U. S. DEPARTMENT OF COMMERCE

BUILDING MATERIALS AND STRUCTURES

REPORT BMS8

Methods of Investigation of Surface Treatment for Corrosion Protection of Steel

by ROLLA E. POLLARD
and WILBUR C. PORTER

NATIONAL
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The National Bureau of Standards is a fact-finding organization; it does not "approve" any particular material or method of construction. The technical findings in this series of reports are to be construed accordingly.

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Foreword

The Present Paper describes the methods used in an investigation now under way of surface treatments for the protection of steel for low-cost housing construction against corrosion. Accelerated laboratory corrosion tests of various pretreatment processes and paints used for steel and galvanized surfaces form an important part of the investigation. Because of wide variations in service conditions, these tests cannot be expected to produce results directly measurable in terms of years of service. However, with the limitation of each type of tests in mind and with comparisons confined to the conditions of testing, such tests form a valuable means of studying the factors affecting the protective value of paints under particular conditions. In the present investigation special attention is being given to the study of conditions affecting corrosion by condensed moisture, such as might occur in the enclosed areas between walls.

Lyman J. Briggs, *Director.*

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ABSTRACT

Some of the factors affecting the protective value of paints for steel and galvanized surfaces are being studied by accelerated laboratory corrosion tests supplemented by outdoor exposure tests. Short descriptions are given of the various methods of testing. The significance and the limitations of such tests as compared with actual service tests are briefly discussed and the materials, pretreatment processes, and paints included in the testing program are outlined. Special attention is being given to the severity of corrosion which may result from condensed moisture.

I. INTRODUCTION

As PART of a general research program on building materials, the National Bureau of Standards is conducting an investigation on the surface treatment for corrosion protection of steel used in the construction of low-cost houses.

The use of steel as a building material is not new, of course. Large amounts have been used for many years as heavy structural members in large buildings. Used in this manner, in heavy sections, covered and protected to some extent by other building materials, the deterioration of steel is not a serious problem, since small amounts of corrosion do little damage, and appearance is not a factor.

In recent years the use of light-gage sheet steel as a building material has increased considerably. Structural members fabricated from such steel are often used as joists or studs in the framework of houses of conventional construction. The so-called "prefabricated" steel house usually consists of wall, floor, ceiling, and roof sections of standard size prefabricated in the shop and joined together on the job by welding, bolting, or interlocking joints. The sections or panels may consist of a steel frame work fabricated from sheet steel and covered on either side by other materials, or may be made entirely of sheet steel or galvanized sheet in cellular units. Sheet steel also is used in considerable amounts in window frames, metal cabinets, metal furniture, and the air ducts of air-conditioning equipment. Among the newer uses of sheet steel in house construction, may be mentioned bathrooms made as a separate unit complete and ready for installation in the desired location and requiring only connections for light, water, and sewer.

When used in the form of light-gage sheet, the protection of steel is a matter requiring serious consideration. A corrosive attack that would be relatively insignificant in a heavy steel beam might perforate a light-gage sheet. In steel houses the initial protection of inaccessible surfaces such as the interior of walls, is particularly important since renewal after installation is not practicable. Condensation within walls has been greatly increased in modern houses by high humidity caused by the use of winter air-conditioning equipment. This is particularly true in colder climates where parts of insulated walls may be cooled below the temperature of the moist inside air for long periods.

II. FACTORS AFFECTING DURABILITY OF PAINT ON METAL

Painting is one of the cheapest and most widely used methods for protecting plain steel. Galvanized steel surfaces are often painted also, both for decoration and increased protection. An important part of the present investigation is a laboratory study of the factors affecting the durability of paint films on steel and galvanized surfaces under conditions somewhat similar to those which might be encountered in service.

The conditions under which house paints are expected to stand up vary considerably, not only in different localities, but also in different parts of the same house. Painted surfaces exposed outdoors, for instance, are affected by the ultraviolet rays of sunlight, moisture in the form of rain or dew, and the expansion and contraction resulting from temperature changes. These factors vary according to climatic conditions. The corrosive action of rain or dew is determined largely by the amount of impurities, such as sulfur dioxide, with which the air may be polluted. The degree of pollution varies considerably in different localities.

In the interior of a house, painted surfaces are not exposed to ultraviolet radiation, but may be subjected to rather wide variations in temperature and to corrosion by condensed moisture. Recent tests at this Bureau have demonstrated the severity of this type of corrosion on unprotected steel and even on galvanized sheet, and have served to emphasize the need for surface

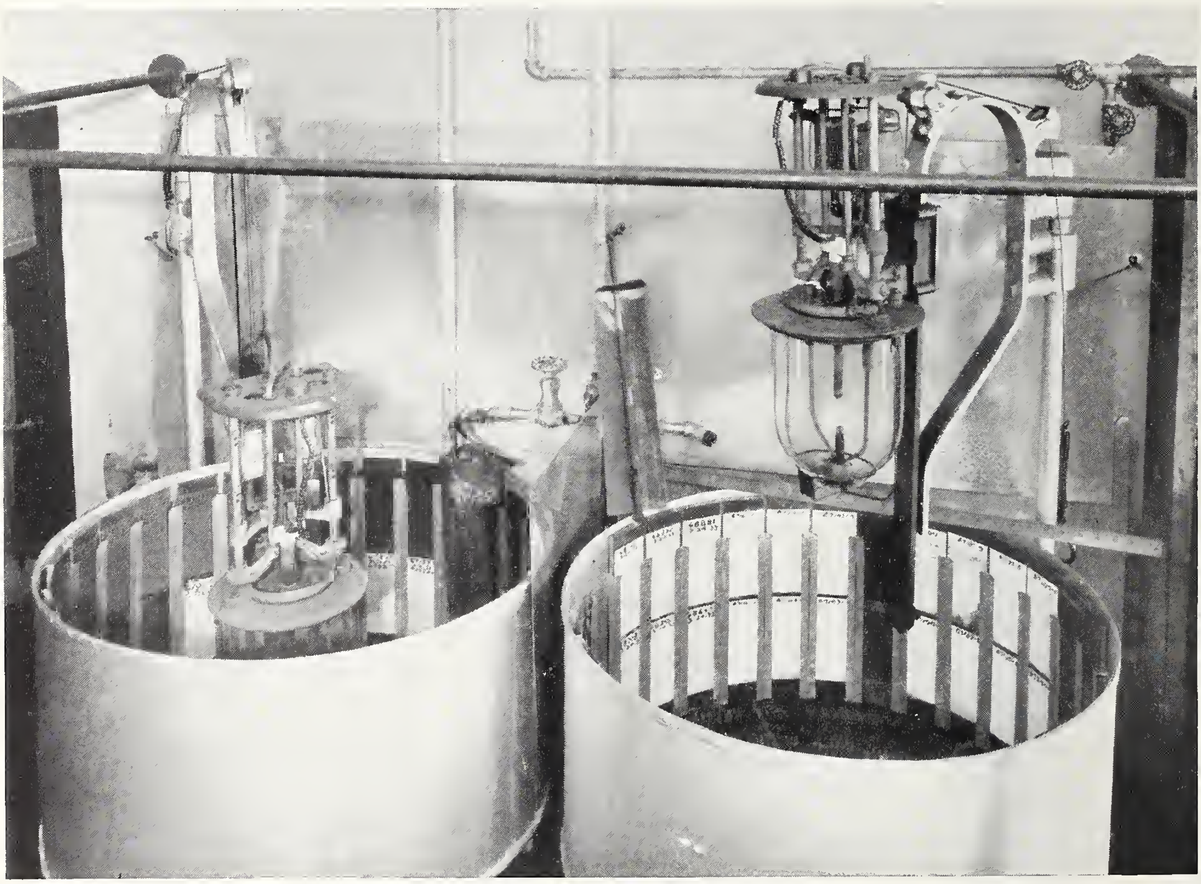


Figure 1.—*Accelerated-weathering apparatus.*

The arc lamp has been raised out of the working position in the unit at the right. The cylindrical rack, with the specimens mounted thereon, makes a complete rotation once in 20 minutes. A fixed water spray (tap water) thoroughly wets each panel once every 20 minutes while the light is continually in operation.

protection. The corrosive action of condensed moisture, like that of rain, is influenced by the impurities in the air from which it is condensed. Corrosion may also be greatly accelerated by accumulations of dust or other dirt.

III. METHODS OF TESTING

Some of the conditions mentioned can be simulated to some extent and with more or less accurate control in laboratory tests. In order to get results within a reasonable length of time, however, it is necessary to change the conditions considerably. In the accelerated weathering, for example, painted specimens are exposed alternately wet and dry to the heat and the ultraviolet light of a carbon-arc lamp. The accelerating factors of this test as compared with ordinary outdoor exposure are (a) almost constant exposure to light containing ultraviolet rays, (b) frequent wetting and drying, (c) frequent abrupt changes in temperature, and (d) high humidity.

The experience of this Bureau in conducting laboratory tests of painted metal panels extending over a period of years indicates that the accelerated-weathering test often produces within a short time corrosion effects similar to those produced by prolonged outdoor exposure. This is particularly true for conditions of exposure in which the effect of sunlight is the dominant factor in determining the life of the paint. An accelerated weathering apparatus similar to that shown in figure 1 is being extensively used in the present investigation. Two other accelerated laboratory tests in use are the moisture-condensation corrosion test and the salt-spray test.

The condensation corrosion test was designed to simulate as nearly as possible the conditions that may occur within a house, particularly in enclosed spaces such as the interior of walls. The test consists in exposing steel panels which have been painted or otherwise treated to the corrosive action of moisture condensed from a controlled atmosphere. Photographs of the condensation corrosion cabinet are shown in figures 2 and 3. The specimens rest in a nearly horizontal position on the cooling tank in the bottom of the insulated box through which air of controlled temperature and humidity is circulated. The degree of purity of the air is also controlled, at least so far as the amount of dust and degree of pollution with sulfur dioxide are concerned. A test run consists in a series of cycles, each of which embraces a condensa-

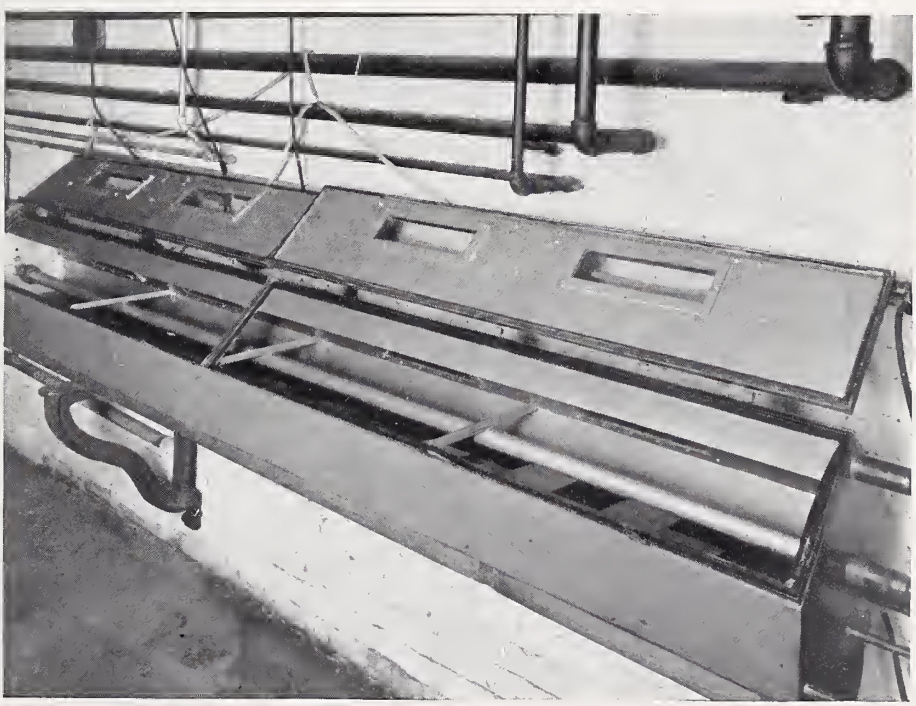


Figure 2.—*Condensation corrosion chamber.*

General view of cabinet above with cover open. When the cabinet is closed, moisture from the humid atmosphere inside can be made to condense on the specimens at will by means of a cooling chamber with which the specimens are in contact.

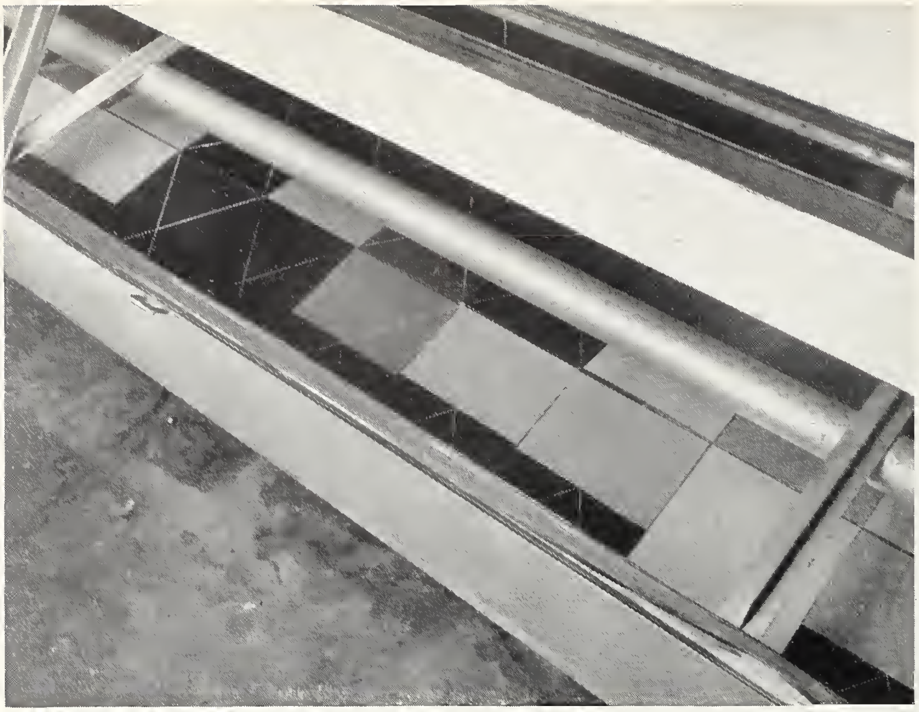


FIGURE 3.—*Interior view of chamber showing specimens in position.*

Note how the specimens have been intentionally scratched for the test.

tion period, a period in which the panels stand wet, and a drying period. Since the composition of the air and the temperatures are such as might be encountered in service, the only accelerating factors involved in the test are the amount of condensed moisture, the length of time wet, and the comparative frequency and suddenness of the temperature changes.

The salt-spray test consists in continuous exposure to the fine mist or spray produced from a 20-percent solution of sodium chloride. The important principles of the testing apparatus are shown in the drawings of figure 4. This type of test, because of its simplicity and speedy results, is widely used in laboratory corrosion testing, although it has been repeatedly shown that the results are comparable to those produced in service only when the conditions of service include frequent wetting by salt water or prolonged exposure to salt spray. Salt-spray tests were included in the present investigation not so much for direct comparison with the corrosive conditions of marine atmospheres, but more as a comparatively quick and simple means of studying some of the factors affecting the protective value of paint films, such as permeability to moisture and inhibitive action of pigments.

The accelerated-weathering tests mentioned above are being supplemented by ordinary outdoor exposure tests at Washington. Part of the exposure test racks are shown in figure 5. Special exposure tests are being made in which specimens are exposed in ventilated enclosures, the specimens being shielded from the sun and direct rainfall but open to the air through louvres and exposed to the condensation of moisture. This test should be similar to the

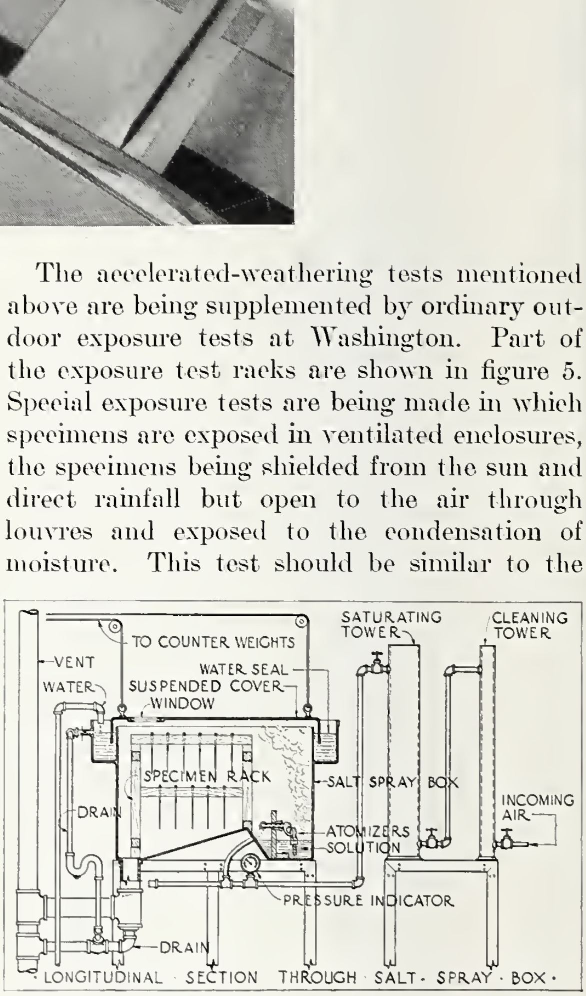


FIGURE 4.—*Diagram showing the principle of the salt-spray test.*

A stream of air which has been cleaned and saturated with moisture "atomizes" the test solution (sodium chloride solution) and produces a mist which completely fills the interior of the cabinet where the specimens are exposed.

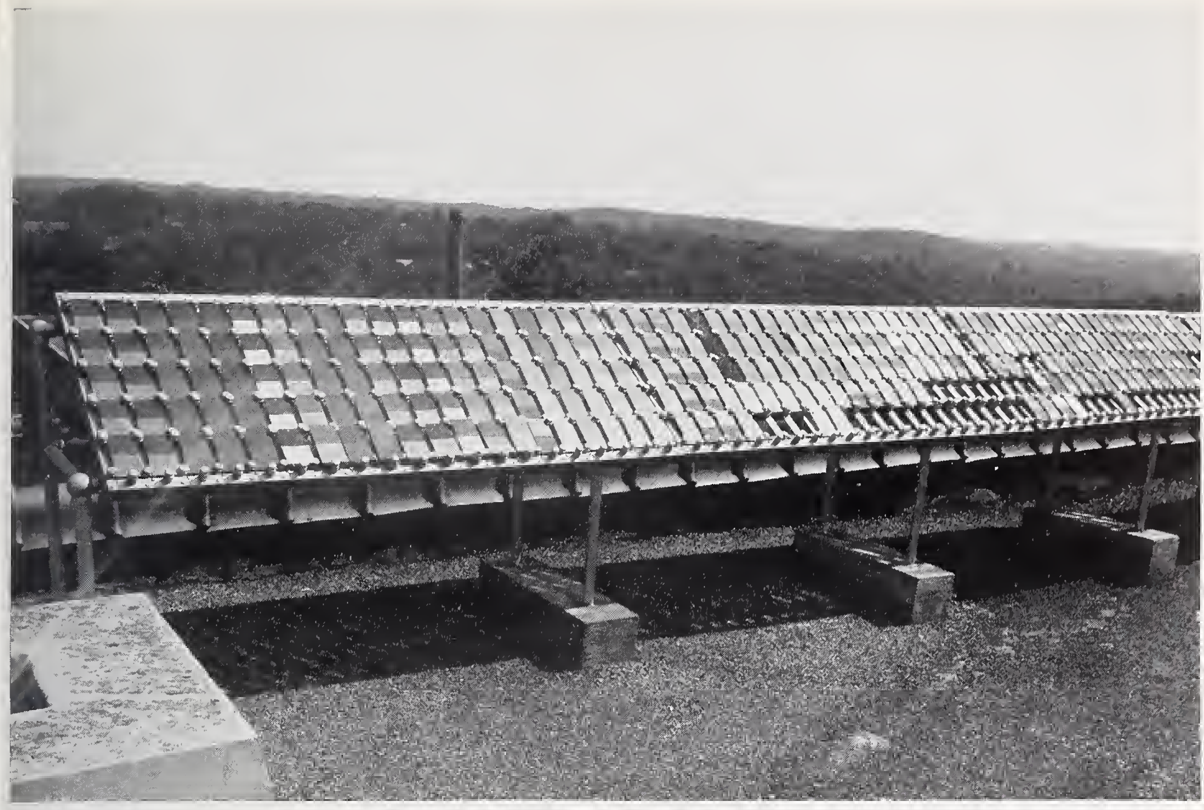


FIGURE 5.—*Part of exposure tests of painted metal panels on roof of Chemistry Building, National Bureau of Standards.*

condensation corrosion test previously described, but probably considerably slower.

The various tests described above should yield useful information on the protective value of various pretreatment processes and paints used for steel and galvanized surfaces. Some of the tests have been used for a number of years and their limitations, as compared with actual service conditions, are well understood. Service conditions vary so widely that actual service tests in different localities may not produce comparable results. It is not to be expected, therefore, that laboratory tests in which similar conditions are changed to speed up the action will produce results directly measurable in term of years of service. However, in the laboratory the conditions of testing are under control and by varying the conditions in different tests, it will be possible to study the factors affecting the protective value of paints under particular conditions.

Most of the panels are 3 by 6 inches. In the condensation chamber, larger panels 5 by 7 inches are being used. After pretreatment the panels are brushed with two coats of primer with 1 week drying time between coats. One-half of the surface is then given one topcoat of an outside finish paint. Two diagonal scratches are made across the front of each specimen. In most cases test panels are prepared in duplicate.

IV. TESTING PROGRAM

1. Pretreatments for Galvanized Steel

Most of the tests to date have been made on painted panels of galvanized steel. The painting of a fresh galvanized surface has always been a difficult problem because of the poor adherence of paint to the smooth surface and because of possible reactions between the zinc and the pigment or vehicle of the paint. Both difficulties may be overcome to some extent by preliminary weathering, which roughens the surface and changes it chemically so that reactions with the paint do not occur so readily. However, weathering takes at least 6 months in most cases, and numerous pretreatments have been proposed and used for modifying the surface so that painting may be done at once.

The pretreatments so far included in the present testing program are:

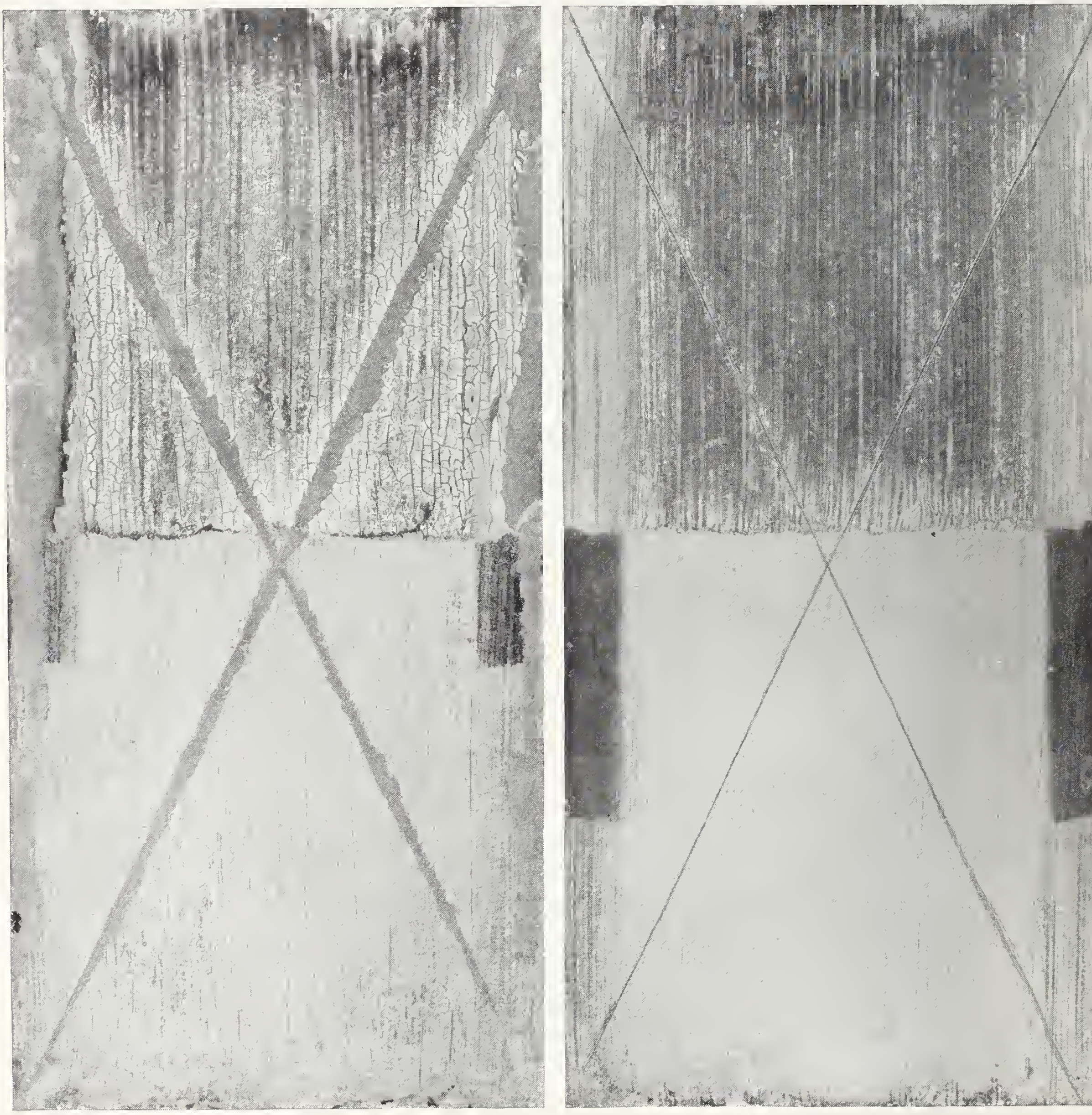
(a) Common laboratory etching solutions, including:

(1) Copper sulfate (8 oz per gal);

(2) Zinc sulfate (8 oz per gal);

(3) Alcohol (60%), toluol (30%), carbon tetrachloride) (5%), hydrochloric acid (5%) by volume;

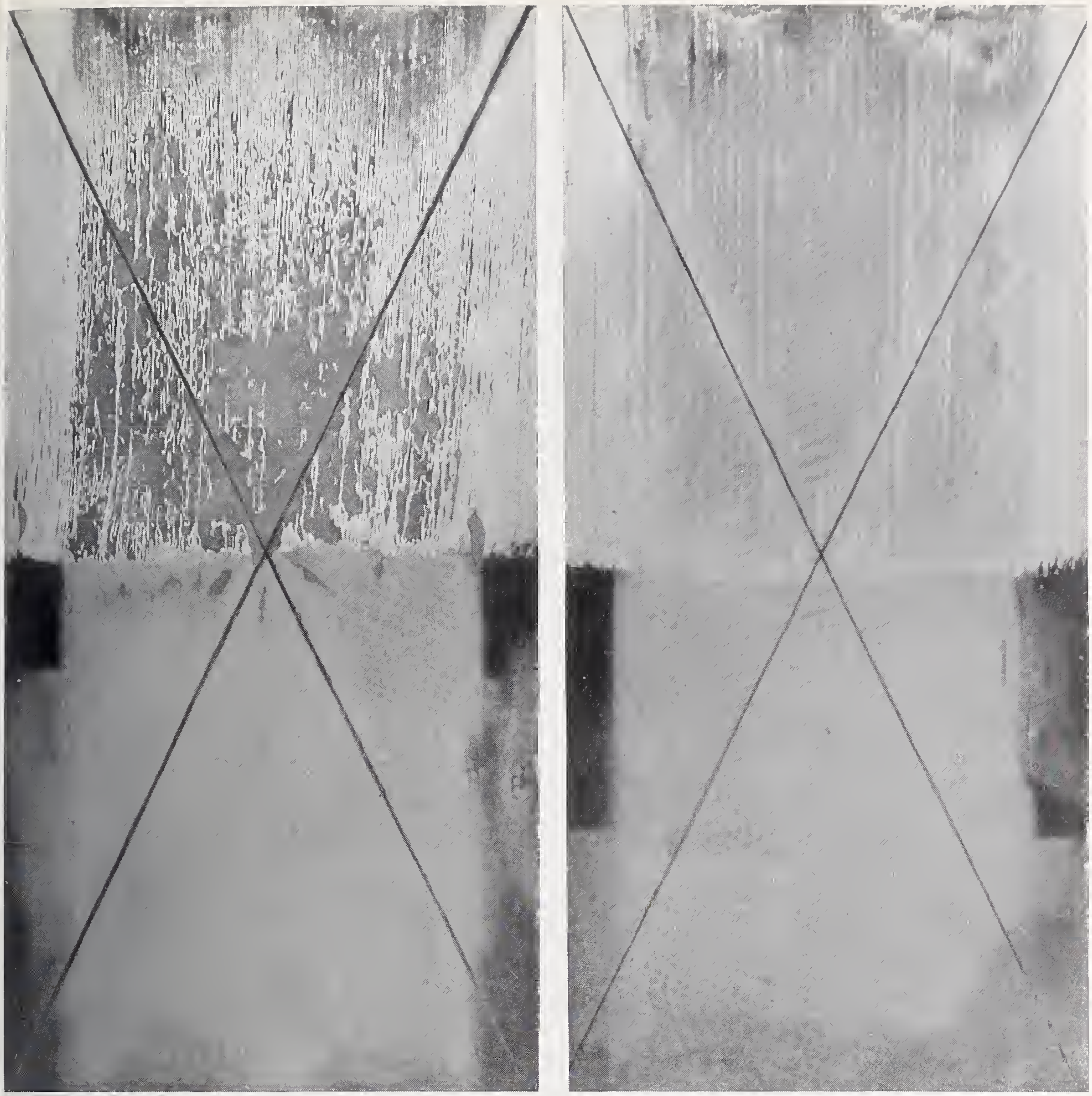
(4) Saturated solution of nickel sulfate (10 parts by weight), antimony-potassium tartrate (0.5 parts by weight), neutralized with ammo-



Panel *A2*. Panel *B2*.

Figure 6.—*Painted galvanized steel panels after the six-months' accelerated-weathering test.*

Panel *A2*, no treatment prior to painting. Panel *B2*, surface-treated prior to painting. Two coats of the same primer were used on each panel; a single top coat was applied to the upper half of the panels.



Panel *A9*. Panel *B9*.

Figure 7.—*Painted galvanized steel panels after the six-months' accelerated weathering test.*

Panel *A9*, no treatment prior to painting. Panel *B9*, surface-treated prior to painting. Two coats of the same primer were used on each panel; a single top coat was applied to the upper half of the panels.

nium hydroxide, made slightly acid with hydrochloric acid, and then diluted to 100 parts by weight with water;

(5) Phosphoric acid (1 part), alcohol (4 parts), by volume; and

(6) Dilute acetic acid (4 %) by volume.

(b) Proprietary pretreatment processes, including:

(1) Zinc phosphate (hot dip and cold wash);

(2) Iron-zinc phosphate (hot dip);

(3) Barium phosphate (hot dip); and

(4) Acid dichromate (hot dip).

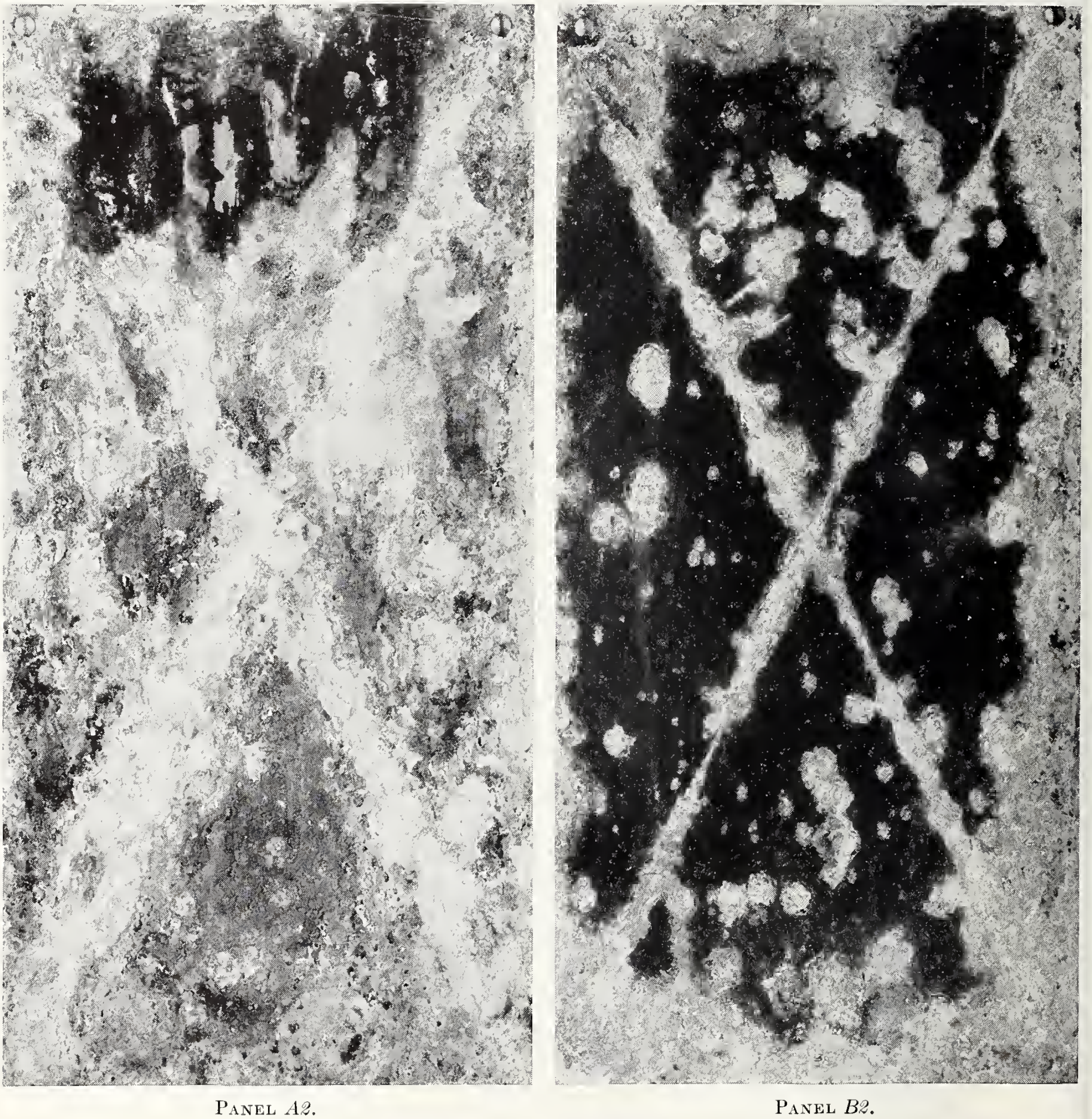
2. Surface Conditions for Plain Sheet Steel

The surface conditions of plain sheet steel prior to painting also has a considerable influence on the durability of the paint coatings applied. Among the surface conditions included in the testing program are the following:

(a) As rolled (hot-rolled annealed sheet);

(b) Acid pickle, including:
   (1) Hot hydrochloric acid (20% by volume);
   (2) Hot sulfuric acid (10% by volume); and
   (3) Hot phosphoric acid (20% by volume).

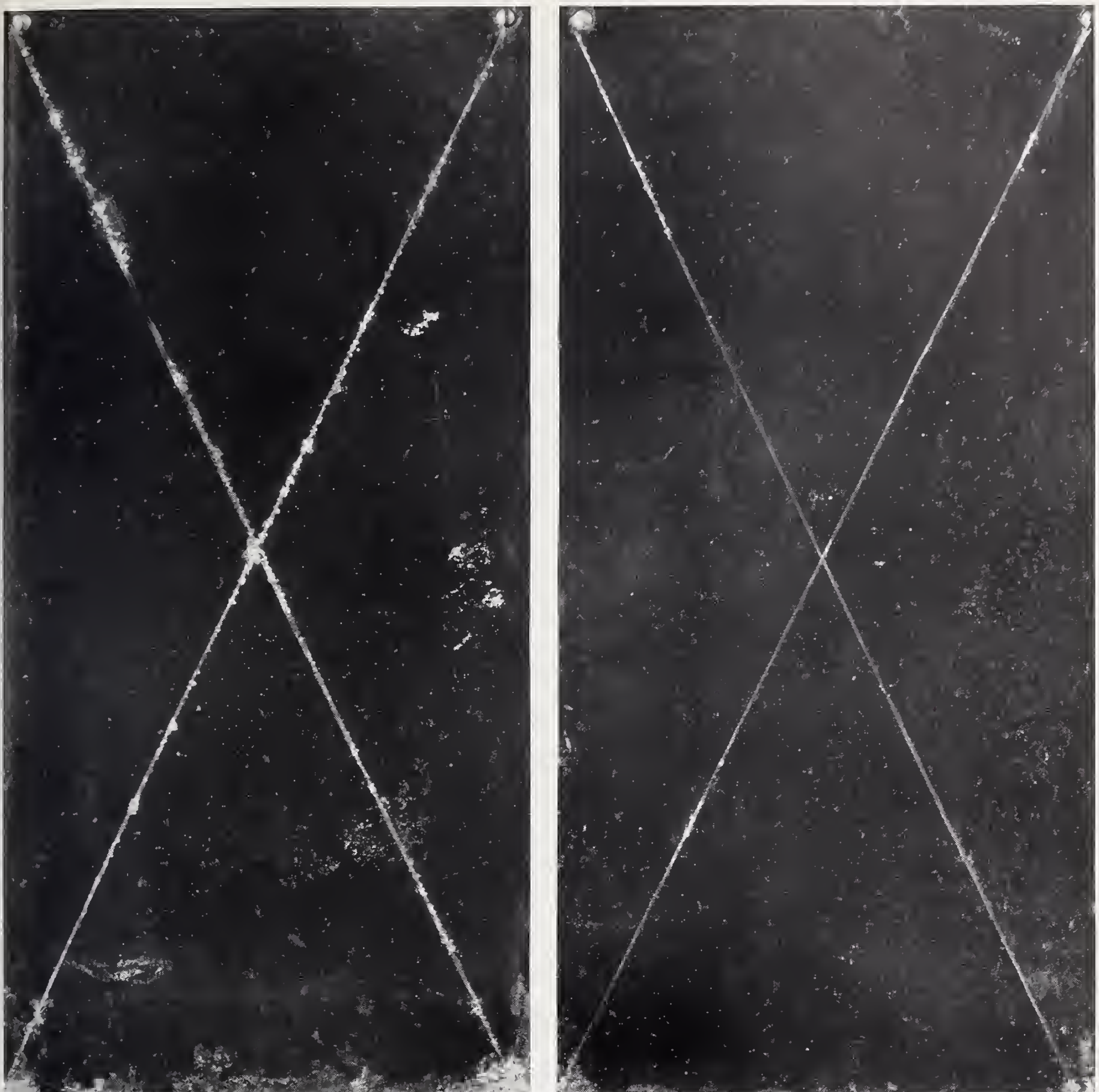
(c) Proprietary pretreatment processes, including:



Panel *A2*. Panel *B2*.

Figure 8.—*Painted galvanized steel panels after the salt-spray test.*

Panel *A2* (4 weeks in spray), no treatment prior to painting; panel *B2* (6 weeks in spray), surface-treated prior to painting. Two coats of the same primer were applied to each panel.



PANEL *A5*. PANEL *B5*.

FIGURE 9.—*Painted galvanized steel panels after 18 weeks in the salt-spray test.*

Panel *A5*, no treatment prior to painting. Panel *B5*, surface-treated prior to painting. Two coats of the same primer were applied to each panel.

(1) Zinc phosphate (hot dip);
(2) Iron-zinc phosphate (hot dip);
(3) Barium phosphate (hot dip);
(4) Phosphate cold wash—inhibitive pigment—aluminum-paint top coat;
(5) Phosphate-chromate cold wash; and
(6) Hot dip chromic acid treatment.

3. PROTECTIVE COATINGS

A total of 60 priming paints for steel or galvanized surfaces are being included in the tests. A small number of different types of top coats are also being tested.

(a) Pigments used in the priming paints and top coats include the following:

(1) Lead pigments (metallic lead, lead

oxides, lead carbonate, chromate, and sulfate;

(2) Zinc pigments (metallic zinc, zinc oxide, zinc chromate);

(3) Aluminum;

(4) Lithopone (barium sulfate-zinc sulfide);

(5) Carbon pigments; and

(6) Iron oxide.

(b) Paint vehicles include representatives of the following classes:

(1) Drying oils;

(2) Synthetic varnishes (mostly oleoresinous, phenolic, and alkyd types);

(3) Asphalt varnishes; and

(4) Natural and chlorinated rubber vehicles.

4. Status of Investigation

A considerable number of accelerated-weathering tests and salt-spray tests have been made on painted galvanized panels. Outdoor exposure tests have been in progress for periods ranging up to 8 months, while condensation tests have been running about 2 months. Photographs of some of the panels after being tested are shown in figures 6 to 9, inclusive. The test program has not been completed, and in the absence of completed results from all types of tests it is not considered advisable to draw definite conclusions at the present time. It may be stated, however, that some of the pretreatment processes show considerable promise of increasing the adherence of paints to galvanized surfaces, and that some of the newer paints may, under favorable condition, give good protection even on untreated surfaces.

Washington, August 8, 1938.

The *National Bureau of Standards* was established by act of Congress, approved March 3, 1901, continuing the duties of the old Office of Standard Weights and Measures of the United States Coast and Geodetic Survey. In addition, new scientific functions were assigned to the new Bureau. Originally under the Treasury Department, the Bureau was transferred in 1903 to the Department of Commerce and Labor (now the United States Department of Commerce). It is charged with the development, construction, custody, and maintenance of reference and working standards, and their intercomparison, improvement, and application in science, engineering, industry, and commerce.

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