[Reprinted from Journal of Chemical Education, Vol. 10, No. 9. September 1933.]

TESTING HOUSE PAINTS *for* DURABILITY

F. L. BROWNE

Forest Products Laboratory,*

Forest Service, U. S. Dept. of Agriculture,

Madison, Wisconsin

Paint making is still an art rather than an applied science. The approach to a scientific knowledge of paints and paint durability must be made by the empirical route. The present article outlines some of the variables which must be taken into account in paint testing and describes a technic for the conducting and recording of durability tests.

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HOUSE paints have been developed empirically out of ancient craftsmanship; they are not yet to be regarded as products of science applied to industry. Many facts have been learned about paints through experience and practical testing but it has not yet been possible to establish general laws of paint behavior to correlate the facts. To be sure, the literature of the subject is replete with theories that are glibly accepted without verification by crucial experimentation and possess a remarkable ability to live on, long after they have been proved grossly inconsistent with the facts. Not only is there competition between rival theories but the facts themselves must be sought among a mass of utterly contradictory assertions often unsupported by citation of evidence. Moreover, there is as yet neither a generally accepted technic of measuring the durability of house paint nor agreement upon a definition of durability. The transformation of paint making from an art to a science is much to be desired but is not likely to be achieved for some time to come even though progress in that direction is proceeding more rapidly than it has in the past. Meantime current problems must continue to be met through frankly empirical experimentation and observation.

The young graduate in chemistry confronted with the problem of paint evaluation often finds it difficult to adjust himself to the empirical method of procedure. His college training usually has taught him very little about it and, still worse, may have led him to hold it in light regard. As a result he tends to shirk the direct attack upon the immediate objective in order to pursue some minor aspect of the problem by methods that are more to his taste. A well-grounded fear that empiricism in papers offered for publication in the chemical journals may be received with little enthusiasm by the evangels of the profession proves an additional discouragement. The young chemist's early years in such industries as paint making would be both happier and more fruitful if his college training taught him that empiricism must blaze the trail for science and that industry must solve its problems empirically when it cannot wait for the more adequate answer ultimately possible through the scientific method.

PAINT FAILURE OF THIS KIND IS NEVER OBSERVED ON PAINT TEST FENCES BUT ALL TOO FREQUENTLY ENCOUNTERED ON HOUSES

It is caused by moisture gaining access to the back of the painted woodwork. The possibility of such developments makes paint tests on houses uncertain; it also makes it necessary to study the behavior of paints when subject to such conditions before their merits for general house painting can be fully understood.

Empirical experimentation to be effective must usually be conducted on a much larger scale than scientific experimentation. This is particularly true of paint testing. Failure to appreciate it has led to great waste of effort and the disappointing results have done much to throw durability tests into disrepute. The durability of a paint depends on many factors besides its composition. Not all of the factors are known. It is, therefore, essential that the testing procedure duplicate practical conditions of service as closely as possible and take account of the probable variations in conditions of service. Many exposure tests are required to accomplish useful comparison of even a small number of paints, and the tests must extend over a period of several

*** Maintained at Madison, Wisconsin, in cooperation with The University of Wisconsin.**

years before conclusions may be drawn. Great care' must be taken to plan the tests adequately and to provide satisfactory methods of inspection, record, and evaluation. An adequate program of exposure testing is necessarily expensive, time-consuming, and exacting in its demands for trained technical supervision. In the writer's opinion durability tests of paint should never be attempted when these requirements cannot be met.

ARTIFICIAL WEATHERING TESTS

Strenuous efforts have been made to devise artificial weathering tests for house paints in which results may be obtained in much less time than is required in natural weathering (*1*). Such tests serve usefully as a subordinate part of the research program in large laboratories. They are useful, for example, in rejecting from a large number of previously untried paint compositions those mixtures so seriously faulty that they merit no further consideration, so that the smaller number remaining can be tested adequately by natural weathering. Artificial weathering tests probably will increase in usefulness as the nature of the changes that take place when paints age becomes better understood and study of the disintegrating influences, one by one, becomes desirable.

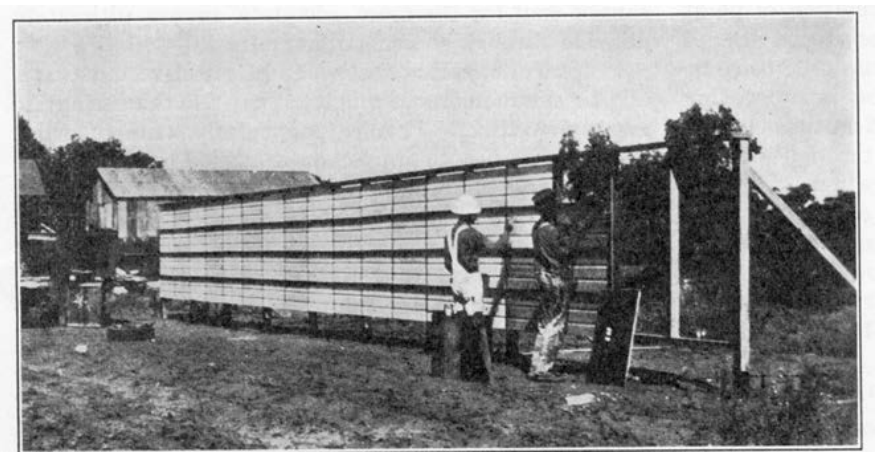
Artificial weathering tests are not at present acceptable as the sole basis for determining the relative durabilities of practical house paints because accelerated deterioration is achieved by deliberate aggravation of some factors in weathering, a procedure that is out of harmony with the requirement that the tests be made under conditions duplicating those of practical service as closely as possible. Results of accelerated tests are not always in satisfactory accord with results obtained by natural weathering.

TESTFENCES

The principal means of measuring the relative durability of house paints is the test fence. For reasons that will be detailed later, houses are less practicable than test fences because complicating factors not yet fully understood sometimes affect the behavior of paint on houses to such an extent that there is often uncertainty whether the deterioration of paint on a house may be attributed purely to normal weathering of the paint. These complicating factors on houses must be studied separately by means of a special technic.

The first paint test fence in the United States is said to have been erected by the U. S. Gutta Percha Paint Company some time prior to 1907 but its existence remained practically unknown outside of the company until recently (*2a*). Many paint manufacturers and paint technologists now conduct such tests (3) but one of the most experienced paint chemists (4) said not long ago that he finds "too few paint companies who have comprehensive and adequate exposure programs. . . . Our future progress in paint development will continue to be based on the evaluations of our exposure tests and not on theoretical considerations." Comparatively little of the data acquired from manufacturers' test fences becomes public through technical publications. The first fence tests to gain public interest were those started in 1907 by the late Senator Ladd while professor of chemistry at North Dakota Agricultural College (*2b*). They were an outgrowth of the famous North Dakota paint law that required all house paints sold in the state to bear a statement of composition unless they contained only white lead, zinc oxide, linseed oil, turpentine, and paint drier. Subsequent test fences to be made public are cited in the list of references (*2c*).

The earlier test fences failed to provide the expected basis for decision between different types of paint. Some of the worst compositions were clearly demonstrated but for the most part opinions about paint formulas remained as divergent after the tests as they were before. The difficulty lay in inadequate understanding of the essential conditions for conducting such tests properly and in the attempt to test too many paint formulas at one time with the means available. Modern knowledge of testing technic, however, has thrown new light on many of the older tests as a result of which a re-examination of the old records often proves very fruitful (5).



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THIS RELATIVELY INEXPENSIVE TEST FENCE AT FRESNO, CALIFORNIA, MAINTAINED BY THE W. P. FULLER CO., HAS BEEN USED FOR TESTS BY THE FOREST PRODUCTS LABORATORY SINCE 1924

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No repairs have been required by the unpainted framework, which is made of heartwood Douglas fir and redwood. Exposures are made on the south side of the fence only. Note that the panels were painted immediately after erection. The amount of paint applied to each panel was determined by weighing on the balance on the upturned box to the left of the fence.

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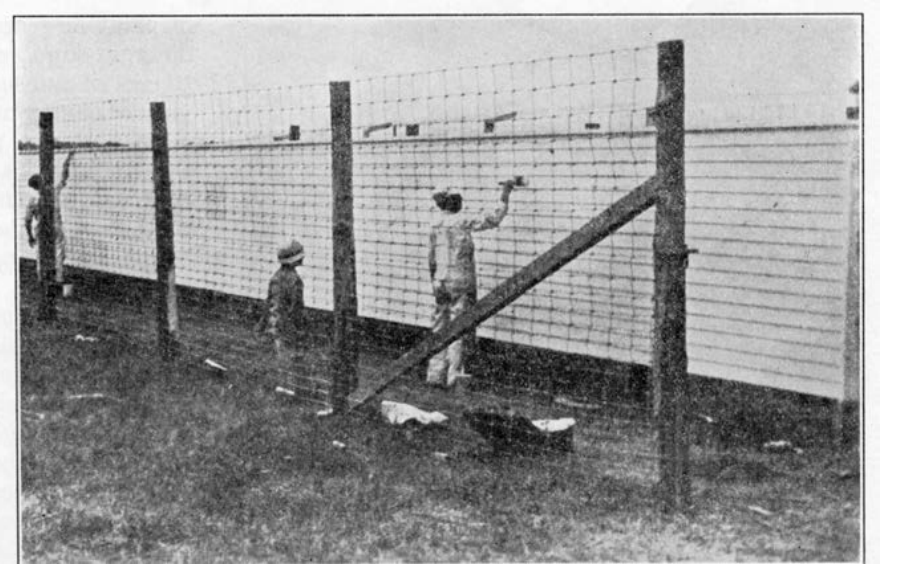


THE TEST FENCE OF THE NORTHWESTERN PAINT AND VARNISH PRODUCTION CLUB AT THE STATE FAIR GROUNDS, ST. PAUL, MINNESOTA, REQUIRES AN OPEN WIRE GUARD FENCE TO PROTECT IT FROM MOLESTATION

Siding lumber is nailed directly to the open framework on both north and south sides. The test areas were marked off by black stripes and numbered after the test paints had dried.

CONSTRUCTION OF TEST FENCES

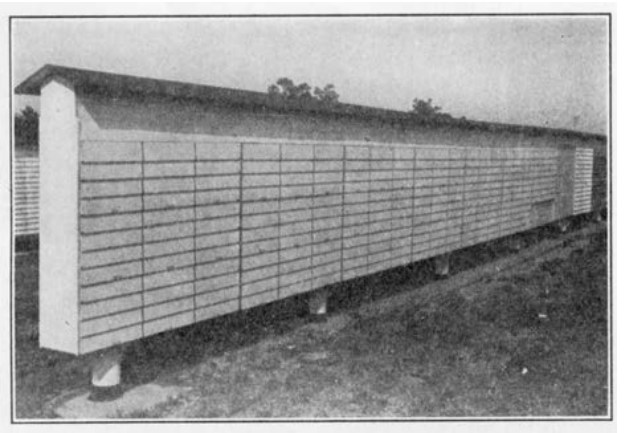
As a rule test fences should be erected in suburban or rural environments rather than in industrial centers. Tests made near factories are subject to serious uncertainties because of extreme accumulation of dirt and soot and possible abnormal chemical reactions with industrial gases. In such surroundings white paints that ordinarily maintain reasonably good appearance have been known to turn totally black and to last much longer than they can be expected to do on residences. Test fences in the country should not be located in unusually damp ground or too close to rivers or lakes to permit the air around the fence to follow the extremes of relative humidity characteristic of the climatic region.

Test fences consist of a simple framework for supporting painted panels. The framework should be durable and strong enough to remain upright during the most severe storms. A very satisfactory construction consists of 4 × 4-inch posts or 6-inch round posts set at least 2½ feet into the ground, projecting 7 feet above ground, and set 6 feet apart from center to center. A concrete collar at the ground line serves to prevent working under wind pressure with consequent loosening of the anchorage in the ground. The posts are subject to decay, at least below the ground line, and must, therefore, be of durable wood. Heartwood of redwood or southern cypress is very durable and heartwood of southern pine or Douglas fir is satisfactory for square posts; cedar or chestnut makes good round posts. Sapwood of any species lacks durability and decays relatively soon. If posts containing much sapwood or non-durable species must be used they should be treated with creosote by impregnation under pressure or treated by the hot-and-cold bath method to a distance at least 18 inches above the ground. Failure to take proper precautions against decay has repeatedly resulted in the blowing down of test fences or in the necessity of replacing posts at frequent intervals. Surface application of creosote does not afford adequate protection for posts and paint is of no use whatever for that purpose. The Forest Products Laboratory fence at Madison, Wisconsin, built with creosoted posts, has stood for nearly eleven years without a single replacement or any sign of rot. A fence at Seattle, Washington, built with untreated posts of Douglas fir, has been in service for the same length of time.

The posts should be connected with a simple framework of 2 × 4-inch stringers and studs to which test panels can be attached and covered with a plate or roof projecting an inch or two beyond the face of the test panels to keep rain water from seeping in behind the panels. It is advisable to build this superstructure also with the heartwood of durable species, particularly so if the framework is to be painted, and to make all joints as tight as possible to keep out rain water. Trouble has been experienced on some test fences with decay setting in at such joints when the lumber contained sapwood. If non-durable lumber is used it is desirable to soak the ends of all pieces in creosote, especially if they expose end-grain sapwood, to brush all surfaces, or at least concealed surfaces, with creosote, and to leave the framework of the fence unpainted, although it may be stained if desired.

If desired the framework may be enclosed with lumber sheathing from the top down to the lowest stringer, which should be not less than 18 inches above the ground. Sheathing presents a supporting surface like that on the sidewalls of most houses but it adds materially to the cost of the fence and is not really necessary.

The most satisfactory test fences are erected vertically because that is the position in which most house paint is used. Most fences run east and west so that test panels face south, if but one side of the fence is utilized, and north and south if panels are attached to both sides. The fence should be far enough from buildings, trees, or other obstructions to expose all panels on the south side uniformly to full sunshine. Paint wears



AN EXCELLENT TYPE OF TEST FENCE MAINTAINED BY THE NATIONAL LEAD CO. AT SAYVILLE, NEW YORK

The framework is covered with sheathing lumber before the test panels are attached. Both north and south sides of the fence are used for tests. The tests shown are a series by the Forest Products Laboratory in which each test panel consists of four boards, six feet long, marked off by stripes into three test areas of which the center is painted with a "control" paint against which the other two are compared.

out most rapidly on the south side and least rapidly on the north side. Tests repeated on north and south sides reveal the range in durability normally to be expected in the region. On the southern exposure paints chalk and colors fade most rapidly, while on the northern exposure dirt collects for a longer time, yellowing of paint oils may be more marked, and there is more chance for mildew to develop. By considering both northern and southern sides the relative appearance of different portions of a house can be gaged more successfully than is possible with southern exposure only.

Some workers prefer test fences on which the panels slope back at an angle of 45 degrees from the vertical because the intensity of sunlight falling on the painted surface is thereby increased and failure of paint is accelerated (*6*). Like other forms of accelerated weathering tests, however, inclined exposure should be used only to supplement rather than to replace vertical exposure. Inclined panels apparently undergo greater extremes of temperature and moisture content than vertical panels and paint on inclined panels acts as it would on vertical panels in a drier and warmer climate. Observations of changes in the appearance of coatings on inclined panels are not entirely representative of the behavior of the paint on vertical panels.

A good wire guard fence around the test fence is often needed to protect it against vandalism. Many persons seem to have an uncontrollable impulse to write on fences. Fences on farms need a guard fence to keep cattle from licking fresh paint with consequent disaster both to the paint and to the cattle. The guard fence should be placed far enough from the test fence to leave plenty of room for photographing test panels.

EFFECT OF CLIMATE

The variations in climate in different parts of the United States materially affect not only the durability of paint in general but the comparative durability of different kinds of paint. There are two opposite extremes of unusually severe climate from the point of view of paint; most of the United States, especially the more populous parts, lies between the two extremes. One extreme is found along the southern Atlantic Seaboard and the coast of the Gulf of Mexico, conditions in Florida being typical. Here, for example, paints containing high proportions of zinc oxide are distinctly more durable than pure white lead paint. The other extreme is found in the southwest, the region of the Great Plains, and the interior valleys of southern California. There white lead paint is distinctly more durable than paints containing even moderate proportions of zinc oxide. In both of these regions all paints fail more rapidly than they do in most other parts of the United States. Common characteristics of the two extreme conditions are relatively high amounts of sunshine and high maximum temperatures. The significant difference between them is the high relative humidity prevailing almost constantly in the one and the exceptionally low relative humidity characteristic of the other during at least a part of the year.

In recent pears there has been a tendency to regard tests in Florida as a form of accelerated exposure testing free from the shortcomings of artificial exposure tests. Florida exposure, however, cannot be accepted as a satisfactory test of paint for use in other parts of the country. Parallel exposures in Florida and in the southwest might be so accepted but it is wisest to test paints for national distribution in at least three characteristically different climates.

CHOICE OF WOOD FOR TEST PANELS

As a rule panels for testing house paints should be made of wood because that is the principal kind of surface upon which they will be used. Paints that endure well on metal often fail rapidly on wood.

One of the principal difficulties in interpreting the results of the earlier test fences arose with the discovery that the nature of the wood had as much effect on the durability of the coating as the composition of the paint, unless the paint is a very poor one indeed. A prominent paint executive dubbed the earlier tests a "lumber lottery" (7). Although recognized since 1912, the necessity for carefully considering the effect of the wood and practicable means of taking it into account have not been properly appreciated until recent years.

Lumber for exteriors of houses is predominantly softwood lumber. The following factors affect the durability of paint on softwood lumber (8):

1. The proportion of summerwood, which is the dense, hard, dark-colored portion of each annual growth ring in the tree. When paint coatings begin to break up and small pieces begin to fall off the wood, the disintegration sets in and progresses rapidly over the summerwood. The more summerwood there is, the sooner such disintegration becomes serious. The density of a board at some standard moisture content usually depends directly upon the proportion

of summerwood. Other factors being equal, the less a board weighs the longer paint lasts upon it.

2. The width of the annual growth rings. Slowly grown wood has narrow growth rings and may, therefore, have narrow bands of summerwood even though the wood is fairly heavy. Slowly grown wood holds paint longer than otherwise similar wood that grew rapidly.
3. The direction at which the surface to be painted cuts the annual growth rings. Edge-grain boards are cut with the principal surfaces approximately parallel to a radius of the log and at right angles to the growth rings. The bands of summerwood are of minimum width in such boards and paint is, therefore, held to best advantage. Flat-grain boards are cut with the principal surfaces approximately tangent to the growth rings so that the bands of summerwood are wider and paint fails more rapidly than on edge-grain boards. Of the two principal surfaces of a flat-grain board the one nearer the bark of the tree often holds paint longer than the one nearer the pith of the tree.
4. The grade of lumber. Lumber is graded for sale according to the size and number of defects, of which the principal ones are usually knots. The high grades hold paint better than the low grades, both because knots often cause early paint failure and because the low grades as a rule come from the central parts of the tree where the growth rings are usually wider.
5. Resin and other extractives. The resins and other extractives in wood have less effect on paint than is commonly supposed (9). The resin characteristic of the white pines and the yellow pines, which contain rosin, exerts a slightly detrimental effect upon the durability of paints that contain zinc oxide. On the other hand the oily extractive in southern cypress and the aqueous extractive in redwood apparently tend to make most paints last longer.

Since lumber is sold primarily by species the following classification of softwoods for painting has been worked out, but it must be remembered that within each species there is wide variation in the above properties and consequent overlapping in painting characteristics:

Group I-Woods that are generally light in weight, of slow growth, hold paint well, and require little paint protection to prevent wood weathering:
Alaska cedar — Western red cedar
Port Orford cedar — Southern cypress
Redwood

Group II—Woods that are generally light in weight but not always of slow growth, that contain resin slightly detrimental to paints containing zinc oxide, and that require more adequate paint protection than woods of Group I:
Northern white pine — Sugar pine
Western white pine

Group 111—Woods that are usually either more rapidly grown or heavier than those of Groups I and II and therefore hold paint less well and that require more adequate paint protection than woods of Group I:
Commercial white fir — Ponderosa pine
Eastern hemlock — Eastern spruce
Western hemlock — Sitka spruce

Group IV—Characteristically heavy woods with wide bands of summerwood over which paint begins to fail comparatively early:
Douglas fir — Western larch
Southern yellow pine

By choosing lumber for test panels with careful consideration for the properties that are known to affect paint behavior, the variability in results caused by the wood may be reduced materially. A relatively large supply of lumber may be sorted for boards of reasonably uniform properties. If such specially selected lumber for test purposes could be made available commercially there would undoubtedly be a demand for it in the paint industry even though it would necessarily be expensive. Variability due to the wood, however, cannot be entirely eliminated even by careful selection and other methods of allowing for it must be adopted.

There are two methods of minimizing uncertainty due to variability in the wood. The first is multiplication of the number of boards in each test panel and of the number of panels painted with each paint, and the second is the procedure of "matching specimens," that is, comparing paints by applying them to neighboring areas of the same boards. The most practicable procedure combines the two. The style of test panel preferred at the Forest Products Laboratory consists of four boards of 6-inch siding, each board 6 feet long. Record is kept of the density, width of growth rings, and direction of the growth rings in each board. The face of the panel is then subdivided into three test

THIS TEST FENCE WAS BUILT IN 1924 WITH LUMBER THAT CONTAINED MUCH SAPWOOD

Although decayed members were repeatedly replaced the fence collapsed early in 1933. The framework was kept painted. Durable lumber or lumber treated with wood preservatives safeguards the investment made in conducting paint tests.

areas each 2 feet long, one of which is painted with some paint chosen particularly as a suitable control against which experimental paints on the other two areas can be compared.

The best wood for testing the relative ability of paints to remain intact over bands of summerwood is southern yellow pine. When a paint formula has been worked out that lasts well on southern pine it may be assumed safely that it will give good service on any other softwood. Paint technologists working for paint manufacturers, however, are often expected to submit test panels to inspection by the sales department or by prospective customers and for that purpose they find southern yellow pine less desirable than a wood on which paint lasts longer and on which the ultimate areas of paint failure are not so conspicuous. For tests planned to disclose the range in behavior that will be exhibited by a paint offered for general use in house painting tests should be made on four kinds of wood, one from Group I, a second from Group 11, and two from Group IV, of which one should be southern yellow pine. The writer recommends the following :

1. Western red cedar bevel siding, "clear" grade, $^1/_2$ × 6-inch size. This will be edge-grain lumber.
2. Northern white pine bevel siding, "B and better" grade, $^1/_2$ × 6-inch size. This will be mostly flat-grain lumber. Ponderosa pine should not be accepted for this purpose in place of northern white pine.
3. Douglas fir drop siding, "B and better" grade, 1 × 6-inch size. This can be purchased entirely vertical grain (edge-grain) if desired but the flat-grain boards afford a more severe test of paints.
4. Southern yellow pine drop siding, "B and better" grade, 1 × 6-inch size. This will be chiefly flat-grain lumber.

Lumber for test panels should not be stored in heated rooms or kept very long in heated carpenter shops or laboratories. It is best stored in unheated rooms or lumber sheds where the relative humidity never falls below that characteristic of outdoor air in the climate in which the test fence is located. For most climates the moisture content of the wood should not be allowed to fall below 10 per cent. of the weight of wood when oven-dry.

Test panels should be mounted on the fence with the boards running horizontally, as they do on most houses. At the Forest Products Laboratory the four boards making up each panel are fastened together by cleats on the back so that the panel can be handled as a unit before it is attached to the fence. It is fastened to the fence by driving zinc-coated nails or screws through the boards into the supporting framework. If panels are mounted against lumber sheathing or if both north and south sides of the fence are covered with test panels it is not necessary to paint the backs of the panels but if only the south side of an open fence is utilized the backs of the panels should be painted with two coats of exceptionally durable paint, such as aluminum paint.

LAY-OUT OF TESTS

Exposure tests are made to best advantage when a fairly large number of related tests are started at one time. By careful attention to the lay-out of such groups of tests it is often possible to weave together several problems in such a way that each one can be studied more adequately than would be possible if each problem were worked out separately at different times.

An excellent illustration of well-planned lay-out is afforded by a test fence at St. Paul, Minnesota, erected by the Northwestern Paint & Varnish Production Club, the Minnesota chapter of the Master Painters' Association, the Paint, Oil, & Varnish Club, and the Retail Lumbermen's Club of the Twin-Cities (*3d*). The principal object was to study the optimum proportions of pigments, linseed oil, and turpentine in priming-coat paints. Panels consist of four boards of 6-inch bevel siding each 12 feet long. On unit 1 of the fence, for example, there are two such panels of redwood. Each panel is marked off into 6 test areas, each 2 feet long. The third test area of each panel is the "control" area, which is painted with three coats of white lead paint following proportions considered most representative of good practice among painters. On the first panel test areas 1, 2, 4, and 5 are painted with three coats of the same kind of paint except that the priming coat was mixed with four different ratios of linseed oil to turpentine and on test area 6 the priming coat was an aluminum paint, the second and third coats being the white lead paint. On the second panel test areas 1, 2, and 4 were painted with two coats of paint only and the paint is, therefore, mixed with a relatively high proportion of pigment, the ratio of linseed oil to turpentine in the priming coat being different for each area; areas 5 and 6 were primed with pigment-rich mixtures but were painted with three coats of paint. By comparing the results on each test area with those on the "control" area of the same panel, comparisons can be drawn fairly throughout the series.

This group of tests, requiring 12 test areas, is repeated on north and south sides of the fence. It is then repeated, again on both sides of the fence, on panels of western red cedar, northern white pine, and Norway pine. Finally the entire procedure is repeated with a white paint containing zinc oxide and white lead and repeated once more with a white paint containing titanium pigment and zinc oxide. Thus there are in all 288 test areas assigned to this study. The large number of test areas, however, is abundantly justified by the assurance that definite conclusions about the primary objective will be reached at the end of the necessary exposure period. In addition, the adequate scale on which the work has been done will yield additional conclusions about (1) the relative merits of two-coat and three-coat painting, (2) the merits of aluminum priming paint, (3) the paint-holding qualities of four species of wood, and (4) the relative merits of three kinds of linseed oil paint. The three paints can be compared even though they are not applied to

"matched specimens" of wood because each of them is applied to a sufficiently large number of test areas, they are applied in a variety of ways, and the lay-out is thoroughly symmetrical, that is, for each test area of any one paint there is an analogous area of each of the other paints.

APPLICATION OF PAINT TO TEST PANELS

It is best to paint test panels after they have been attached to the fence but it is often inconvenient to do so when the fence is located at a distance from the laboratory. If painted on the fence the priming coat should be applied within a day or so after the carpenter has attached the panels because even brief weathering of wood has been shown to impair the durability of paints.

Exterior paints applied and allowed to dry indoors before the panels are attached to the fence often develop a coarse form of paint checking that is not representative of the paint when applied under more practical working conditions. In its new building the Forest Products Laboratory has a large, flat roof with southern exposure in front of the painting laboratory. Test panels will be fastened temporarily to racks on this roof for painting and drying and will later be moved to the test fences for permanent exposure. If painting is interrupted by sudden rainstorms, trucks will be available for moving panels with wet paint into the laboratory until the storm passes.

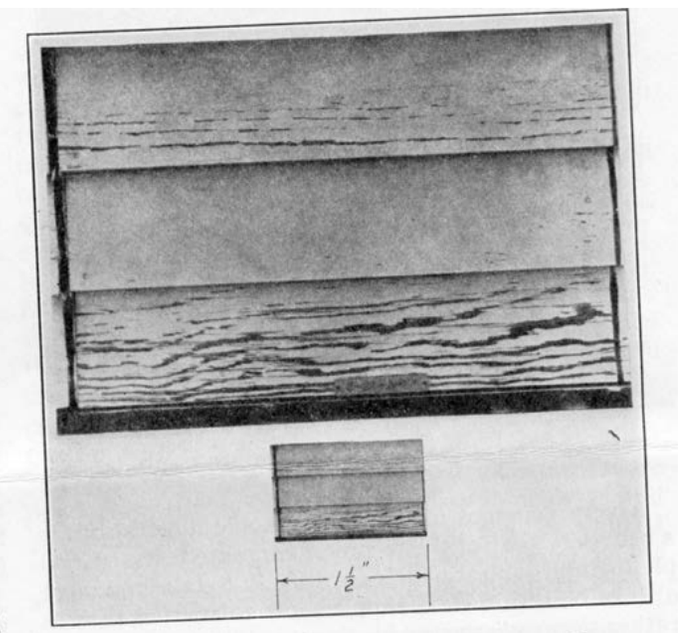
Test panels should be held in a vertical position while painting because mixtures that will cause trouble with running, sagging, and beads at the edges of boards will reveal their shortcomings in that position. Record should be kept of the amount of paint applied per area of surface and these spreading rates should fall within the range characteristic of practical painting. The tendency in many exposure tests has been to apply coatings much too thinly (10).

INSPECTIONS AND RECORDS

Carefully planned inspections and records made in the light of a definite scheme for evaluating paint service are necessary if exposure tests are to be fruitful, yet all too frequently investigators have seriously neglected this aspect of the work. There are as yet no generally accepted standards of procedure although some progress in that direction is being made.

Paints fail through a gradual development of numerous defects, the mechanism and significance of which are not yet well understood (*11a*), (*11d*). Since none of them can be measured strictly objectively and quantitatively the inspector must necessarily resort to personal judgments that are largely subjective in character (*11b*). Such methods of observation are usually foreign to the training of the graduate in chemistry and yet, if his work lies in the development of house paints, they are essential for determining the value of the products of his labor. Paint inspection, therefore, is a highly specialized art that should be undertaken only after present knowledge of the subject has been mastered and a definite plan of procedure has been adopted.

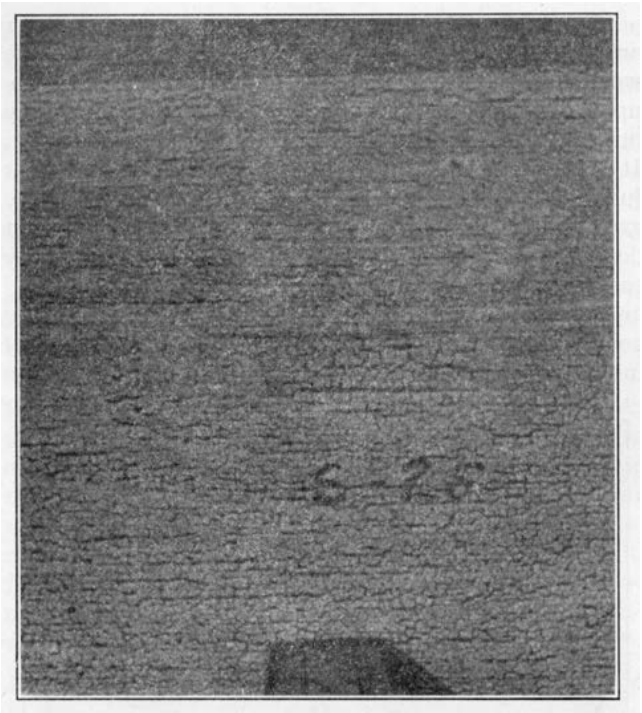
If possible, the responsibility for all inspections for any one organization should rest in one man.. If the work must be shared all inspectors must first of all agree upon a satisfactory system of judging to which they must adhere conscientiously if their results are to agree. It is further necessary that they periodically check their judgments against each other. To do so a fairly large group of panels representing a wide range in paint deterioration should be inspected independently by each inspector. Their results should next be compared and finally discrepancies should be reconsidered by going over the questionable panels together. Groups of inspectors should never set out upon a fence inspection together, especially if they have not been schooled in a common system of judgment. The discussions that arise make it almost impossible for any one of them to adhere consistently to one plan throughout the inspection and the results of such group inspection are less useful than those made independently by any one of the group.



THE NATURE OF THE WOOD IS AS IMPORTANT AS THE NATURE OF THE PAINT IN DETERMINING THE LIFE OF A PAINT COATING

This illustration shows a test area made up of three boards of the same species of wood painted with the same kind of paint. The bottom board is the heaviest and has the widest bands of summerwood; the middle board is the lightest. The illustration shows also the very small photographs used by the Forest Products Laboratory for making records of inspections and the enlargement obtained from it.

The Forest Products Laboratory makes three detailed inspections a year of its test fence at Madison and makes other observations between times to watch for significant developments that may call for additional record. More distant stations cannot be visited so frequently but are inspected at least once each year. The system of judging test panels and the plan for recording and evaluating data followed by that Laboratory have already been published in detail elsewhere (*11c*).



A PHOTOGRAPHIC RECORD OF A TEST AREA SHOULD ALWAYS BEGIN WITH A VIEW OF THE ENTIRE AREA BUT IT IS OFTEN DESIRABLE TO SUPPLEMENT IT WITH CLOSER VIEWS SHOWING DETAILS OF TYPICAL PAINT DEFECTS, SUCH AS THIS ONE WHICH SHOWS PAINT "CHECKING"

The area included in this view is about $2^2/_3$ by $2^1/_2$ inches.

A very generous use of photographic illustrations is a necessary part of the record of exposure tests. Good photographs of test panels are difficult to take and must always be regarded as supplements to written records rather than substitutes for them. A photograph that shows the entire area of a test panel or test area fails to reveal minute defects that are significant in the written record. On the other hand photographs or photomicrographs of limited portions of a test area may give a very misleading impression of the area as a whole. An excellent plan is to photograph the entire test area and to supplement this with photographs or photomicrographs of small portions of the area having typical defects.

It is usually necessary to take a very large number of photographs of which only a few will ultimately appear in final reports or publications. With a view to economy and compactness of records the Forest Products Laboratory has adopted a camera for photographic records in paint panel inspection that uses standard motion-picture film stored in cartridges for daylight loading. Each exposure occupies the space of two frames of the usual motion picture, making a contact print about 1 by $1^1/_2$ inches in size. From 35 to 40 exposures can be made with one loading of the camera. Test areas 16 by 24 inches in size fill the field when taken from a distance of about $3^1/_2$ feet. The camera has an accurate range finder for adjusting the focus rapidly without using a measuring tape. The F 3.5 lens permits snapshots even on very cloudy days so that it is rarely necessary to use a tripod. An auxiliary lens that can be quickly slipped in place adjusts the camera for taking photographs at a distance of $9^5/_8$ inches, which is easily measured off with a foot rule; the area photographed at this distance is about $2^2/_3$ by 4 inches; that is, it is about $^3/_8$ actual size in the contact print and may easily be enlarged to full size or to twice actual size. With this equipment, which can be carried in an overcoat pocket or in a corner of a brief case, the writer often takes less than half an hour to photograph a test fence requiring 100 exposures. The contact prints are about the size of two common postage stamps so that a complete photographic record for a test area can be mounted on one 8-by-10 inch sheet which, together with the standard form of inspection record (*11c*), provides the entire history of the area on two sheets of paper. Although the contact prints are so small they show a surprising amount of detail, especially when viewed through a good reading glass, and those exposures chosen for closer examination or publication can be enlarged to at least 4 by 6 inches very satisfactorily.

EVALUATION OF RESULTS

An exposure test should lead to a decision about the durability or at least the relative durability of the paint tested. Few experimenters in the past have attempted to bring their work to such conclusion. As a rule they have been content to describe what happened and to leave it to others to draw their own conclusions. Evaluation of the results of exposure tests is admittedly a very difficult and complex problem but those most familiar with the facts should accept most responsibility for dealing with it.

If durability is conceived as the period of time that will elapse before users of the paint will renew the coating it becomes evident that the behavior of the paint itself is only the beginning of the story. The patience of the paint user with paint defects or his ability to meet the cost of repainting is the center of interest. Perhaps the chemist needs help from the psychologist and the economist to complete his study, but with or without such aid he should reach definite conclusions about the relative serviceableness of the products he tests.

The writer's opinions about evaluating the serviceableness of house paints have already been published (*11c*). For the present purpose it is sufficient to point out the following classes of paint users whose needs must be considered: (1) those who may become sufficiently dissatisfied with a paint because of changes in appearance, such as soiling and fading, to renew the coating before it shows signs of failing to remain intact; (2) those who do not repaint until the coating begins to disintegrate but repaint before the disintegration goes very far; (3) those who may not repaint until the old coating has failed very badly and the house has needed repainting for several years; and (4) those who never bother to repaint at all. For the first group a paint endures only as long as its appearance satisfies them. For the second group it endures as long as the coating holds together. For the third group it is less important

that the coating endure than it is that the coating fail thoroughly, leaving a reasonably smooth surface free from patches of partly loosened old coating whose jagged edges will show through the new coating. The fourth group probably is little concerned about paint durability. Paints considered durable by the first group are often unsatisfactory to the second and third; a few good paints are acceptable to the first two groups but not to the third; no paint of the present day is entirely satisfactory to all groups.

In considering the requirements of different users of paint nothing has been said about protection afforded the wood by the coating. Much nonsense has been said and written about the subject. In the first place paint is impracticable as a preservative of wood against decay by attack of wood-destroying fungi (12). Houses are protected against decay by building them so that none of the wood becomes wet unless it be temporarily. If paint-neglected houses were seriously subject to decay paint users of groups 3 and 4 would soon come to grief and would be far less numerous. There are difficulties with decay in some houses but they occur as often where paint is well maintained as they do where it is neglected and the remedy lies either in improved construction of the house or in the use of naturally durable kinds of wood or of wood treated with toxic preservatives.

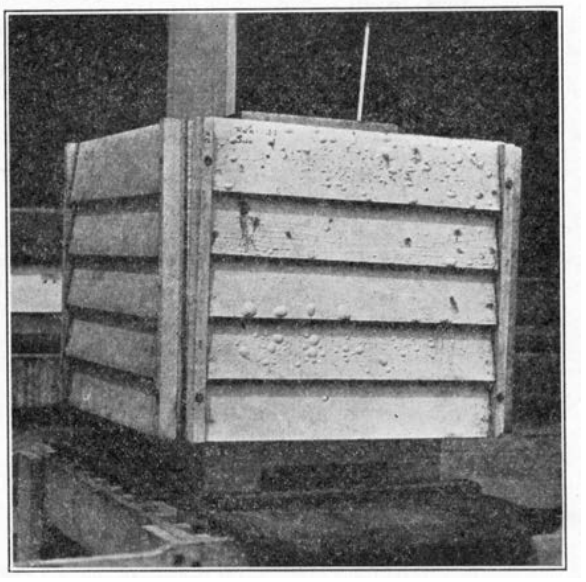
Unpainted wood or paint-neglected wood is subject to a form of deterioration known as wood weathering, against which paint affords adequate protection (12). The degree of protection afforded by different paints can be measured quantitatively and entirely objectively by technic that has been published and has been used in several laboratories (13). The practical significance of paint protection is somewhat uncertain, however. On the one hand, it is true that changes in moisture content with consequent swelling and shrinking cause a great deal of trouble in using wood but, on the other hand, many houseowners, especially farmers and wage-earners, do not seem to object very much to more or less weathered wood. Paint users of group 1 probably demand adequate paint protection but their painting habits insure adequacy of protection without worrying about it. For paint users of group 3, which is probably much more numerous if not so conspicuous, protection appears to be of minor importance.

EXCEPTIONAL BEHAVIOR OF PAINT ON SOME HOUSES

As a rule paint lasts somewhat longer on houses than it does on the south side of a test fence because few houses are as fully exposed to sunshine as a properly located test fence. Some houses will be found in nearly every community, however, on which paint not only fails more rapidly but fails in a very different manner than it does on test fences (14). Such failure may become noticeable within a few months after painting and become pronounced within a year. In typical cases the first abnormal development is blistering but the houseowner rarely makes complaint at that stage and may never notice that it has occurred. Later on the paint cracks and comes off in conspicuous scales whose size and shape bear no relation to the bands of summerwood beneath. Houseowners' complaints are usually made after this stage has been reached, when the surface not only presents a disreputable appearance but is very difficult to repaint properly. Abnormal paint failure of this kind is caused by moisture collecting behind the painted boards during the season when the interior of the house is kept at a materially higher temperature than prevails out of doors. The source of the moisture may be leaking joints of one kind or another (15) or condensation from air within the hollow sidewalls when the air is chilled below its dew point.

Although the extreme examples of abnormal paint failure caused by moisture are easily recognized the less well-defined cases are not. The writer has seen houses on which the type of paint failure was identical with that of similar paint on test fences but the comparatively early development of failure suggested that a few boards of siding be removed, whereupon the moisture in the sidewalls was revealed. Abnormal paint failures caused by moisture are so widely prevalent that the houseowners of the country are suffering a serious economic loss through unsatisfactory paint service and unduly frequent and expensive repainting. Even when the cause of the trouble has been discovered, it is still impossible to tell many of these houseowners what they can do, within their economic means, to prevent recurrence of such difficulties.

The uncertainties about abnormal moisture failure make paint testing on occupied houses difficult as well as inconvenient. Normal paint failure is best studied by means of test fences. On the other hand, paints should also be studied under controlled abnormal con-



"BLISTERING BOX"

For studying the failure of paint caused by the action of moisture behind painted woodwork the Forest Products Laboratory uses small "blistering boxes" placed out of doors in cold weather; the interior of the box is kept warm and moist.

ditions because some kinds of paint are more seriously damaged by moisture than others. The only really satisfactory remedy for such conditions lies in research that will make it possible to build houses with certainty that moisture will not collect in the sidewalls, but meantime houses subject to moisture conditions will have to be painted for many years. A technic for studying moisture failures is gradually being developed. The writer builds test panels of 4-inch bevel siding 15 by 17 inches in area which are painted and exposed to the weather on a test rack for varying intervals of time, after which they are subjected to abnormal moisture conditions by attaching them in position as the sidewalls of a "blistering box," within which the air is kept warm and humid by means of a pan of water heated electrically. The box is operated out of doors during cold weather. When the paints have blistered thoroughly the supply of moisture within the box is cut off and the panels allowed to dry out again while the temperature gradient through them is maintained. The panels are then returned to the exposure rack until the coatings fail by scaling. In the writer's opinion it is essential that the ultimate scaling of the coating be taken as the endpoint of the test rather than the preliminary blistering while the panels are on the "blistering box."

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