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Accelerated Testing to Compare the Corrosion Control Abilities of Common Barrier Coatings Used by Autobody Repair Technicians

Kelvin Karl Kramer
University of Northern Iowa

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Accelerated Testing to Compare the Corrosion Control Abilities of Common Barrier Coatings Used by Autobody Repair Technicians

Abstract

The autobody repair technician has a choice of several different brands of undercoatings to be used to provide barrier protection against corrosion. This study attempted to determine if the corrosion control ability varied among the products available when those products were tested using accelerated corrosion testing procedures.

DEPARTMENT OF
INDUSTRIAL TECHNOLOGY
University of Northern Iowa
Cedar Falls, Iowa 50614-0178

Accelerated Testing to Compare the Corrosion
Control Abilities of Common Barrier Coatings
Used by Autobody Repair Technicians

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Research Paper

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to the Graduate Faculty
of the Department of Industrial
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In Partial Fulfillment of the Requirements for
the Non-Thesis Master of Arts Degree

by
Kelvin Karl Kramer

July, 1982

Approved by:

Dr. Michael R. White, Advisor

Dr. Patrick W. Miller, Graduate
Faculty Member

July 16, 1982
Date

7/16/82
Date

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VITA

..... Born . Iowa

1965 - 1969 Autobody Repair Technician
Trainee
Mason City, Iowa

1967 - 1969 A.A., North Iowa Area
Community College
Mason City, Iowa

1969 - 1972 B.A., University of
Northern Iowa
Cedar Falls, Iowa

1971 - 1973 Autobody Repair Technician
Clear Lake, Iowa

1973 - Teacher of Industrial Arts
Clear Lake High School
Clear Lake, Iowa

1971 - 1978 Automotive Service Work
Clear Lake, Iowa

1978 - 1980 Autobody Repair Technician
Thornton, Iowa

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CHAPTER I
INTRODUCTION

Background of the Study

Corrosion causes billions of dollars in damages annually (Lamm, 1975). Corrosion damage to automobile bodies, which occurs because of rusting from the inside of enclosed panels, is a major problem. This corrosion may be slowed by application of barrier protection to the backside of these panels. Some of these protectants are applied at the factory. Other coatings are applied by dealers and franchised undercoating specialists. During repair procedures by autobody technicians these coatings are often disturbed, which will lead to a reduction in their effectiveness in controlling corrosion. In an attempt to restore these coatings' effectiveness as well as providing additional reliability to the repair, the autobody repair technician can apply one of several types of barrier protection.

Statement of the Problem

Of the barrier protection products commonly available that can be economically applied by autobody repair technicians, what type provides the most effective corrosion control?

Purpose of the Study

The autobody repair technician has a choice of several different brands of undercoatings to be used to provide barrier protection against corrosion. This study attempted to determine if the corrosion control ability varied among the products available when those products were tested using accelerated corrosion testing procedures.

Assumptions

1. Accelerated laboratory tests can predict the corrosion control ability of undercoating products.
2. The designated procedures developed and approved by the American Society of Tests and Measurements were assumed to be the standards for product testing and evaluation accepted by most industries.

Limitations

1. The evaluation of corrosion control was limited to the results obtained using accelerated test procedures.
2. Tap water was used instead of distilled water in the preparation of the corrosive salt solution used for the immersive tests.
3. No active control over the administration of the salt-fog cabinet tests was possible.

Delimitations

1. Undercoating products evaluated using the salt-fog cabinet included the following manufacturers: (a) 3M Company, (b) Permatex Corporation, (c) Go-Jo Industries (marketed under the label Swiss), (d) Radiator Speciality Company (marketed under the label Tite-Seal), (e) TRW Incorporated, and (f) Siloo Incorporated.
2. Exposure time for the salt-fog test was 120 hours.
3. Exposure time for the immersive test was 336 hours.
4. Undercoating products evaluated using the immersion tank included the following manufacturers: (a) 3M Company, (b) Permatex Corporation, (c) Go-Jo Industries (marketed under the label Swiss), (d) K-Mart Corporation, and (e) Radiator Speciality Company (marketed under the label Tite-Seal).
5. Spray Galv, manufactured by Dyna-Flux Corporation, was the only spray galvanizing compound used as a barrier protection in this study.
6. A total of three coupons were prepared for each product tested.

Definitions

There are several definitions that are necessary in order to have a generally accepted meaning for the

terminology used in this study.

Airstone is the common name aquarists apply to the sparger used to aerate the aquarium water.

American Society of Tests and Measurements (ASTM) is an organization that develops, evaluates, and certifies testing and measurement procedures so that industry-wide standardized procedures are established.

Coupon refers to the small metal panels to be used for testing purposes.

Double-Coating is a common spray paint technique used in many refinishing procedures. As the material is applied using spray equipment, a pattern will appear after each pass. On the succeeding pass the refinisher will overlap the previous pass by one half its width. The effect is to put a double coat on the entire surface.

Undersealant refers to the asphaltic coating auto-body repair technicians apply to unseen areas for rust protection and sound deadening. This product is also referred to as 'undercoating.'

CHAPTER II

REVIEW OF LITERATURE

Corrosion

Corrosion, or oxidation as it is sometimes called, is a common fact of everyday life. It is a problem which affects many materials found in everyday life, especially the steel products so prevalent in the manufactured articles produced by society today. Iron, a major constituent in steel, is found in nature in the form of hematite (Fe_2O_3) and magnetite (Fe_3O_4). The application of large amounts of energy, primarily to remove the oxides along with the addition of other elements, convert these forms of iron oxide into steel. Nature in its own way, unless the surface is protected, will attempt to reverse this procedure until the materials have been converted through the electrochemical process of corrosion back to their more stable form of iron oxide (Vermilyea, 1976).

In The Application of Corrosion Principles, Rowe (1976) cites several different factors which effect corrosion of metal objects. Many of these factors relate to the environment around the metal surface. Temperature, as it is increased, has the effect of speeding up the rate

of the corrosion process. Exposure of the surface to acid, alkaline, or salt materials speed up the electrochemical process of corrosion as well. Essentially, all that is needed to cause corrosion is exposure of the steel surface to oxygen and moisture combined with the previously-mentioned items accelerating the rate of that corrosion.

Corrosion of steel can be controlled. This is done by providing some form of a barrier between the metal surface and the corrosive environment. Coatings which provide this barrier for protection may be of several types. The ones most commonly found on parts of the automobile are chrome (i.e., layers of copper, nickel, and chromium), galvanized surfaces, organic coatings, and petroleum-based rust preventatives. The term organic coatings refers to the use of lacquers and enamels with their respective primers. These paints are used to protect the exterior of the automobile. To aide in corrosion control of the inner parts, petroleum-based rust preventatives are used. Some examples of this form of barrier protection are common grease, wax resin used to coat the inside of car body cavities, and asphaltic coatings commonly referred to as undercoatings.

The corrosion of automobile parts is a very expensive problem. In 1968, it was estimated that it cost American

motorists five billion dollars in rust repair or depreciation costs. In 1975, that estimate had been increased to 7.5 billion dollars (Lamm, 1975).

Automotive corrosion can be defined as one of two types, inside and outside. As the names imply, the outside rust refers to corrosion of the exterior body parts and inside refers to corrosion found on the inside walls of fenders or other enclosed body panels. Outside corrosion or pitting usually results because of poor surface preparation techniques during the painting procedure or damage that occurs to the paint film from a nick or scratch. To a lesser extent, infrequent cleaning and waxing of the auto may accelerate the rusting of the car body.

The rusting of the inside of the parts is primarily caused by design and environmental (atmospheric) factors. Such factors include accumulation of road salts that create a chemically active environment to accelerate corrosion and collected layers of dust that hold moisture in enclosed areas and accelerate corrosion.

Rust may occur almost anywhere on the automobile body. In addition, geographic location may affect where rust is most likely to occur. In coastal areas, salts from the ocean are carried through the atmosphere and deposited on the vehicle causing corrosion. This occurs

naturally through the normal condensation of dew on objects during the night. This type of corrosion is most likely to occur on the upper internal surfaces of the vehicle and is hard to stop and even more difficult to repair. This is due to the fact that damage to internal surfaces is often undetected until it is too late to do much about it.

In those areas of the nation where salts are used to remove ice from the roads in the winter, a different area of the vehicle is likely to rust. These salts accumulate on the lower parts and underneath the body of the auto primarily through splash as the vehicle is driven over salt-laden roads. Because of the design of the automobile body and chassis (with many ledges and crevices), salts are accumulated and held, causing corrosion to develop.

Rust Repair

There are many techniques that may be used in the repair of autobody corrosion. In beginning, the autobody repair technician must first assess the extent of the damage due to rust. This may be established through the consideration of two factors: Location of the damage; and, the causing factor. The location of the damage is a determining factor in helping the body repair technician decide on the best procedure to follow in making the

repair. The causing factor has to be determined so that it may be corrected if the repair is going to last.

Outside surface rust is recognized by examining the painted surface for signs of discoloration and blistering. The areas most likely to be affected are those underneath and adjacent to trim moldings and other outside hardware. Surface rust is also likely to form in areas that were chipped by gravel thrown up by the tires. To obtain a quality repair, it is of major importance that the surface rust be completely removed. This is done by grinding or sandblasting the surface until it is clean. Phosphoric acid is then used to clean and etch the bare metal. This preparation is done to help inhibit further corrosion from reforming as well as increasing the effective surface area for better substrate adhesion. Proper refinishing techniques should be followed to maximize the effectiveness of the repair.

Other factors that should be considered during the reassembly after refinishing are the use of plastic or other rust-resistant molding clips. Even though they are quite popular, the use of steel clips against the steel body is sometimes a causal factor in promoting the reformation of surface rust at the point of contact. It is also important that the new paint be given time to properly harden. If this is not done and the moldings are

reinstalled on a painted surface which has not been afforded proper cure time, the molding may cut into the fresh paint, breaking the seal and allowing the corrosion process to start all over at the point of the break. In addition, an owner of a vehicle should be informed of the correct cleaning and waxing procedures to use on an automobile to add longevity to the repair job.

Inside rust is usually a more serious problem. This is due to the fact that rusting may go on for some time before the problem becomes evident. Because the corrosion has had a head start before discovery, the damage often may be quite extensive. Before any type of repair or reconstruction is attempted it is important to first remove the rusted metal. This should be done by cutting away the rusted area. It is a common procedure to then weld in a patch, or if the damage is extensive enough, replace the entire panel.

Fiberglass and epoxy materials are also used to form patches to reconstruct corroded panels. The key to their success lies in proper surface cleaning and preparation. Cleaning means the removal of all the rust by sandblasting or grinding. The grinding of the surface roughens it so that the plastic products will adhere better.

It is also important in repairing internal rust problems that a proper protection is used. As mentioned

earlier, a barrier should be placed between the metal and the corrosive environment around it if rust is to be controlled. Traditionally, asphaltic materials like undercoating have been used. Problems can arise if, as time goes on, the undercoating material dries and shrinkage takes place. This shrinkage may cause the material to pull away from the metal surface forming small pockets. It is in these pockets (where corrosive materials may collect) that a rust problem will return. Within the last few years, improved types of undercoatings have been developed. These are used by franchised dealers specializing in autobody rust prevention. Oils which emit rust-inhibiting vapors are also available. Galvanizing materials are available in spray cans. This, at one time, was a process which required dipping the metal in a hot tank. Special primers are now available which contain zinc compounds to inhibit rust. These primers may include special oils to provide a vapor barrier to exclude moisture (Romney, 1979). Conversion coatings, which chemically interact with the corrosion to neutralize the oxidation, slow down the process of rusting on the inner surfaces of body panels. The usage of the above-mentioned products and procedures could slow the rusting of these inner surfaces which would mean that the repair's 'life expectancy' is increased.

Corrosion Testing

Thousands of different ways may be used to test corrosion. This is due to the diverse nature of the corrosion problem and the accepted fact that the most accurate method of corrosion testing is to field test under actual conditions. The problem with field testing is that it may take several years. Because of current needs of industry and manufacturers, shorter testing methods are often desirable.

The attempt to predict corrosion rates using tests of shorter duration spawned the development of accelerated testing methods. These types of test procedures require the use of very well-controlled testing conditions. Fontana and Greene (1978) suggest that two factors, reproducibility and reliability are desirable results of corrosion tests. They also suggest four different classifications of corrosion tests: "...(1) laboratory tests including acceptance or qualifying tests, (2) pilot-plant or semiworks tests, (3) plant or actual service tests, and (4) field tests..." (p. 116).

Laboratory tests generally involve a limited number of small specimens tested under conditions that carefully control variables. Pilot-plant studies are executed in a similar manner as those conditions of laboratory tests. The major difference in these tests are the actual conditions in which the tests are conducted. Besides using

as many actual conditions as can be reproduced in the test conditions, pilot-plant studies are usually executed over a longer period of time. The combination makes the pilot-plant or semiworks test more accurate than laboratory tests.

Plant or service tests are conducted on the job or in actual usage conditions. Field tests may be similar but they are usually organized so the results can be generalized. An example might be the testing by a paint manufacturer of many specimens of certain types of paint, placed on racks and exposed to the atmosphere. The information obtained in the results of such tests would predict the paints' behavior and durability when exposed to atmospheric conditions (Banov, 1976). If that manufacturer would also use the same paints to paint automobiles and then drive them while being exposed to the same climate, the data collected from this service test would accurately predict the usefulness and durability of an automotive finish in that type of climate. This is because it was tested under actual conditions in which it would be used.

Salt-Fog Testing

A common accelerated laboratory exposure test is the salt-fog test. Specimens are suspended in a cabinet and exposed to a fog of salt spray solution. The salt-fog

solution is a 5% concentration of sodium chloride and water. The cabinet is sealed and has a heating unit which maintains the temperature at 95° Fahrenheit (35° C). In addition to controlling the temperature, the humidity within the cabinet is also maintained at a set level (Burns & Bradley, 1967). Precise information about test conditions and procedures is given in Standard Method of Salt Spray (Fog) Testing (ASTM Designation: B 117-73).

Immersion Testing

Immersion testing is a form of accelerated corrosion testing where test specimens are placed in a corrosive solution. The conditions of the test are carefully controlled to allow the experiments to be repeated accurately.

The container used to house the liquid and test specimens is made of corrosion-proof materials. The container should also be sealed to help control evaporation of the corrosive liquid. Since the temperature must be maintained at a constant, some form of thermostatically controlled heating must be used. The racks supporting the coupons in the tank should be electrically nonconductive and provide at least a space of .5 inch (1.27 cm) between each coupon. This spacing eliminates the chance of electrolytic corrosion taking place and avoids coupons from touching one another. The coupons may be immersed partially or completely in the corrosive solution. The

solution most commonly used is a 5% concentration of sodium chloride in distilled water. The above-mentioned description outlines the general test requirements dictated by ASTM (Designation: G 31-72 and D 870-54). Other more specific procedures are designated in those standards. These apply to specialized types of metals and protective coatings.

Preparing Test Specimens

The publication Standard Methods for Preparation of Steel Panels for Testing Paint, Varnish, Lacquer, and Related Products (ASTM Designation: D 609-73) can be used to determine guidelines pertaining to product specifications and preparation procedures to be followed in preparing metal coupons for testing. Cold-rolled steel panels are a popular choice for coupon use. The metal sheets are washed with a brush and a nonprecipitating solvent is used to clean the surface to make it ready for application of the coating. After final washing and wiping with a lint-free cloth, care must be exercised to keep 'fingerprints' and other contaminants off the metal surface. In some cases, after coating, the edges of the coupon should be sealed. ASTM (Designation: D 1654-74) also dictates that the coated specimens be scribed down the center leaving an intended place for corrosion to start.

Evaluating Test Results

After exposure to the corrosive atmosphere of the test, the coated metal coupon can be examined in several different ways. The two general methods of evaluation are the use of weight loss due to exposure and the usage of corrosion creepback examination methods (ANSI/ASTM Designation: G 1-72; ASTM Designation: D 1654-74).

ASTM (Designation: D 1654-74) describes the correct methods for preparing and evaluating metal coupons exposed to accelerated laboratory corrosion tests. Following these methods requires that a tungsten carbide tool be used to scribe the surface of the coated specimens. After exposure, the metal panels are washed and dried. Two procedures are usually followed after this cleaning. The first procedure involves the application of an adhesive tape over the scribed line. This special tape is then removed to help determine how well the coating has adhered to the test panel. A dull knife or spatula may also be used to scrape the surface near the scribed line. One form of evaluation measures corrosion growth by observing the extent and distance the corrosion has advanced from the scribed line. Another method of observation would entail examination of the complete surface and the use of photographic methods or a drawing to help determine the extent of corrosion damage. ASTM

(Designation: D 610-68) describes completely the procedures used when approved photographic reference standards are to be used to assign a percentage value to the corrosion covering. ASTM (Designation: D 1654-74) also suggests the use of a transparent ruled plastic grid to accurately count the rust spots to determine the percentage of the surface which was attacked by the corrosion.

Inspection and evaluation of pitting corrosion is technically more difficult than examination of surface rust growth. This is due to the fact that the rust spots are not just counted but the depth and shape of the pits must be measured. This requires special equipment to make depth measurements. Complete details for examination and evaluation of pitting corrosion is found in ASTM (Designation: G 46-76).

CHAPTER III

METHODOLOGY

To attempt to determine if there were differences in the corrosion control abilities of commonly available aerosol undercoatings, metal coupons coated with barrier protection materials were exposed to two different corrosive environments. Half of the specimens were exposed to a salt-fog environment in an ASTM approved test cabinet. The remaining half of the coupons were exposed using immersive test equipment.

Preparation of Coupons

From a large sheet of 21 guage cold rolled sheet steel, 60 coupons were sheared to a 6 inch (15.24 cm) by 8 inch (20.32 cm) size. The coupons did not have the edges machined as was suggested by one reference (Fontana & Greene, 1978, p. 120). The outer edges of the coupons used in the immersive tests were sealed with Scotch Brand transparent tape prior to coating application. A .44 inch (1.11 cm) hole was drilled on center, .75 inch (1.91 cm) from the top edge of each coupon. Using a hammer and hand stamps, the coupons were sequentially numbered from 1 to 60.

Coating Materials

Eight different brands of aerosol automotive undersealant were used in the salt-fog test. Because two of the products obtained in the first purchase were discontinued by the supplier, they were not used for the immersive tests. The products evaluated during both test procedures were: (a) 3M Undercoating, (b) 3M Rubberized Undercoating, (c) Permatex Undercoating, (d) Permatex Rubberized Undercoating, (e) Swiss Undercoat, and (f) Tite-Seal Undercoating. The two products tested in the salt-fog cabinet and not included during immersive testing were: (a) TRW Undercoating, and (b) Siloo Undercoating. In addition, K-Mart Undercoating was used in the immersive tests. Of the undercoatings tested, two manufacturers described their products as being 'rubberized.' The others were labeled plainly as 'undercoating' or 'undersealant.' All products were described as being useful as sealers and for sound-deadening purposes. Each also claimed to control rust. Additionally, a spray galvanizing compound (Spray Galv) was purchased from a local welding supplier. Although not generally used as a form of barrier protection by autobody technicians, it was also compared with that of the undercoating materials (See Appendix A).

Coating Application and Preparation for Exposure

After purchase, each can of material was shaken for five minutes on a commercial paint shaker. Prior to coating application, each can was also shaken for a two-minute period by hand. In an attempt to apply the coatings in an even manner, two simple aids were developed (See Appendix B). One was a strip of sheet metal with a 90° angle on the end. It was fastened to the can with large rubber bands, leaving the longer end protruding in front of the can approximately 10 inches (25 cm). This was used to help keep the cans at the same distance from the surface to be coated. Sheets of paper with horizontal lines 0.5 inch (1.27 cm) apart were also used as a backdrop for the coupons and utilized to keep the spray pattern even. The backside of the coupon received two double-coats of the spray undercoating. The front side received a single double-coat of undercoat sealant.

A total of three coupons were prepared for each product to be tested. Coupons were weighed before and after each side was coated to determine the amount of undercoating applied during each step. Each specimen was then scribed using a tungsten carbide scribe, leaving a clear mark of exposed sheet metal down the center of both sides. The line was 1 inch (2.54 cm) below the hole in the top to 0.5 inch (1.27 cm) from the bottom of the sheet (See Appendix C).

Salt-Fog Exposure

During the first test sequence, 30 coated coupons were exposed in a Harshaw G-S Salt-Fog Cabinet according to ASTM Standards (Designation: B 117-73). The time of exposure was 120 hours (See Appendix D).

Immersion Testing

Description of Basic Equipment. The researcher developed immersive test equipment using a common aquarium and related aquarium equipment (See Appendix E). The all-glass aquarium and accessories were designed for salt water usage and were non-corrosive. The snug-fitting top served to control all but minimal evaporation. The 150 watt tank heater provided and maintained the desired solution temperature of 98° Fahrenheit (36.7° C). A hydrometer designed to accurately measure the specific gravity of a marine aquarium was usable to measure the specific gravity of the corrosive salt solution.

Solution Preparation. The corrosive solution used for the immersion test was a 5% sodium chloride solution. This was the same concentration which was recommended for salt-fog testing procedures as specified in the ASTM (Designation: B 117-73). In a conversation with Dr. J. Ernesto Indacochea (1982), it was suggested that a 5% sodium chloride solution could be made by mixing five grams

of salt with 95 milliliters of water. To prepare 190 milliliters of this salt solution, a laboratory balance and a graduated beaker was used to measure accurately. The specific gravity of that solution was measured using a hydrometer and found to be 1.04. Filling of the immersion tank to the correct level required 20 gallons (75.71 liters) of test solution. The test solution was prepared by mixing 475.15 grams of ordinary noniodized table salt and 20 gallons (75.71 liters) of tap water. Warm water was used to facilitate rapid dissolving of the sodium chloride. After pouring the mixed solution into the aquarium, the hydrometer was used to measure the specific gravity. The 1.04 reading verified the accuracy of the mixture ratio.

Apparatus. The immersion tank used was a 29 gallon (109.78 liter) all-glass aquarium measuring 29 inches (73.66 cm) long by 12 inches (30.48 cm) wide and 18 inches (45.72 cm) high. The aquarium was fitted with a matching top that fit snugly to prevent rapid evaporation of the test liquid. The top was used to prevent heat loss and to maintain a constant temperature. Since the aquarium was not filled completely, the remaining volume, being sealed by the cover, allowed an environment of very high humidity to exist around the upper third of the coupons which were not immersed in the salt solution.

The coupons were hung in the center section of the tank from .38 inch (.95 cm) wooden dowels supported by a wooden rack. The support stand was designed to allow a minimum of 0.5 inch (1.27 cm) spacing between each coupon.

According to ASTM (Designation: G 31-72), aeration of the test liquid may or may not be specified. The researcher decided to aerate the solution to maintain constant temperature and to accelerate the corrosion rate. Because the heat source was from a central place in the middle of the back part of the tank, it would have been difficult to maintain a constant temperature throughout the entire tank area without using aeration. The resulting circulation stabilized the temperature throughout the tank with the only exception being the area adjacent to the heater. In addition, a piece of Plexiglas was placed between the adjacent coupons and the heater to avoid direct transfer of heat.

A singular source of air made it difficult to obtain even circulation throughout the tank. To verify that even circulation was obtained, careful observation of the corrosion growth on control coupons was observed during the first hours of specimen exposure. This visual observation did not indicate any observable differences in the rate of corrosion growth between the control coupons.

Additionally, it should be noted that extra control coupons were placed at the outside end of the specimen rack to block any direct impingement upon the test coupons by the air stream.

Evaluation Procedures

The exposed specimens were evaluated using a visual examination and a measurement of weight loss due to corrosion. The respective ASTM methodology was used for each type of evaluation (ANSI/ASTM Designation: G 1-72; ASTM Designation: D 1654-74).

By weighing each specimen carefully before and after exposure, the amount of weight lost is indicative of the corrosion which has taken place. The accuracy of this type of evaluation is dependent upon careful and equal cleaning of each specimen. ASTM (Designation: G 46-76) provides additional information about this and other surface evaluation techniques.

Methods of preparation and evaluation of coated specimens are given in ASTM (Designation: D 1654-74). The procedures described here are to evaluate corrosion creep-back from a scribed line as well as techniques to evaluate the rest of the testable surface. To inspect the surface corrosion, the undercoating was removed using cleaning solvent in a parts washer. Once the solvent had softened the material, a nylon bristle cleaning brush was used to

remove all traces of the undercoating. Because the edges were unsealed, the outer 0.5 inch (1.27 cm) of the perimeter around the coupon was not evaluated. By measuring the extent of growth of the corrosion away from the scribed line, an average distance of failure was established. This was done by noting the furthestmost growth of a corrosion cell as well as minimum creepage points. ASTM (Designation: D 1654-74) has established tables to be used to assign numerical failure ratings (See Table I).

To measure corrosion on the area of the coupon beyond the creep from the scribed line a special template was developed. By using a transparent sheet with a .25 inch (.64 cm) grid, the surface of the coupon was covered and the corrosion spots counted. By comparing the squares with one or more points of failure to the total number of squares, a percentage value was determined. These percentages were used for comparison purposes (See Appendix F).

Table 1
Rating of Scribe Failure

Average Measurement of Failure From Scribe		Rating by Number
in.	mm	
0	0	10
1/64	0.4	9
1/32	0.8	8
1/16	1.6	7
1/8	3.2	6
3/16	4.8	5
1/4	6.4	4
3/8	9.5	3
1/2	12.7	2
5/8	15.9	1
1 or more	25 or more	0

Note. Taken from "Standard Method of Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments", ASTM Handbook, 1979, 27, 330-332.

CHAPTER IV
FINDINGS, DISCUSSION, AND RECOMMENDATIONS

Findings

Salt-fog test. The amount of corrosion growth evident after 120 hours of exposure in the Harshaw G-S Salt-Fog Cabinet was not sufficient enough to draw conclusions.

Immersion test. After 336 hours of exposure in the immersion tank, all 26 test coupons showed signs of corrosion growth (See Appendix G). The bare metal coupons, when evaluated (using the template grid) all received a rating of 100% corrosion over the entire coupon surface. The percentage of coating failure over the entire coupon surface showed wide differences between the products tested (See Appendix I). The product with the lowest failure rating was Spray Galv with 1.5% and the highest was Permatex Rubberized with 100%. The measurement of corrosion creepback from the scribed line also showed wide differences between the coated samples. When comparing averages between coupons, the smallest was Spray Galv with .03 inch (.40 mm) and the largest was Permatex Rubberized with 2.88 inches (6.55 mm). Comparison

of weight loss due to test exposure showed a range of .02 grams (Spray Galv), to 1.46 grams (Permatex Rubberized). The average weight loss of the control coupons was 7.66 grams.

Discussion

Salt-fog test. The amount of corrosion growth evident after 120 hours of exposure in the Harshaw G-S Salt-Fog Cabinet was not sufficient enough to draw conclusions. On many of the coupons the scribed line in the center did not show any corrosion growth. This could be attributed to two factors: (a) improper mounting in the cabinet, and/or (b) expansion of coating materials. A more complete exposure could have possibly been obtained if the coupons were mounted at a 15 to 30 degree angle instead of hanging them in a vertical position as was done. This would increase the effective exposure area of the coupon.

Due to the elevated temperature of 100 Fahrenheit (37.7 C) in the test cabinet, the coating material may have expanded enough to seal the scribed line. By sealing the scribed opening, this could protect the metal from corrosion. After removal from the test cabinet and normalization of the coupon temperature, some of the coupons with softer undercoating materials showed signs of closure. Other coupons with scribed lines remaining clearly visible

after exposure did not show signs of rusting. This supports the speculation that the coupons were not exposed to the corrosive atmosphere to the extent that corrosion was developed.

Immersion test. A wide range of results between samples of the same product were evident (See Appendix I). The measurement of failure rate over the entire surface showed the largest differences in coupons coated with both 3M products as well as the Permatex Undercoating. Before generalizing the results of this study, it should be cautioned that the immersion test equipment was not ASTM approved.

Weight loss figures were altered because the tape used to seal the edges allowed small amounts of crevice corrosion to develop. When examining the percentages of coating failure (See Table II) the reader should also note weight loss figures. Since percentage figures were derived by the presence of corrosion cells and not the size of the cells, a more accurate representation of the actual extent of corrosion was obtained by using both weight loss and percentage figures. For example, the K-Mart failure averages appeared quite high yet the actual depth of the pitting was slight as is indicated by the smaller amount of weight loss.

Table II
 Comparison of Average Overall Coating Failure
 by Rank Order

Product	Front % Failure	Back % Failure	Average %	Weight Loss
Spray Galv.	1.5	1.5	1.5	.02
Swiss	21.0	11.0	16.0	.63
3M	24.0	59.0	41.0	.43
Tite-Seal	33.0	53.0	43.0	.71
K-Mart	77.0	14.0	45.0	.41
Permatex	50.0	45.0	48.0	.70
3M Rubberized	82.0	63.0	72.0	.71
Permatex Rubberized	98.0	96.0	97.0	1.24

When evaluating the creepback failure, two points should be made:

1. No set pattern appeared when comparing the single-coated front side to the double coat on the backside.
2. The smallest creepback ratings do not necessarily reflect the least weight loss.

From the test results, the superior performance of the spray galvanizing compound was evident in both corrosion creepback and overall protection (See Table III). However, this coating blistered and fell off easily after removal from the test environment. The adhesion of this product may be increased by lengthening the cure time (24 hours were allowed in this test). The manufacturer suggests several thin coats instead of one heavy one.

When selecting and using undercoating products, the practitioner should carefully consider the limitations of the study before applying the results. The test results are only intended to predict the coating's performance considering the conditions of this study.

Table III
 Comparison of Average Creepback Failure
 by Rank Order

Product Name	Frontside		Backside		Weight Loss ^b
	Creep- back ^a	ASTM Rating	Creep- back ^a	ASTM Rating	
Spray Galv	.397	9	.397	9	.02
Permatex Rubberized	1.190	7	1.190	7	1.24
K-Mart	2.580	6	2.580	6	.41
3M	3.240	5	2.520	6	.43
Swiss	5.230	4	2.710	6	.63
Tite-Seal	5.290	4	3.310	5	.71
3M Rubberized	4.760	5	4.890	4	.71
Permatex	6.550	3	5.890	4	.70

^ain mm.

^bin grams.

Recommendations

In evaluating the results and the data collected in the process of performing this study, several points should be made. These recommendations are intended for two groups of people: (a) researchers who intend to replicate the study or perform tests in a related field; and, (b) the practitioner who may directly apply the knowledge gained from the results.

For the researcher.

1. A coupon hanger should be developed that is nonconductive, noncorrosive, and will not warp when wet. Plastic, rather than wood, may be a better material choice for these tests.
2. Upon removal from the tank, the surfaces of the coupons should be coated with a clear protectant to avoid further rusting.
3. The effectiveness of the immersion tank in producing corrosion evenly on all coupons throughout the tank should be replicated to check the accuracy of the equipment. This could possibly be done by repeating the 336 hour immersion test using coupons coated with identical protectants. By recording the position of each sample and comparing the corrosion rates between them, the uniformity of corrosion within different areas of the tank could be determined.

4. The tests outlined in recommendation number two should be repeated with and without aeration.

5. The rate of coating failure should be examined completely. If during testing, a representative number of coupons were withdrawn and evaluated at predetermined time intervals (e.g., one, two, and three weeks), the rate of coating failure could be better estimated.

6. To provide the practitioner with greater objectivity in selecting undercoating materials, a more complete analysis of coating properties should be made. These would include: (a) resistance to shrinkage over extended time periods and temperature; (b) abrasion resistance; and, (c) adhesion characteristics when under stress (i.e., road shock and vehicle vibration).

For the practitioner.

1. It is recommended that spray galvanizing compounds be used as a base coating for undercoating materials.

2. When used in conditions similar to the test, a double coat of K-Mart undercoating is recommended to provide the best corrosion protection.

3. When using K-Mart or Swiss undercoating, double coatings are recommended to provide better protection.

4. When using 3M or Tite-Seal undercoating, the use of a single coat is recommended to provide maximum protection.

APPENDIX A
PRODUCTS EVALUATED IN TESTS

Manufacturers of Products Evaluated
Corrosion Tests

- 1) K-Mart Undercoating
--- K-Mart Corporation
Troy, Michigan 48084

- 2) Permatex Undercoating
--- Woodhill / Permatex
Kansas City, Kansas 66115

- 3) Siloo Undercoating
--- Siloo Incorporated
393 Seventh Avenue
New York, New York 10001

- 4) Spray Galv
--- Dyna-Flux Corporation
Castle Hayne, North Carolina

- 5) Swiss Undercoating
--- Go-Jo Industries, Inc.
P.O. Box 991
Akron, Ohio 44309

- 6) 3M Undercoating
--- 3M Company
3M Center
St. Paul, Minnesota 55101

- 7) Tite-Seal Undercoating
--- Radiator Speciality Company
Charlotte, North Carolina 28237

8) TRW Undercoating

--- TRW Replacement Division
TRW Incorporated
8001 East Pleasant Valley Road
Cleveland, Ohio 44131

These products were evaluated in the immersion test



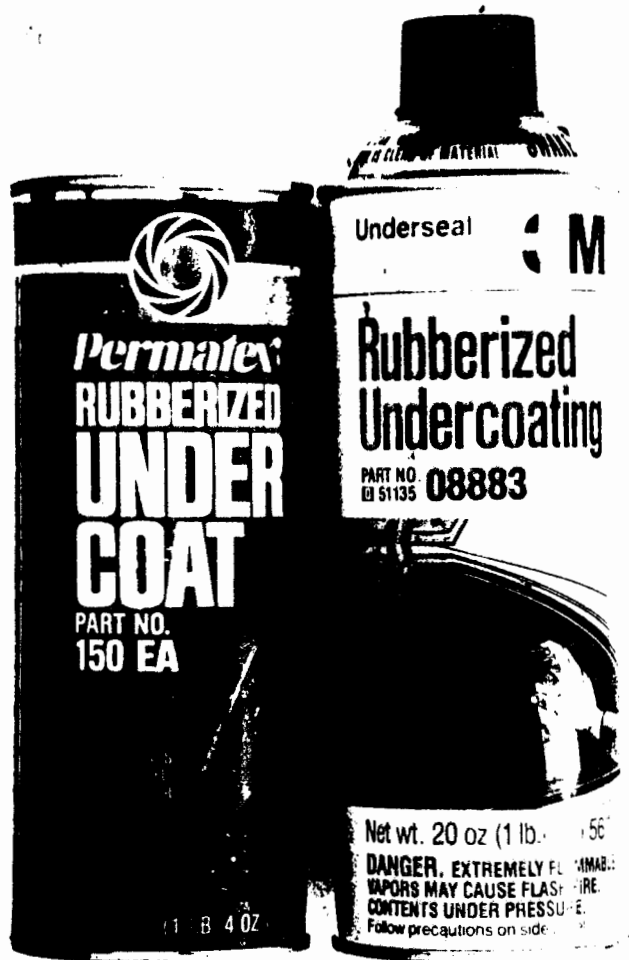
Permatex

3M

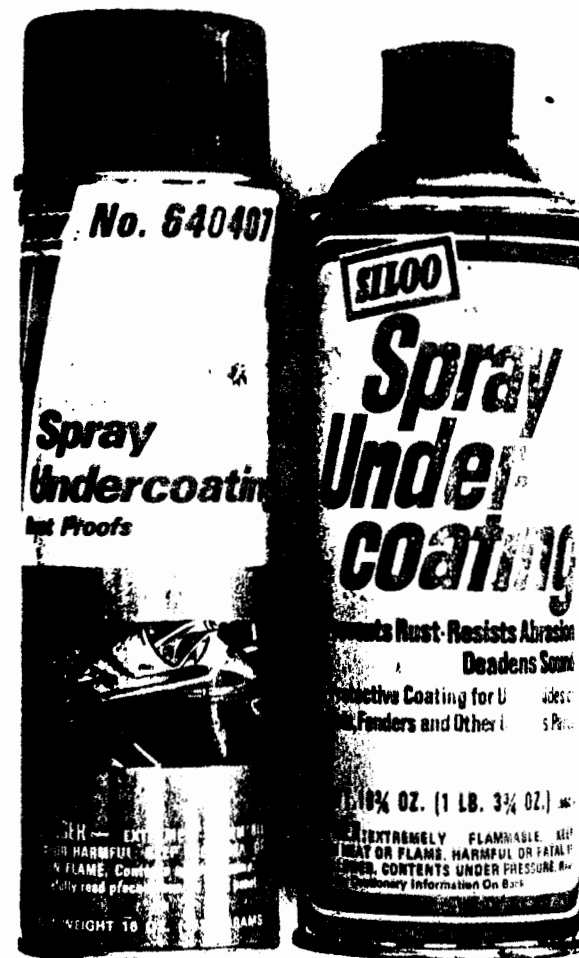
Swiss

Tite-Seal

K-Mart

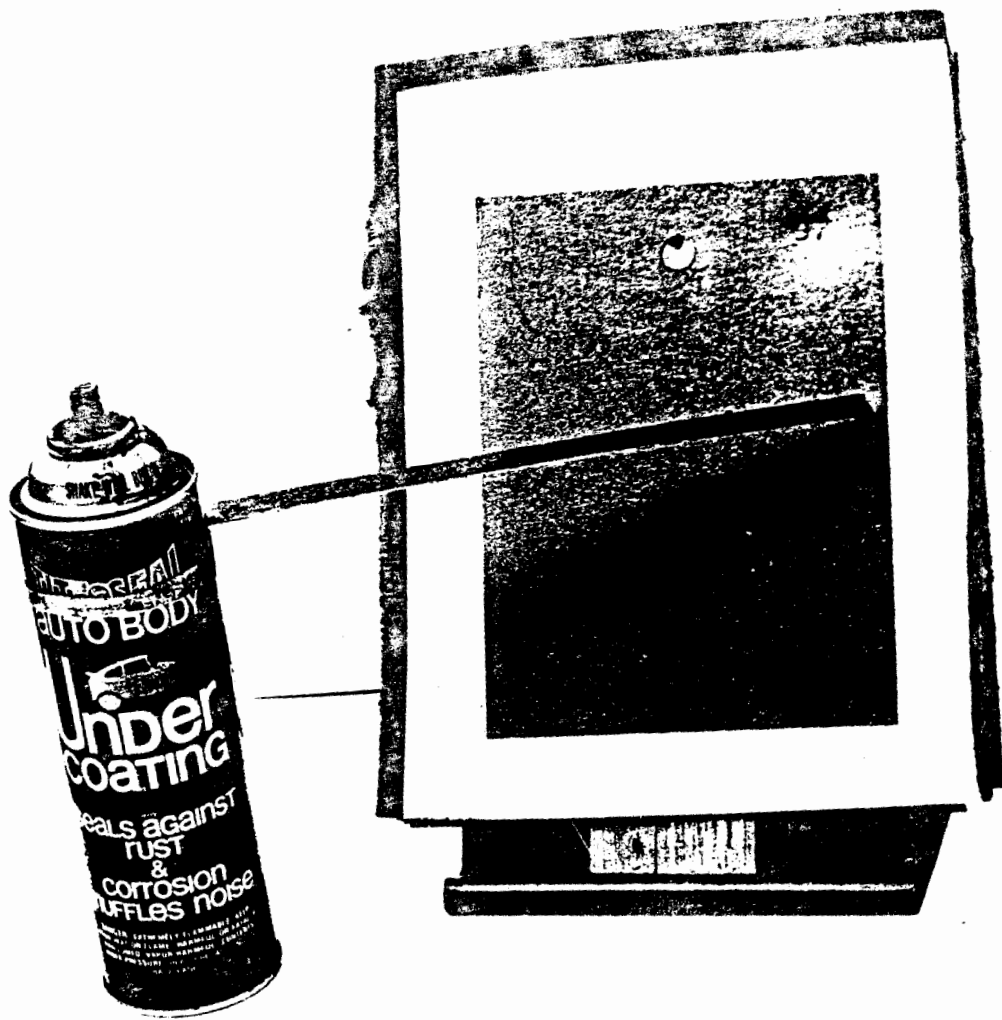


Shown here are the two brands of 'rubberized' undercoatings tested



Shown here are the two brands which were tested in the salt-fog test only

APPENDIX B
COATING APPLICATION AIDS



This illustration shows the spray guide and coupon support stand used to aid in coating application.

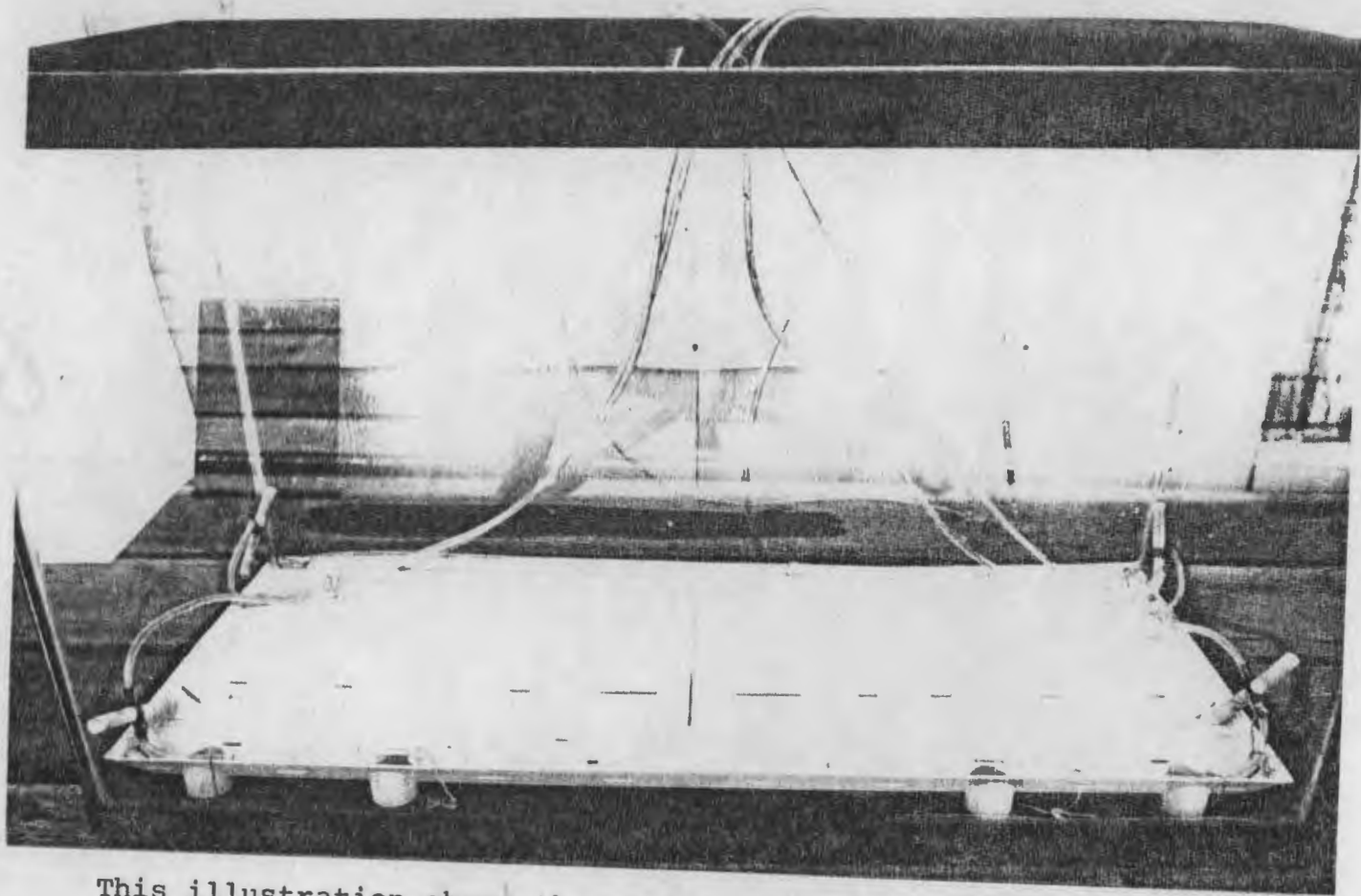
APPENDIX C
COUPON SCRIBING APPARATUS



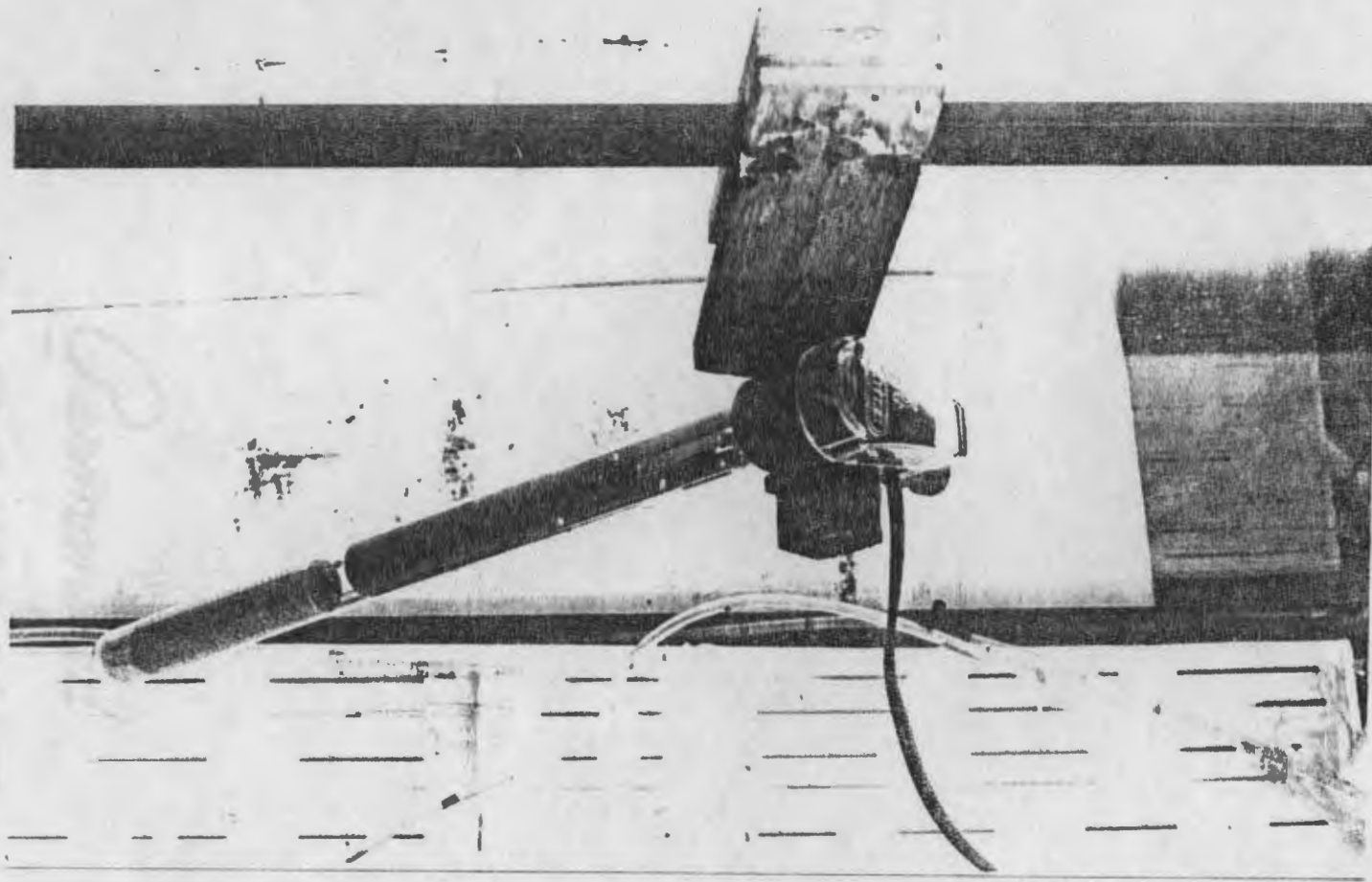
Shown here are the aligning fixture
and scribe used to scribe the coupons

APPENDIX D
HARSHAW GS SALT-FOG CABINET

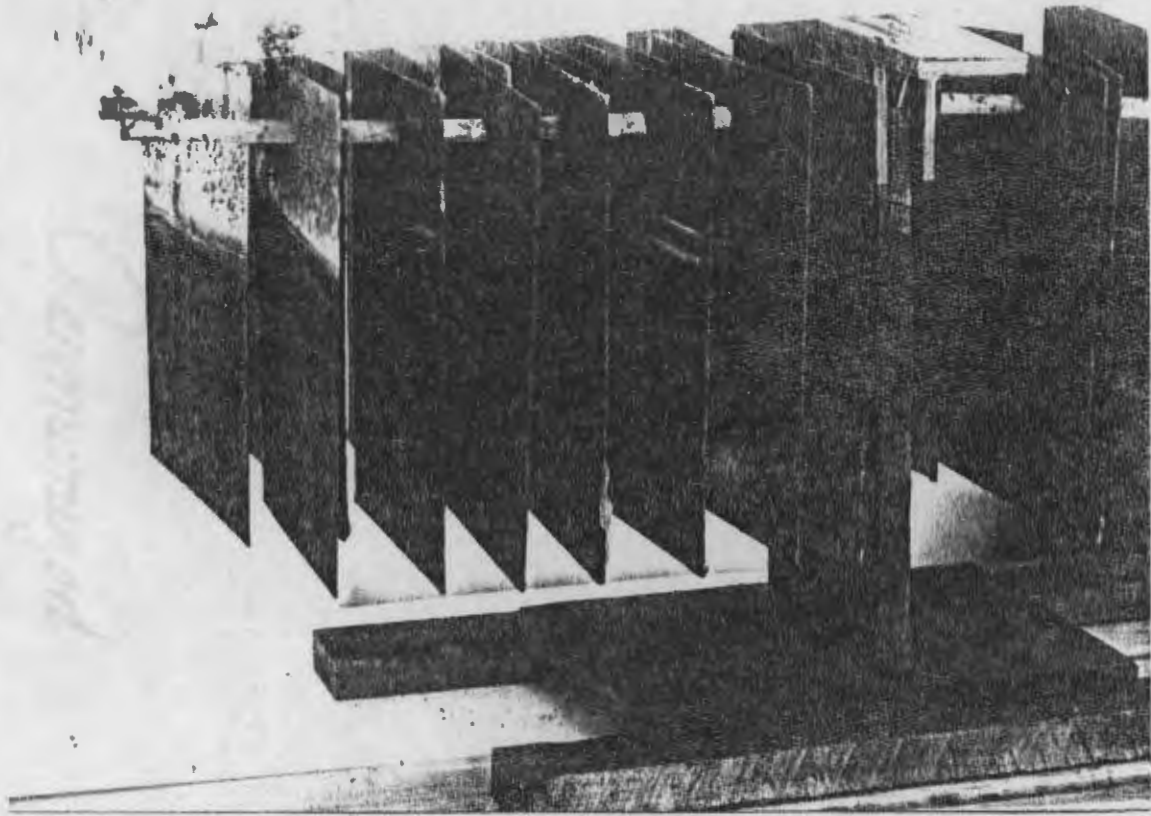
APPENDIX E
IMMERSIVE TEST EQUIPMENT



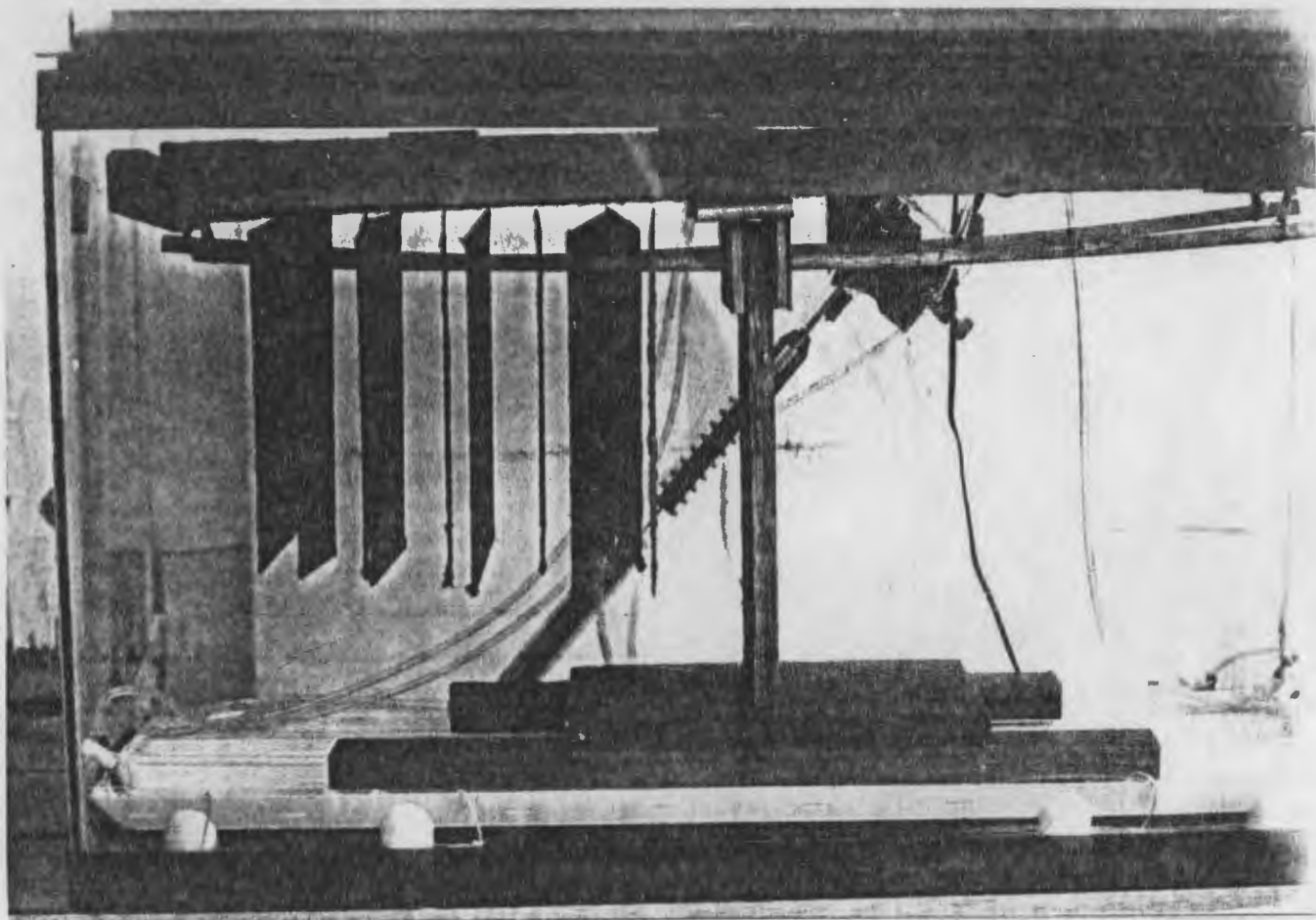
This illustration shows the positioning of the airstones at the corners of the aquarium



This top view shows the position of the thermostatically-controlled aquarium heater in the tank

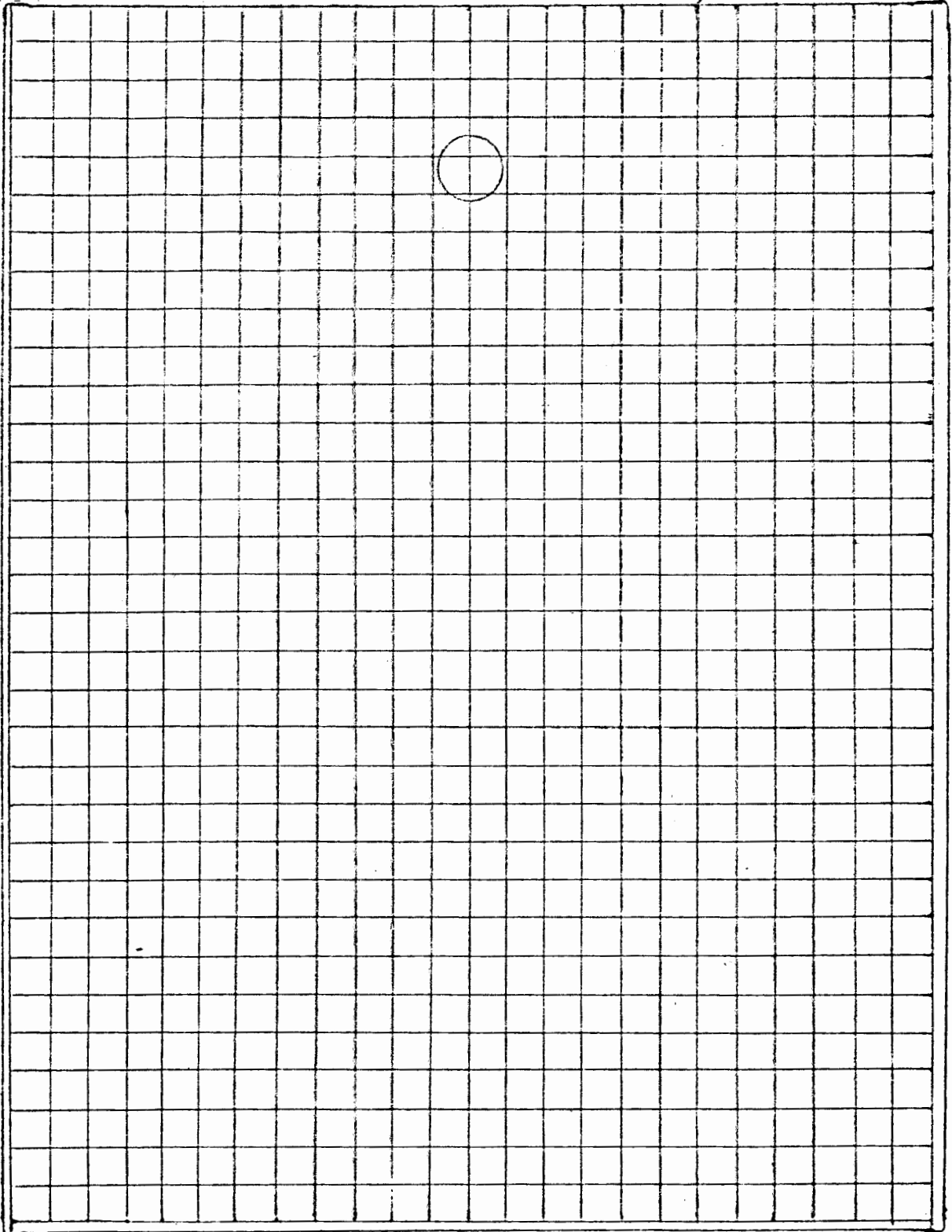


Coupon rack and coupons shown after exposure

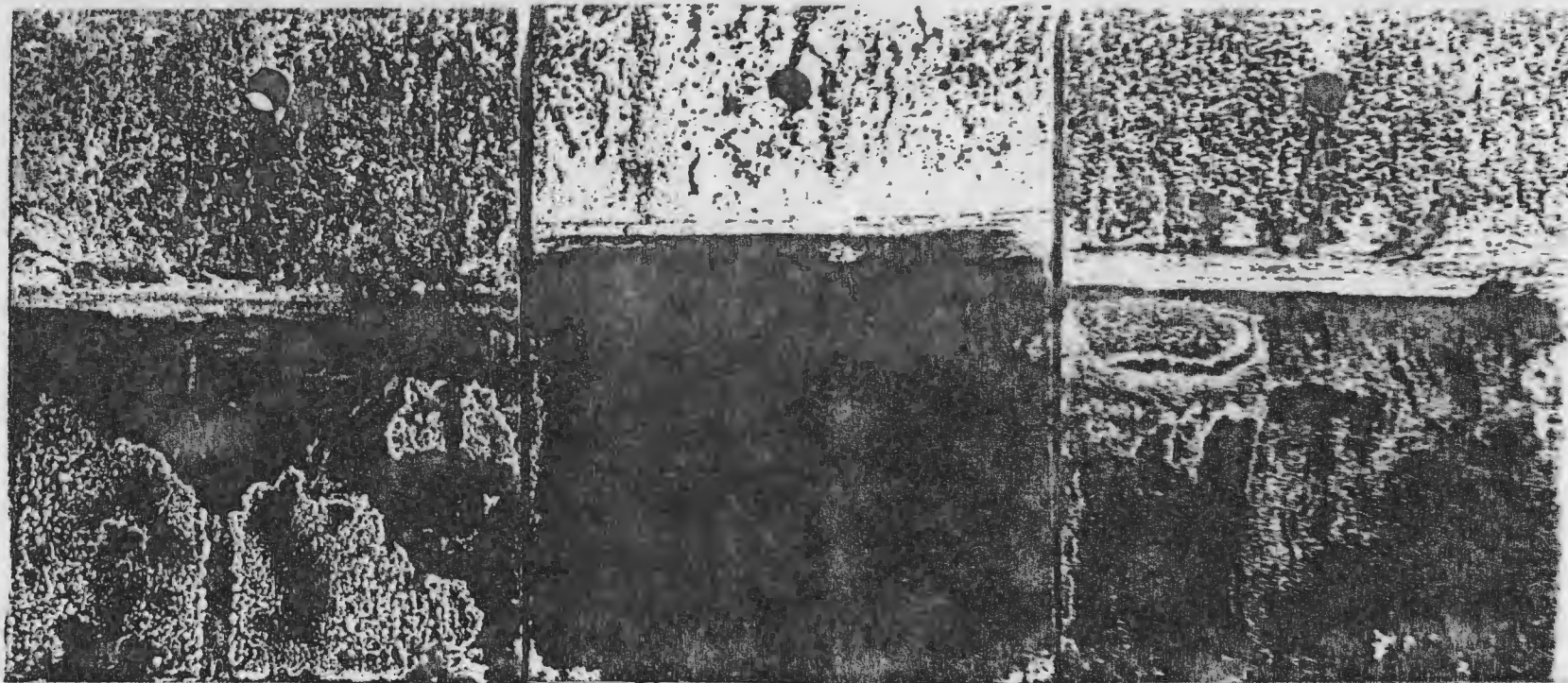


This picture was taken after tank was drained and cleaned. It shows the position of the coupon rack in the tank. Note coupons shown are not properly mounted.

APPENDIX F
CORROSION EVALUATION GRID



APPENDIX G
COATED COUPONS AFTER EXPOSURE IN IMMERSION TANK

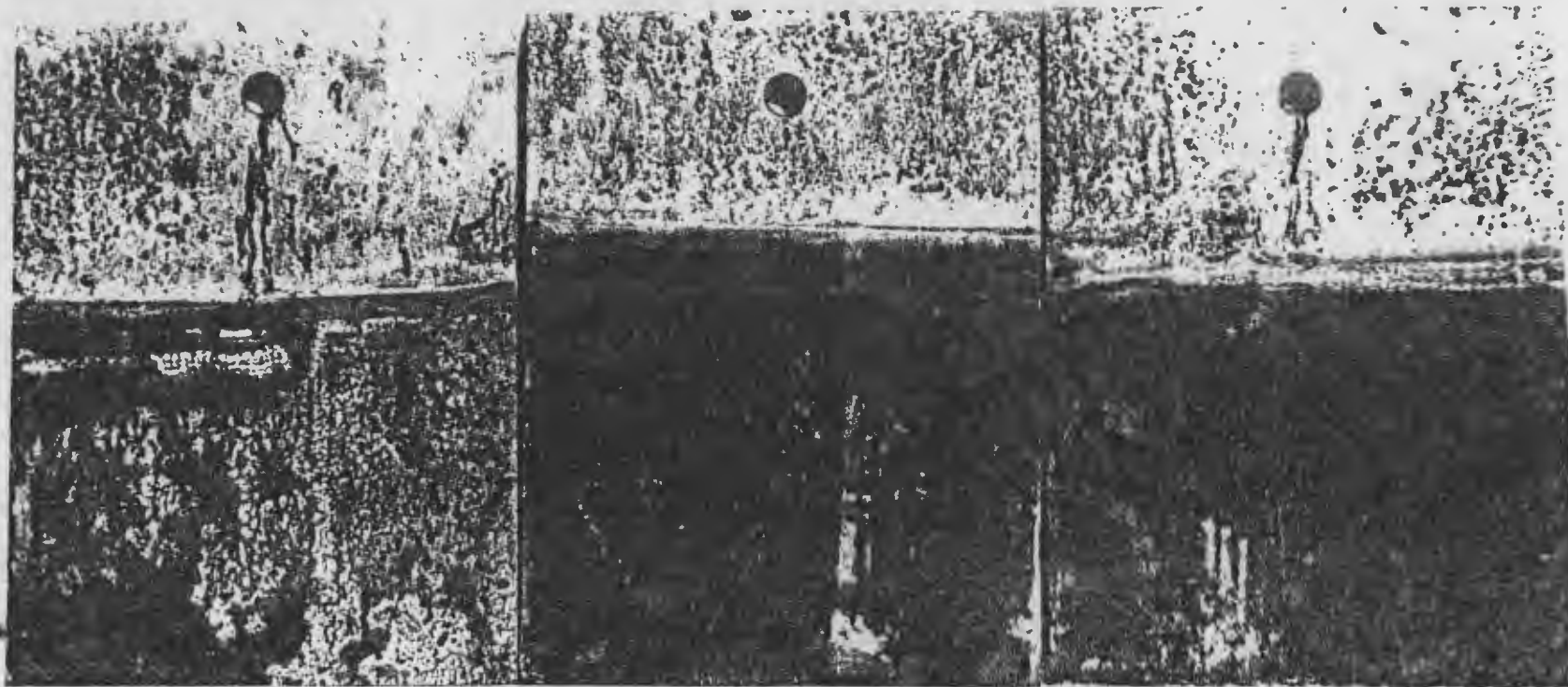


Coupon #31

Coupon #32

Coupon #33

Control - Front

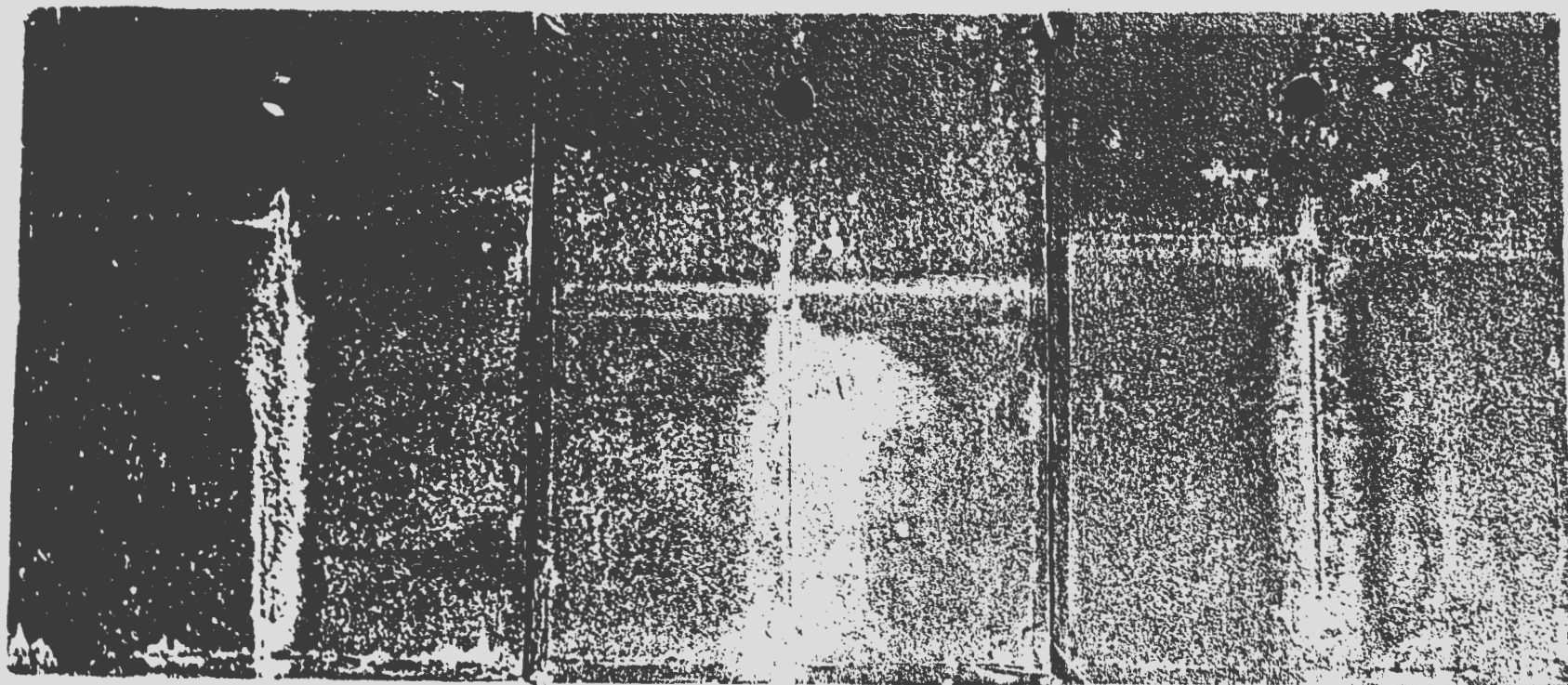


Coupon #31

Coupon #32

Coupon #33

Control - Back

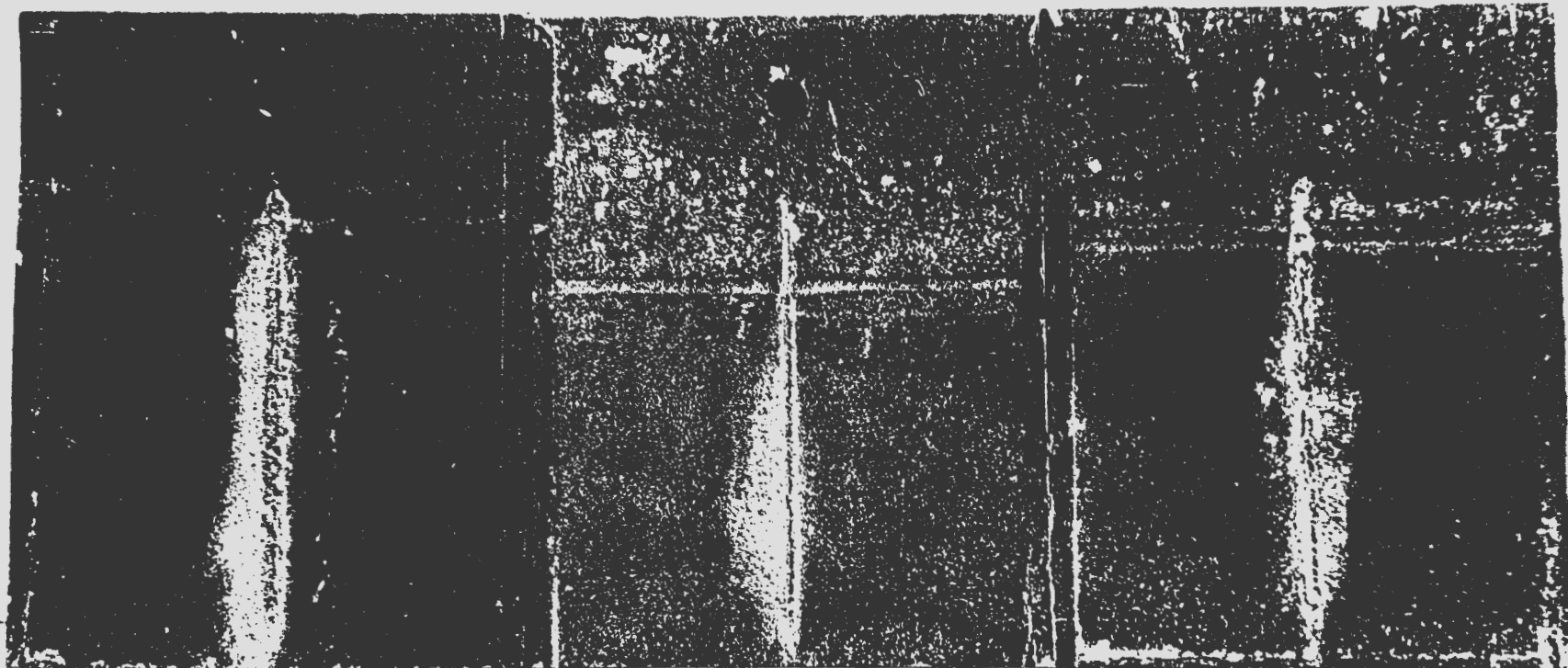


Coupon #34

Coupon #35

Coupon #36

Permatex - Front

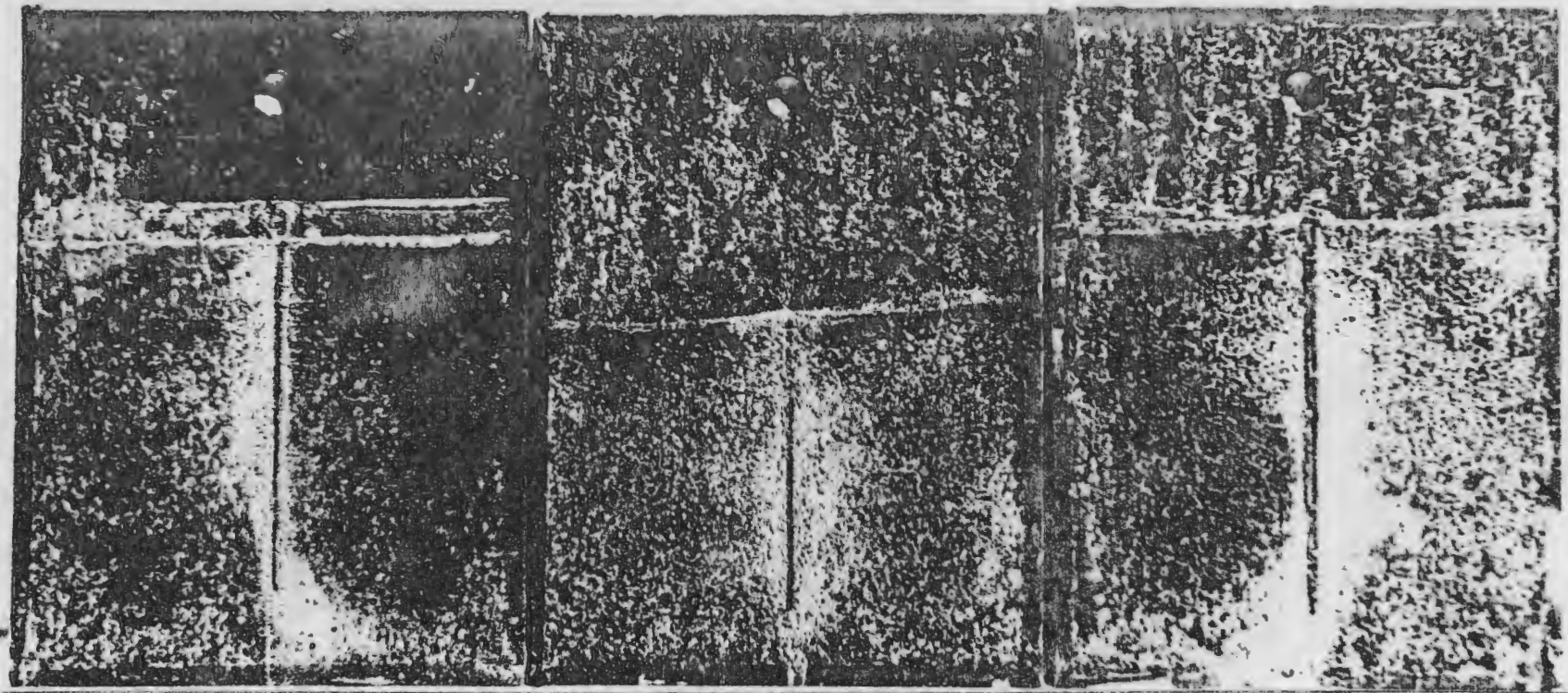


Coupon #34

Coupon #35

Coupon #36

Permatex - Back

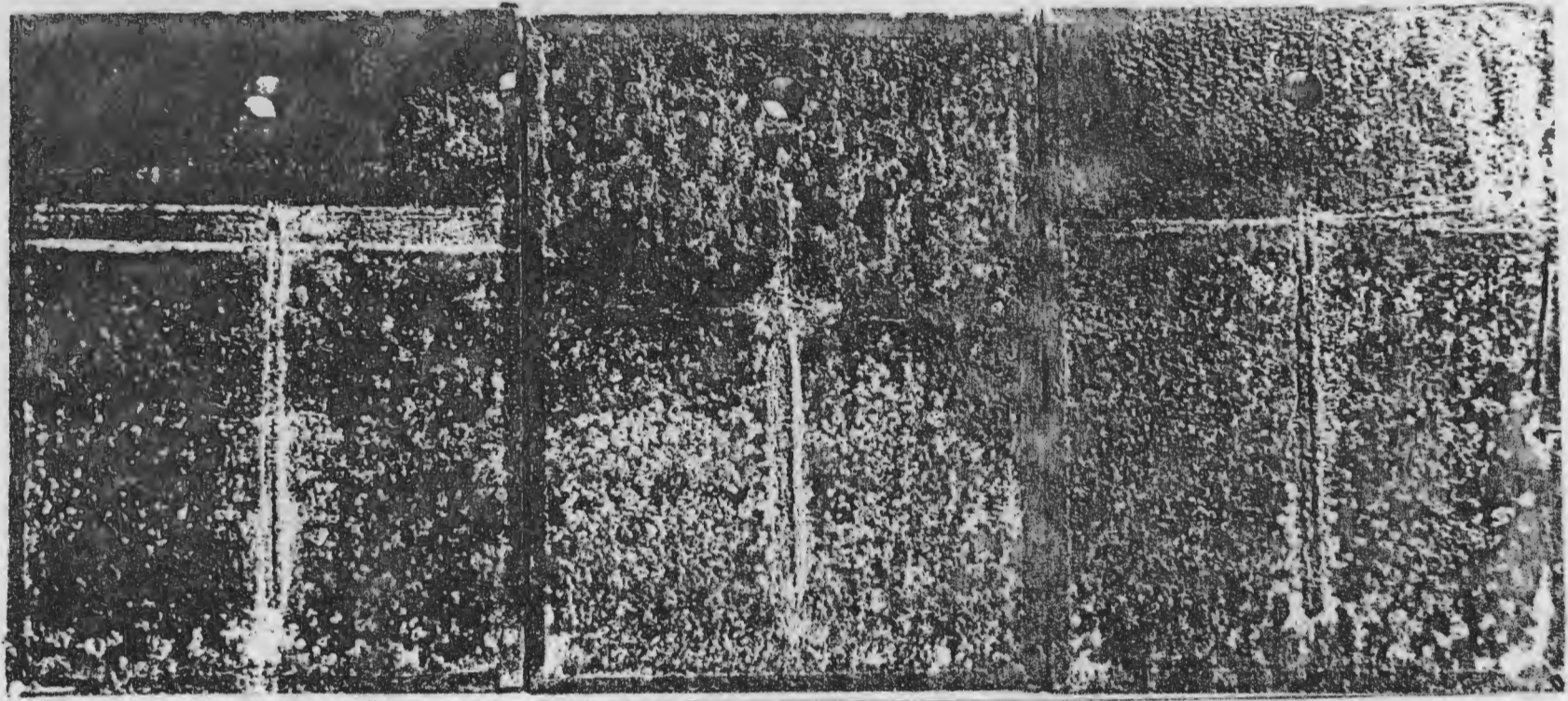


Coupon #37

Coupon #38

Coupon #39

Permatex Rubberized - Front

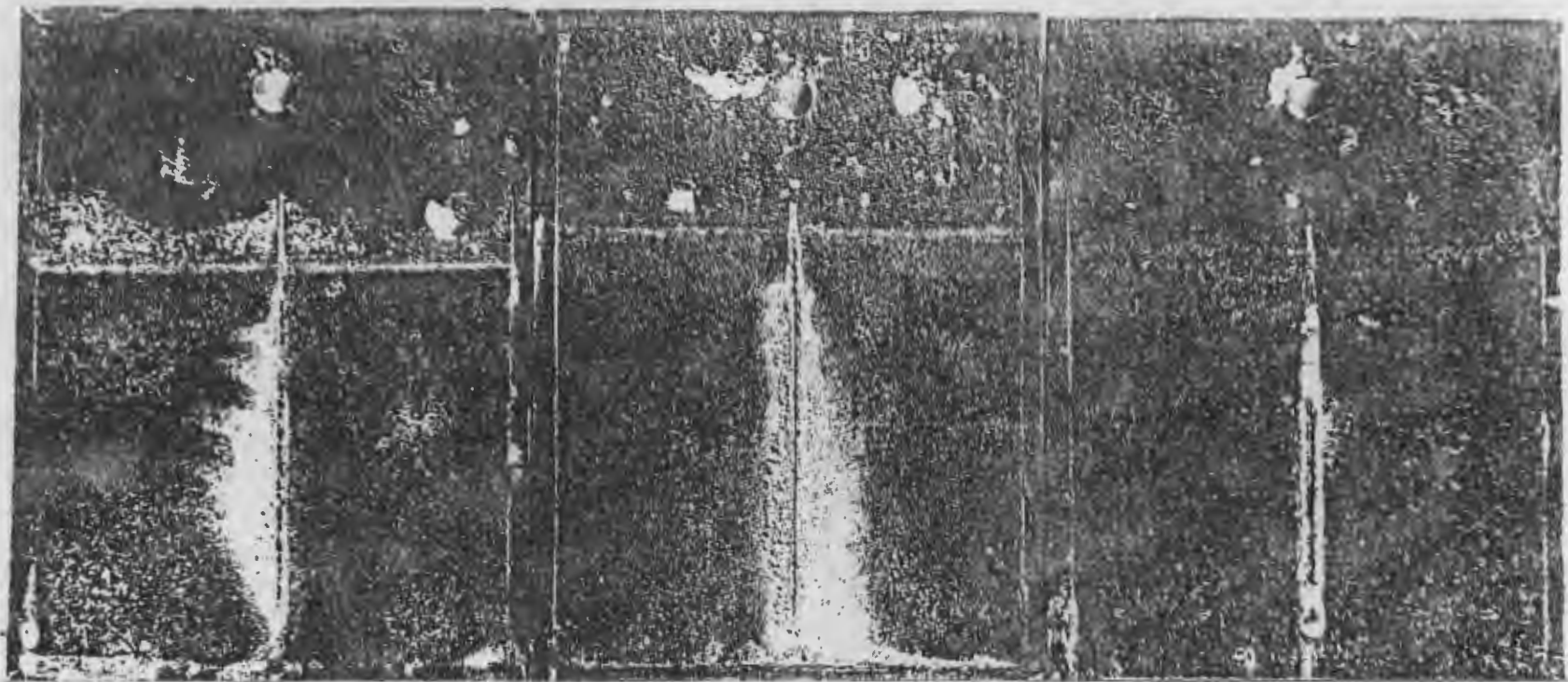


Coupon #37

Coupon #38

Coupon #39

Permatex Rubberized - Back

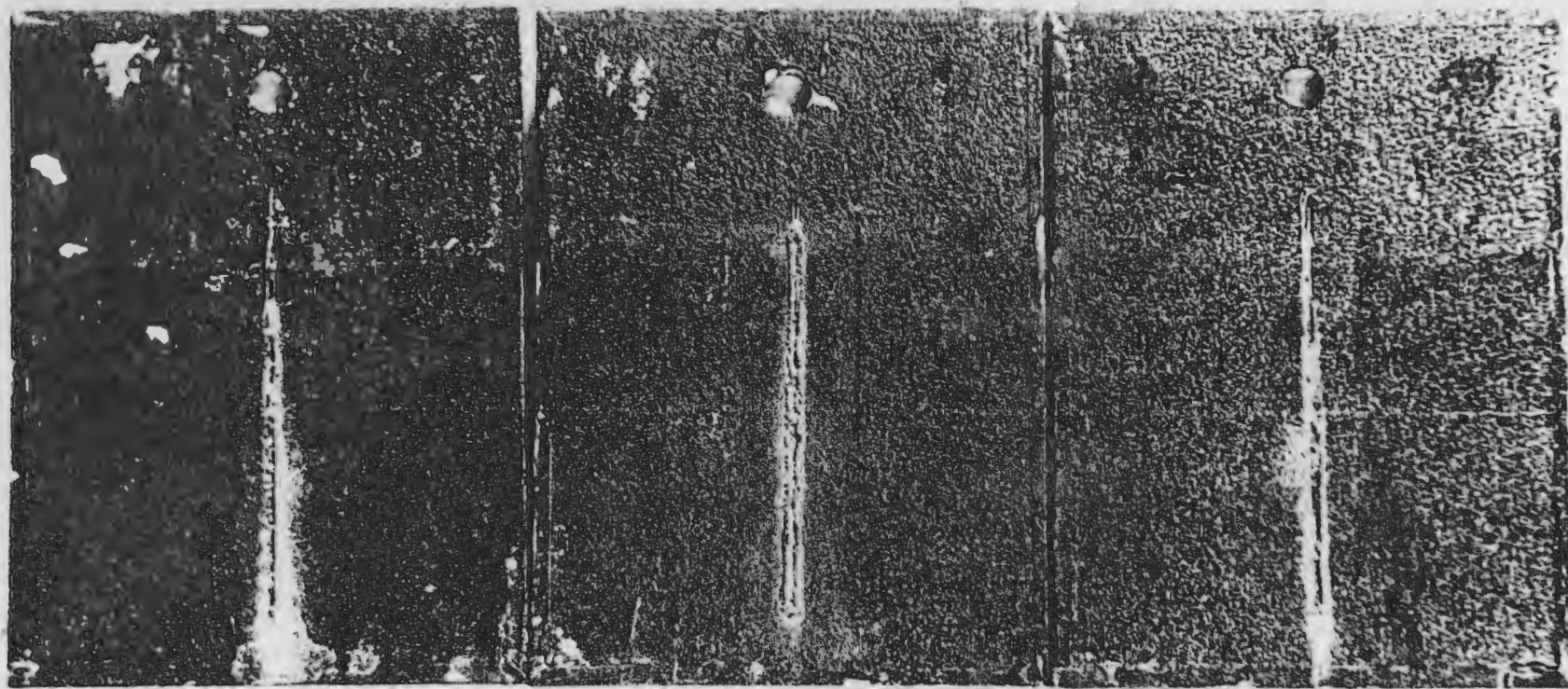


Coupon #40

Coupon #41

Coupon #42

Swiss - Front

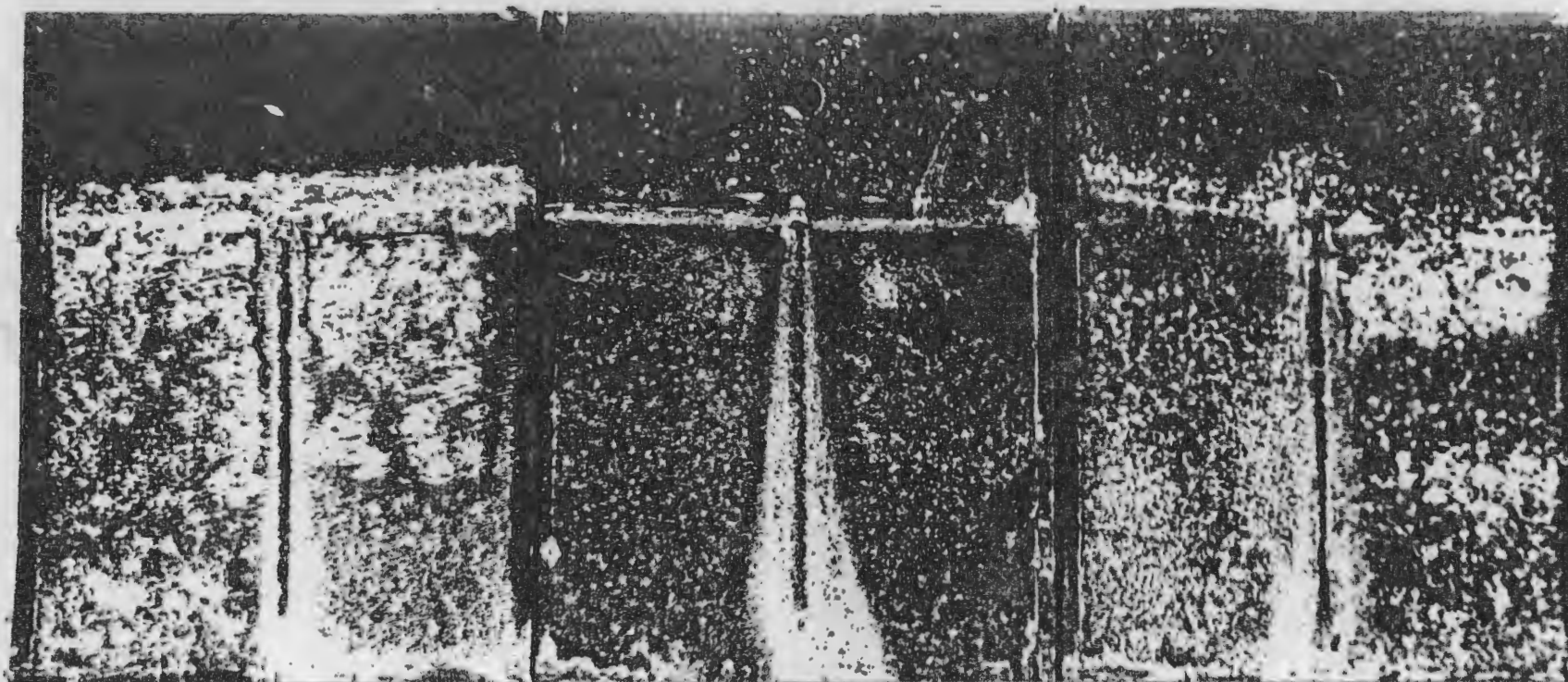


Coupon #40

Coupon #41

Coupon #42

Swiss - Back

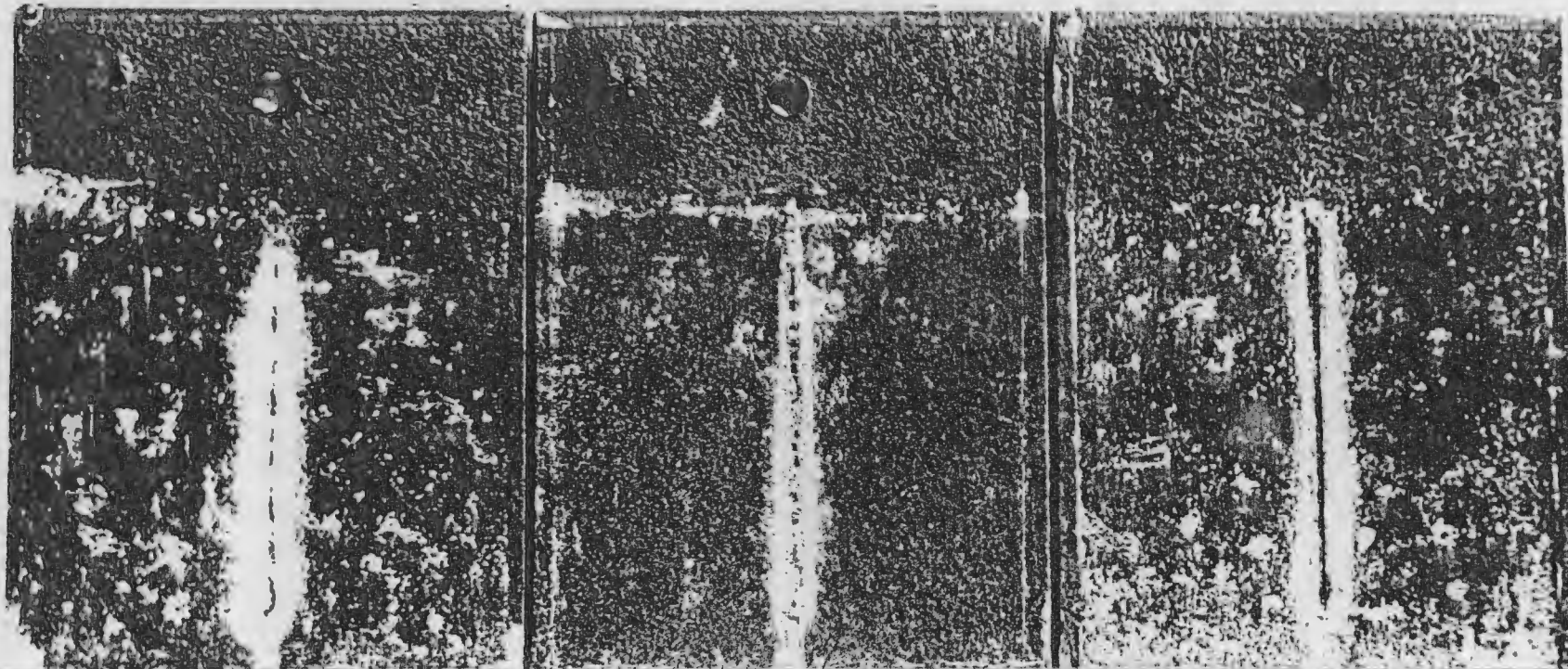


Coupon #43

Coupon #44

Coupon #45

Tite-Seal - Front

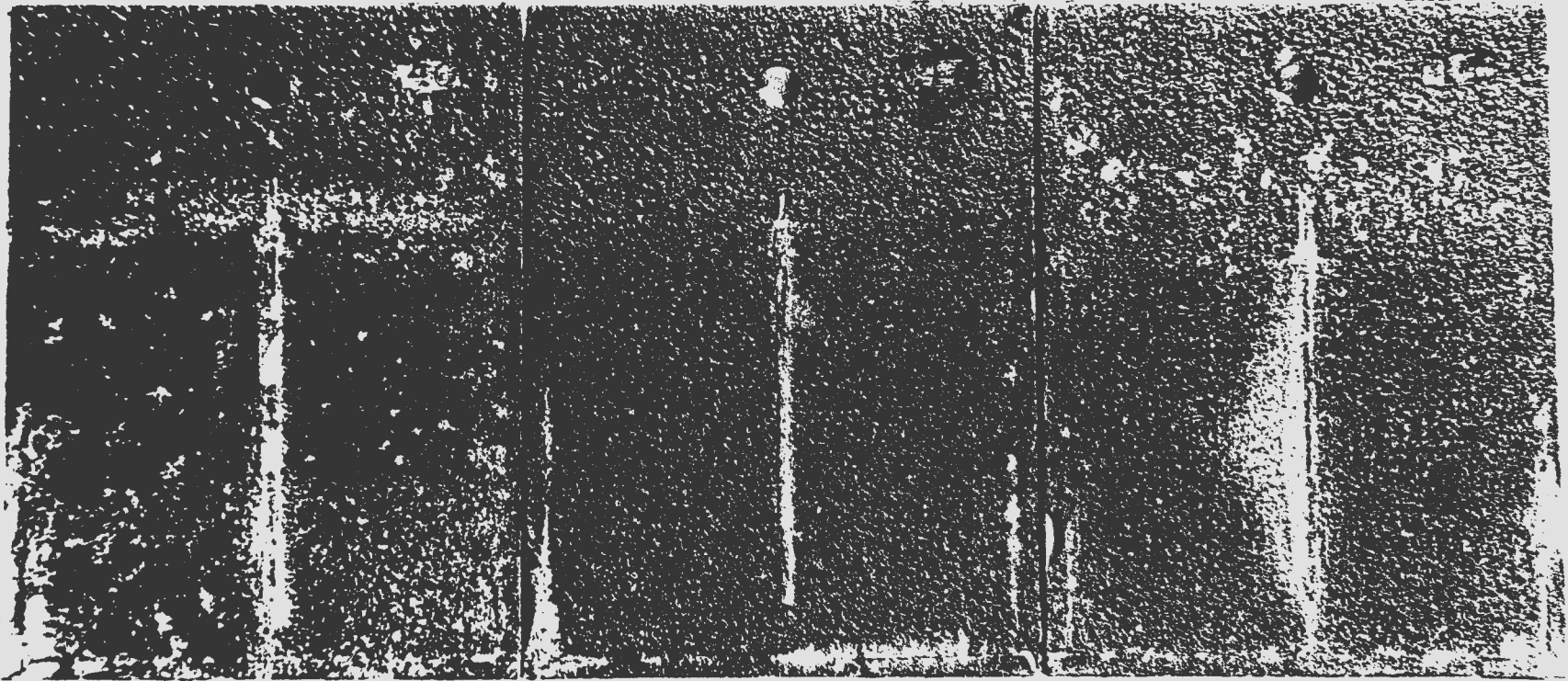


Coupon #43

Coupon #44

Coupon #45

Tite-Seal - Back

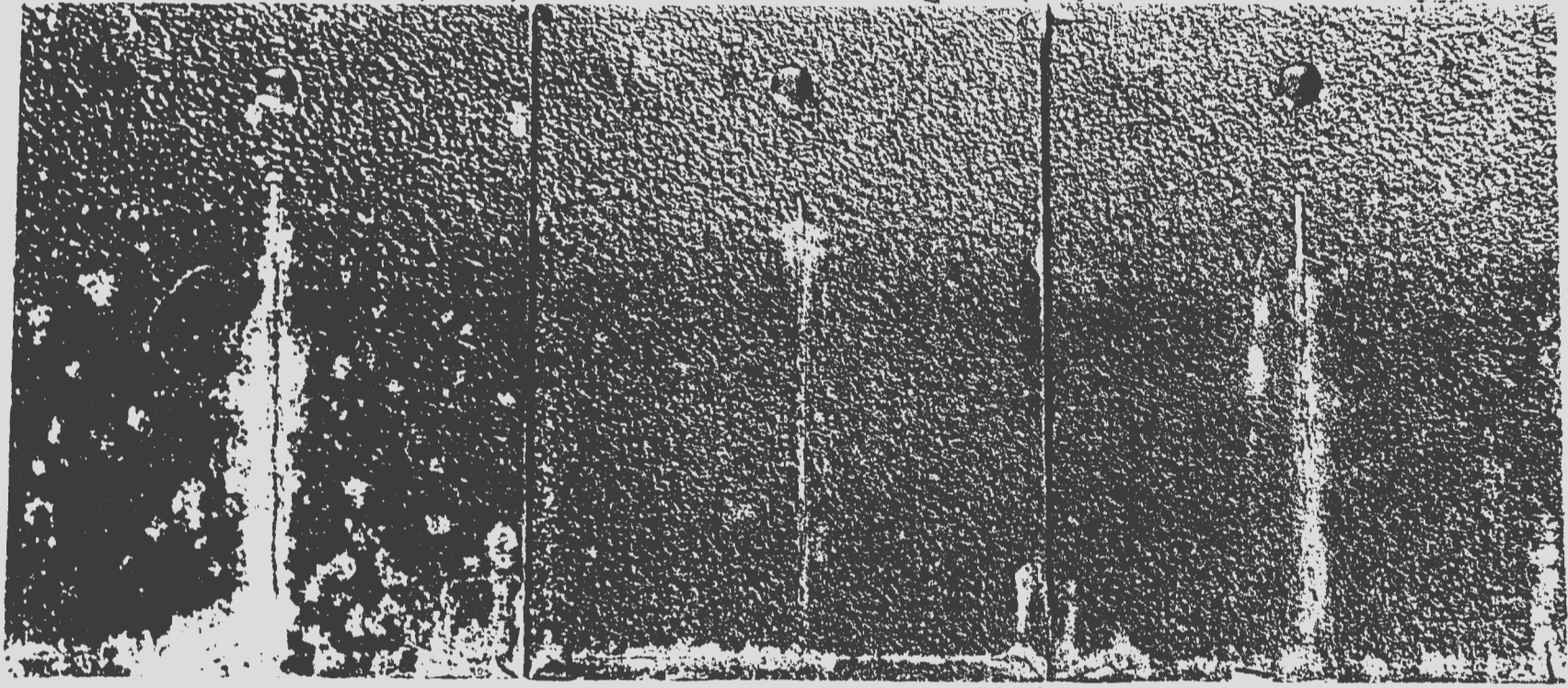


Coupon #46

Coupon #47

Coupon #48

3M - Front

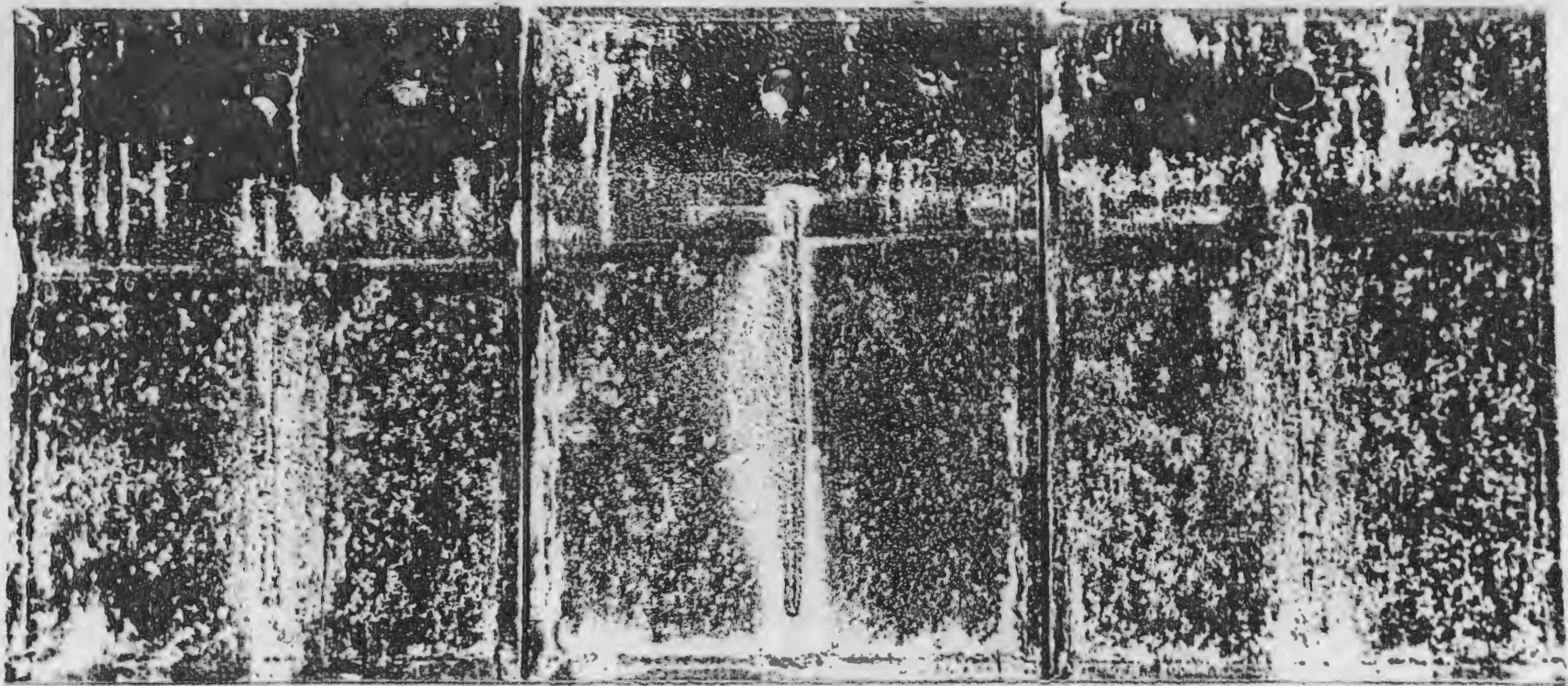


Coupon #46

Coupon #47

Coupon #48

3M - Back

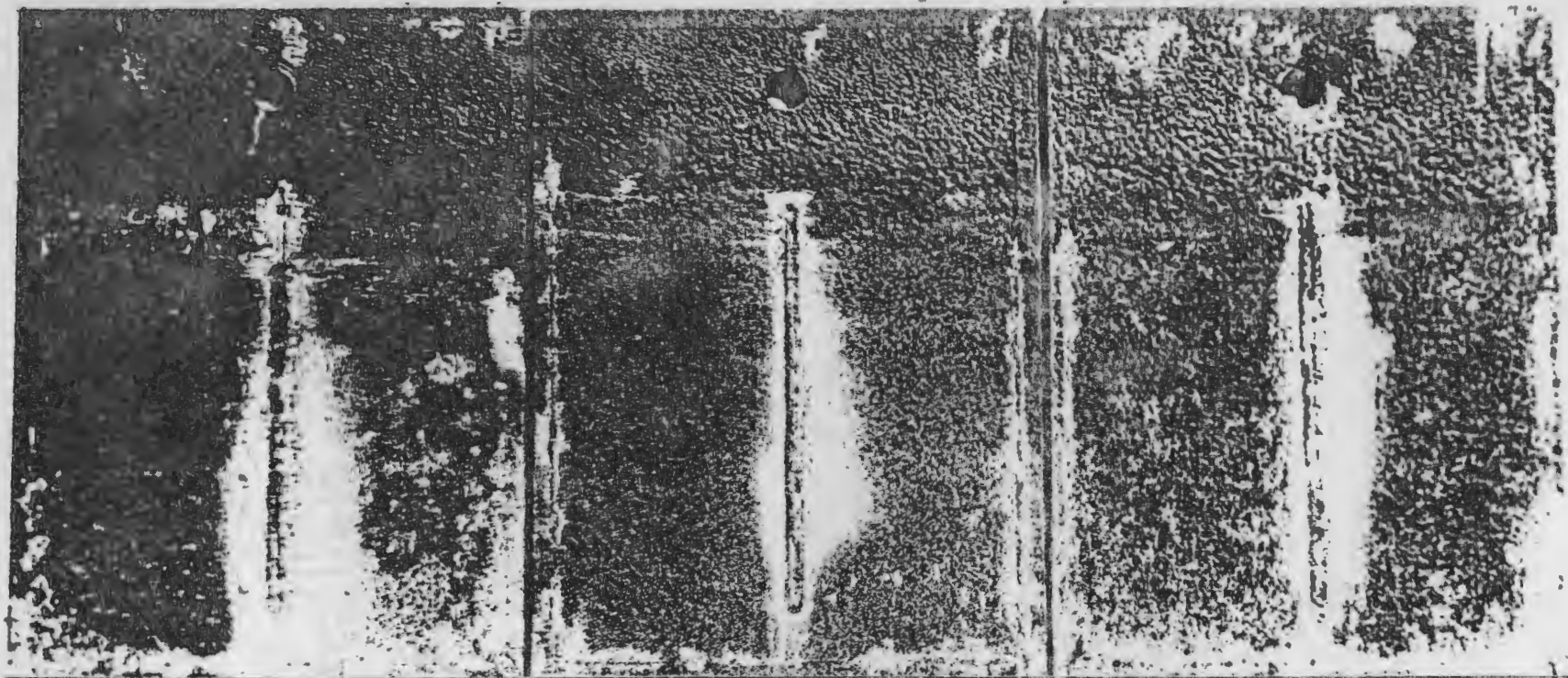


Coupon #49

Coupon #50

Coupon #51

3M Rubberized - Front

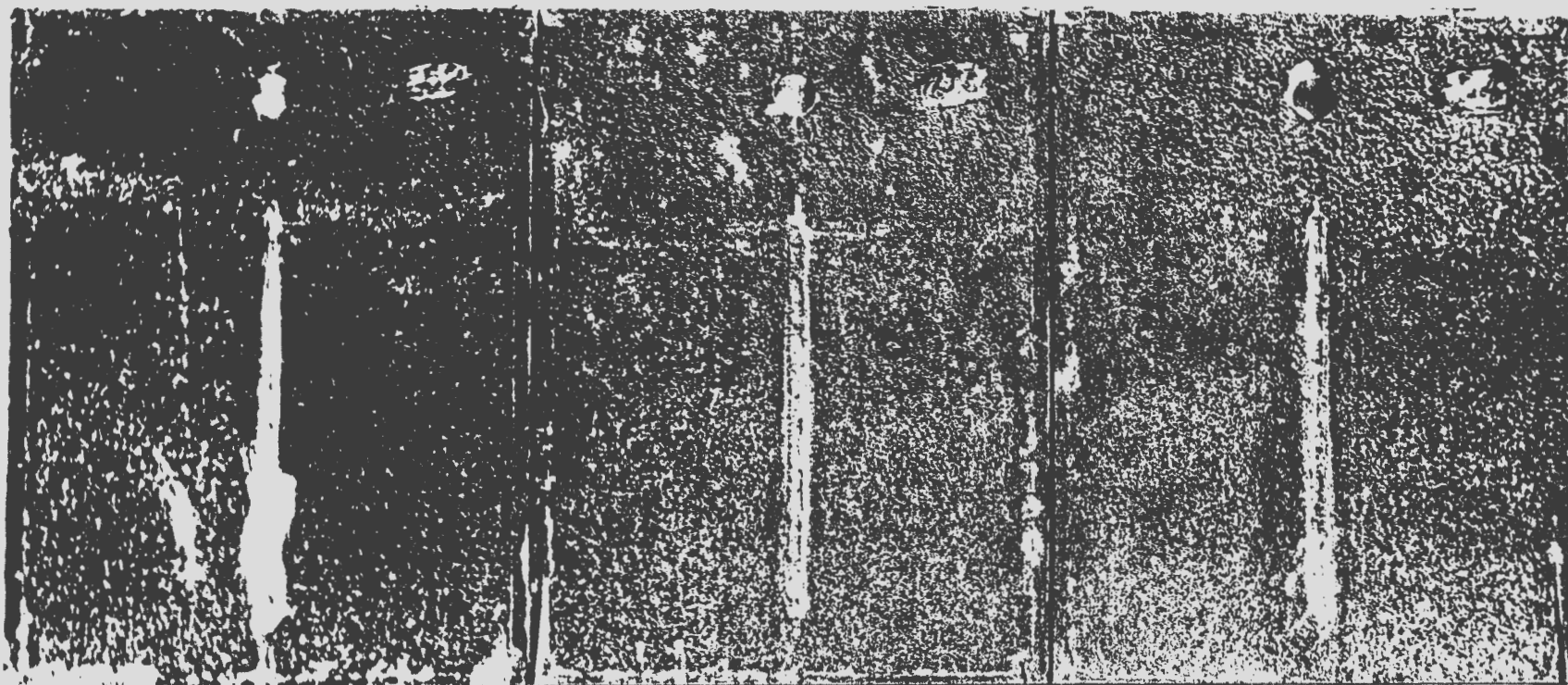


Coupon #49

Coupon #50

Coupon #51

3M Rubberized - Back

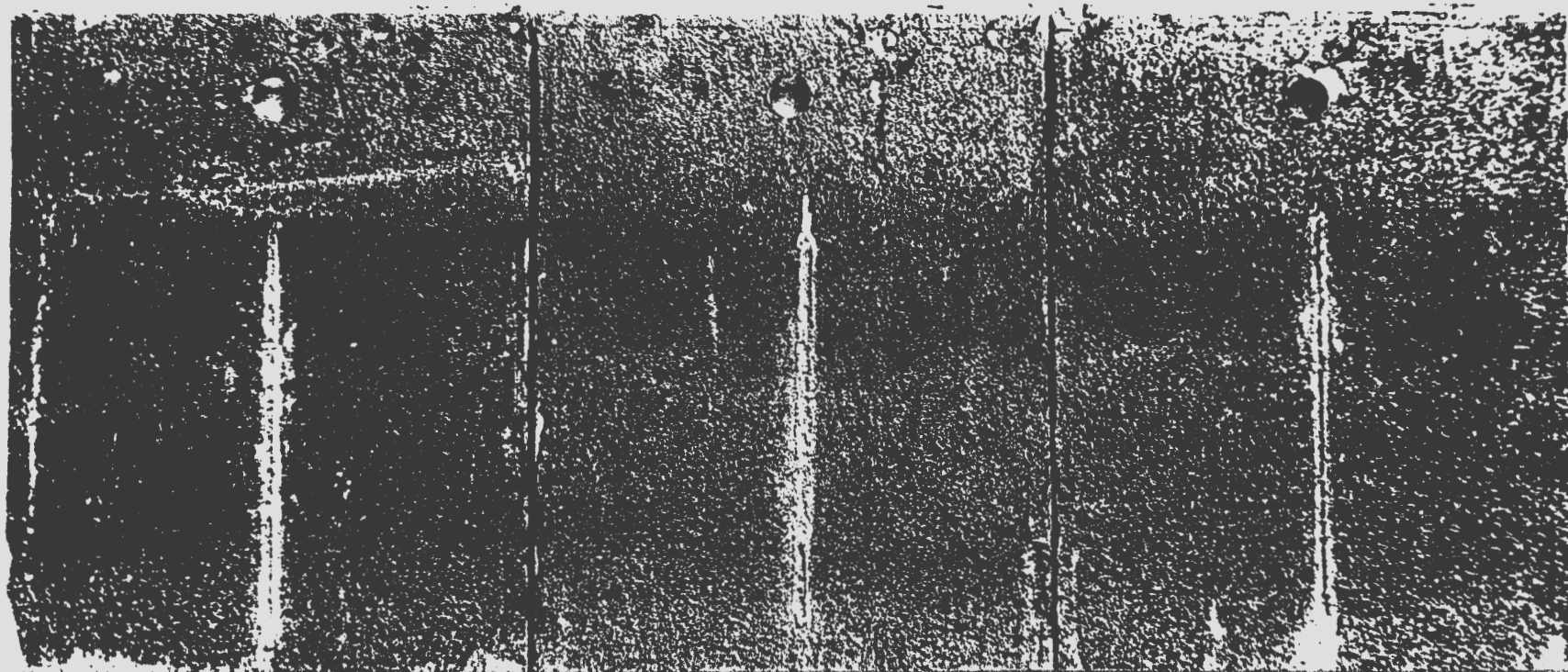


Coupon #52

Coupon #53

Coupon #54

K-Mart - Front



Coupon #52

Coupon #53

Coupon #54

K-Mart - Back

APPENDIX H
COUPON WEIGHT LOSS DURING IMMERSIVE TEST

Coupon Weight Loss
During Immersive Testing

Product Name	Coupon Number	Original Weight	Weight After Testing	Weight Loss	Average Weight Loss
Control	31	208.40	200.86	7.54	7.66
	32	213.00	205.84	7.16	
	33	212.45	204.15	8.30	
Permatex	34	212.78	212.14	0.64	0.70
	35	212.02	211.28	0.74	
	36	212.45	211.72	0.73	
Permatex Rubberized	37	212.01	210.77	1.24	1.24
	38	206.71	205.68	1.03	
	39	211.34	209.88	1.46	
Swiss	40	210.95	210.23	0.72	0.63
	41	206.07	205.42	0.65	
	42	209.05	208.52	0.53	
Tite-Seal	43	211.70	211.09	0.61	0.71
	44	210.35	209.62	0.73	
	45	212.22	211.42	0.80	
3M	46	209.90	209.16	0.74	0.43
	47	209.40	209.22	0.18	
	48	211.11	210.74	0.37	
3M Rubberized	49	209.58	209.20	0.38	0.71
	50	209.08	208.50	0.57	
	51	209.32	208.15	1.17	
K-Mart	52	211.13	210.77	0.36	0.41
	53	209.73	209.24	0.49	
	54	210.22	209.83	0.39	
Spray Galv	55	211.31	211.29	0.02	0.02
	56	213.71	213.69	0.02	

APPENDIX I
COUPON CREEPBACK AND FAILURE MEASUREMENTS

Coupon Creepback and
Failure Measurements

Product Name	Coupon #	Front of Coupon							Back of Coupon						
		Farthest Failure	Metric (mm)	Closest Failure	Metric (mm)	Average Creepback	Effected Squares [Ⓐ]	% Of Failure	Farthest Failure	Metric (mm)	Closest Failure	Metric (mm)	Average Creepback	Effected Squares [Ⓐ]	% Of Failure
Control	31 32 33	Complete corrosion of exposed surface							Complete corrosion of exposed surface						
Permatex	34	0.59	15.08	0.13	3.18	4.56	161	30	0.75	19.05	0.16	3.97	5.76	140	26
	35	1.44	36.51	0.09	2.38	9.72	454	86	0.84	21.43	0.06	1.59	5.76	448	85
	36	0.75	19.05	0.09	2.38	5.36	185	35	0.88	22.23	0.09	2.38	6.15	126	24
Permatex*	37	0.13	3.18	0.03	0.79	0.99	511	96	0.13	3.18	0.03	0.79	0.99	498	94
	38	0.16	3.97	0.06	1.59	1.39	530	100	0.16	3.97	0.06	1.59	1.39	527	99
	39	0.13	3.18	0.06	1.59	1.19	524	99	0.13	3.18	0.06	1.59	1.19	501	95
Swiss	40	0.81	20.64	0.06	1.59	5.56	120	23	0.38	9.53	0.03	0.79	2.58	67	13
	41	1.00	25.40	0.09	2.38	6.95	140	26	0.47	11.91	0.09	2.38	3.57	54	10
	42	0.44	11.11	0.06	1.59	3.18	67	13	0.25	6.35	0.06	1.59	1.99	49	9

Ⓐ Maximum squares = 530 per side

*Rubberized product

Coupon Creepback and
Failure Measurements

Product Name	Coupon #	Front of Coupon							Back of Coupon						
		Farthest Failure	Metric (mm)	Closest Failure	Metric (mm)	Average Creepback	Effected Squares @	% Of Failure	Farthest Failure	Metric (mm)	Closest Failure	Metric (mm)	Average Creepback	Effected Squares @	% Of Failure
Tite-Seal	43	0.50	12.70	0.06	1.59	3.57	72	14	0.34	8.73	0.06	1.59	2.58	338	64
	44	0.75	19.05	0.09	2.38	5.36	340	64	0.38	9.53	0.09	2.38	2.98	388	73
	45	1.00	25.40	0.09	2.38	6.95	111	21	0.63	15.38	0.06	1.59	4.37	58	11
3M	46	0.63	15.88	0.06	1.59	4.37	196	37	0.50	12.70	0.06	1.59	5.18	328	62
	47	0.38	9.53	0.06	1.59	2.78	46	9	0.25	6.35	0.03	0.79	1.79	49	93
	48	0.31	7.94	0.09	2.38	2.58	133	25	0.06	1.59	0.03	0.79	0.60	117	22
3M*	49	0.75	19.05	0.13	3.18	5.56	485	92	0.75	19.05	0.22	5.56	6.15	454	86
	50	0.59	15.08	0.25	6.35	5.36	308	58	0.47	11.91	0.25	6.35	4.56	140	26
	51	0.31	7.94	0.22	5.56	3.37	501	95	0.22	10.32	0.41	5.56	3.97	405	76
K-Mart	52	0.25	6.35	0.06	1.59	1.98	439	83	0.31	7.94	0.13	3.18	2.78	82	16
	53	0.34	8.73	0.06	1.59	2.58	425	80	0.28	7.14	0.09	2.38	2.38	65	12
	54	0.44	11.11	0.06	1.59	3.18	353	67	0.30	7.54	0.11	2.78	2.58	67	13
Spray Galv	55	0.03	0.79	0.03	0.79	0.40	11	2	0.03	0.79	0.03	0.79	0.40	9	2
	56	0.03	0.79	0.03	0.79	0.40	7	1	0.03	0.79	0.03	0.79	0.40	5	1

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