 26.
Glass
Haze - 70.4%

Figure 27.
Coating No. 5
Haze - 46.5%

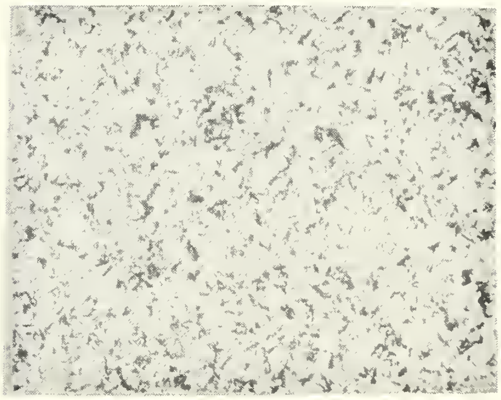

Figure 28.
Coating No. 3
Haze - 49.1%

Figures 23 - 28. Abrasion Patterns of Glass and Five Coatings at 40 Seconds Exposure.

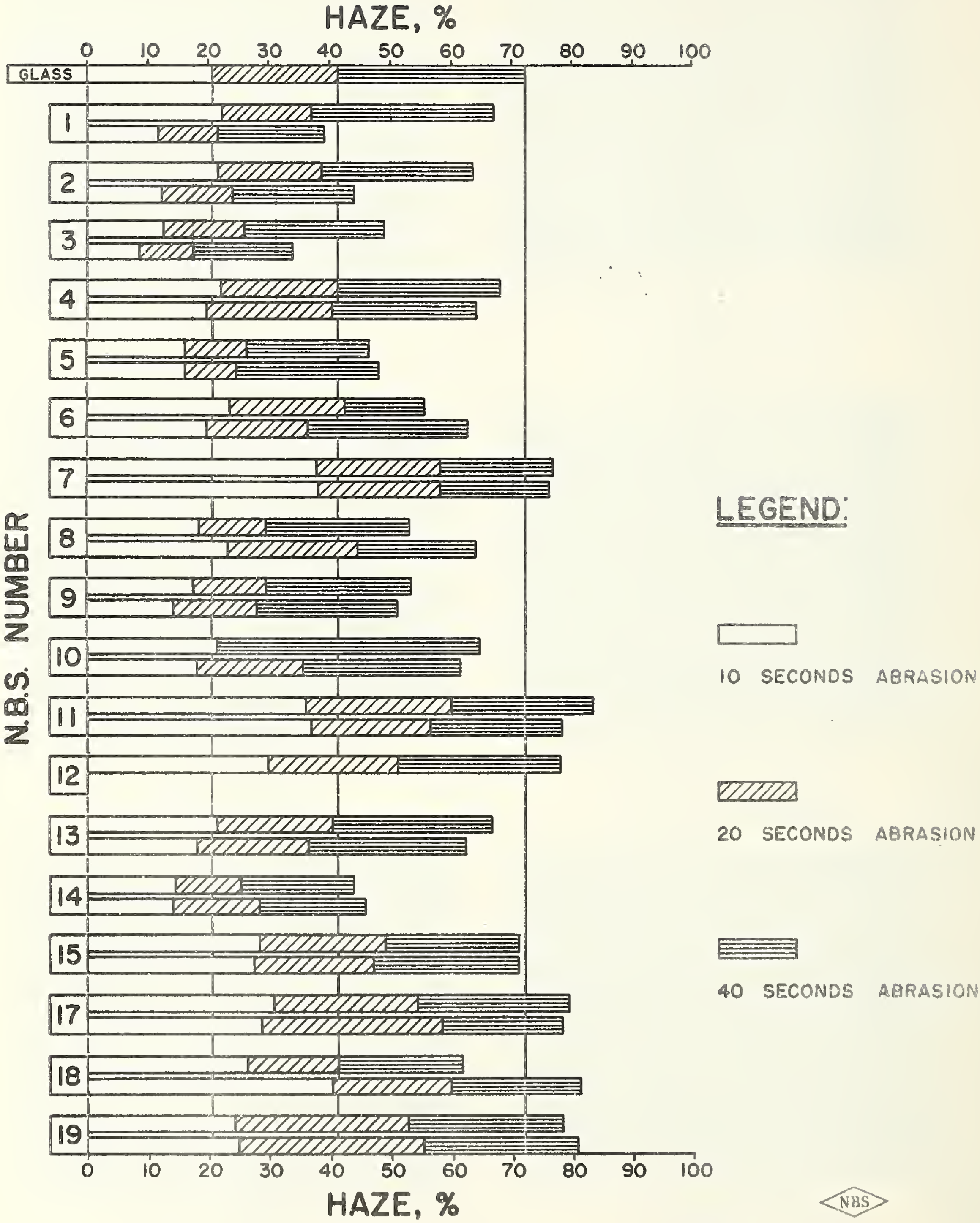

FIGURE 29. ABRASION RESISTANCE IN TERMS OF HAZE OF COATINGS COMPARED WITH DOUBLE-THICKNESS WINDOW GLASS.

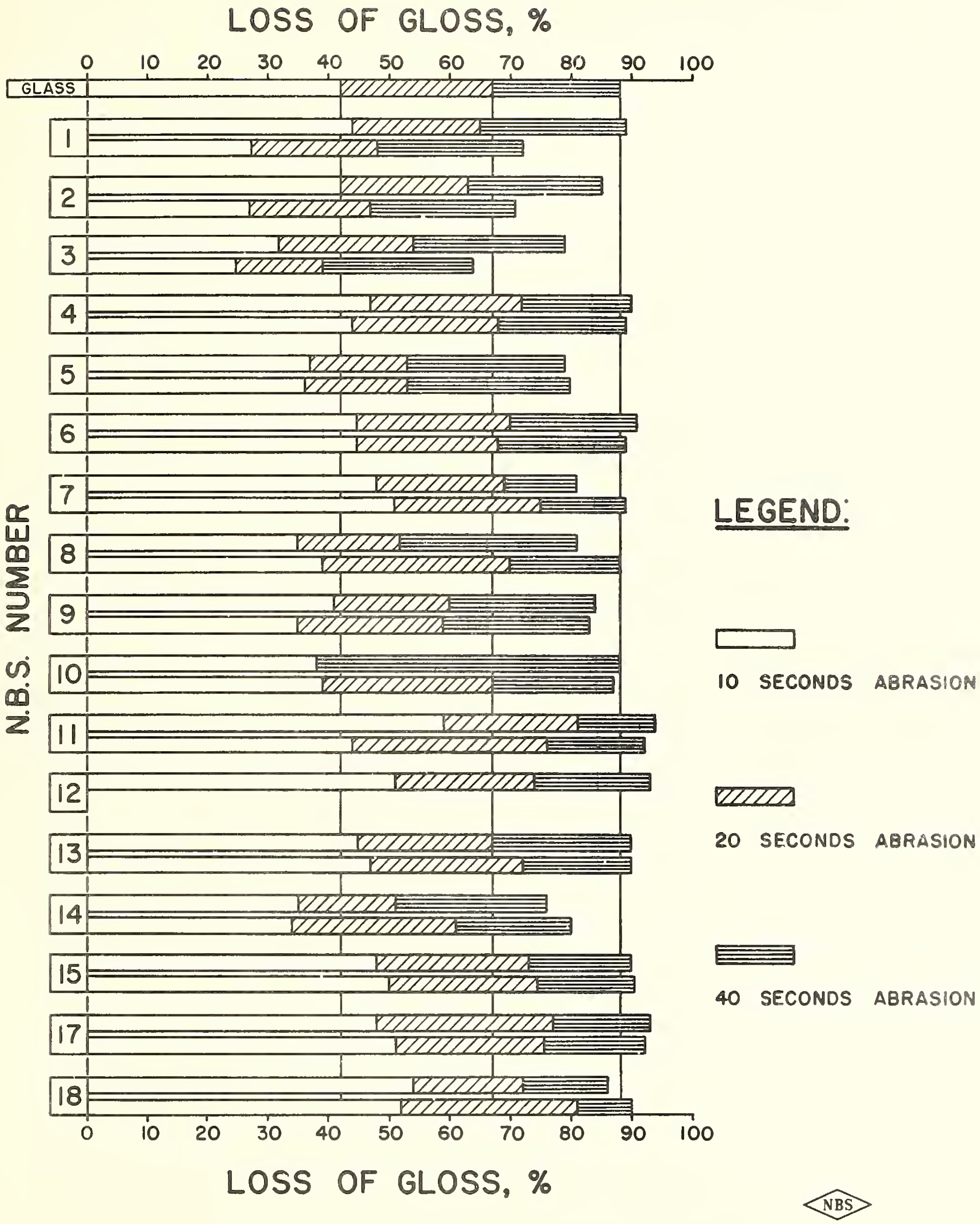

FIGURE 30. ABRASION RESISTANCE IN TERMS OF GLOSS-COATINGS COMPARED WITH DOUBLE-THICKNESS WINDOW GLASS.

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