Chalking of Titanium Dioxide Pigmented Exterior Finishes

OUTSIDE HOUSE PAINTS[1]

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Extensive tests on outside house paints have been made and have in general agreed with the literature in showing that the greater the degree of acceleration, the poorer the correlation with results under practical exposure conditions.

Increasing amounts of titanium dioxide are being employed in white outside house paints to obtain improved whiteness, cleanness, hiding power, and durability. Until recently, however, use of white titanium dioxide in tinted outside house paints involved danger of excessive chalking and fading. As a result of development work, white titanium dioxide pigments have been developed with inherently slower chalking properties but with the self-cleaning characteristics generally associated with titanium-type pigments. Extensive exposure studies have been made comparing outside house paint formulas based on these new pigments with previous accepted formulas. The data indicate that the new titanium dioxide pigments can be used in tinted outside house paints to obtain improved cleanness, hiding power, and durability along with excellent tint-retention characteristics.

THE performance of outside house paints has been tested under many conditions, and the results have been widely reported in the literature. This company has been making systematic and extensive exposure studies on outisde house paints since 1932, in order to evaluate old and new pigments as well as exterior paint formulas. The information obtained has been used to guide the development of improved pigments and to assist established paint manufacturers in the formulation of better outside house paints.

Testing Methods

Exposure tests have been made under a wide variety of conditions. Accelerated testing machines have been tried. Various climatic conditions have been considered by making exposure tests on 45° south fences in Florida, Texas, and Delaware. These tests have been supplemented by exposures on south and north vertical fences in Delaware. Paints giving promise of good durability have been further tested on houses in various parts of the United States.

The test panels used, except in instances where the studies involved various woods, were selected edge-grain white pine. Each panel was painted on the back and edges with a good protective coating prior to the application of the test paint to the front of the panel. However, when moisture failure tests were of prime importance, unbacked panels were used.

Certain factors were held constant in an attempt to limit the number of variables as far as possible. Pigment volumes were maintained at 28.5 per cent. The vehicle used throughout the tests, unless otherwise specified, consisted of 92 per cent alkali-refined linseed oil and 8 per cent kettle-bodied linseed oil, body Q. With this binder there was incorporated a high-lead low-manganese linoleate-type drier to the extent of 0.6 per cent lead as metal and 0.02 per cent manganese as metal, calculated on the nonvolatile vehicle in the paint. Sufficient mineral spirits was added to reach a top-coat consistency of 90 Krebs-Stormer units. Three-coat self-primed systems were used with reductions for the various coats as follows: First coat, paint thinned with one pint of linseed oil per gallon; second coat, paint thinned with one half pint of linseed oil per gallon; third coat, paint used without thinning. When commercial paints were used as controls, they were reduced according to the manufacturer's directions. In preparing the panels, the following painting schedule was followed as closely as possible: The paint applied for the first coat was allowed to dry for 2 days before application of a second coat. A drying period of 3 days was allowed after the application of the second coat before the third coat was applied. The panels were placed on the test fence as soon as possible after the third coat had dried.

The exposed panels were inspected periodically with particular attention to such paint film changes as chalking, checking (including microscopic checking), cracking, flaking, erosion, dirt collection, mildew, and general appearance. In the case of tinted paints, special consideration was given to tint retention and discoloration. In certain instances screen staining was also investigated. The progress of each of the films was followed throughout the life of the paint, the final observation being directed to the type of surface left for repainting after the failure of the original paint. Such tests as these permitted the accumulation of extensive data from the thousands of paints exposed.

Certain combinations of materials displayed more promising results than others, and these paints were subjected to additional tests by actually painting houses with them. These houses are well diversified as to location, and were carefully selected and prepared for the tests. Whenever possible the previous painting history of the houses was ascertained. If the earlier paint was in suitable condition, the test paint was applied over it.

[1] The first paper in this series was published in January, 1940 (5).

A		B	
Ti-Ba pigment	40	Ti-Ba pigment	
Basic carbonate white lead	40	Cofumed 35% leaded ZnO	
Mg silicate	20	Mg silicate	

FIGURE 1. COMPARISON OF PANELS EXPOSED AT 45° AND VERTICALLY TO THE SOUTH FOR 44 MONTHS IN DELAWARE

If the house was not suitable for repainting because of bad paint failure, severe moisture conditions, or other reasons susceptible of correction, the proper preliminary steps were taken. They included removal of old paint, elimination of leaks, special treatment of sappy wood, etc., before application of the test paints. Each house was painted with several control coatings so that relative failures could be observed under similar conditions of application and exposure.

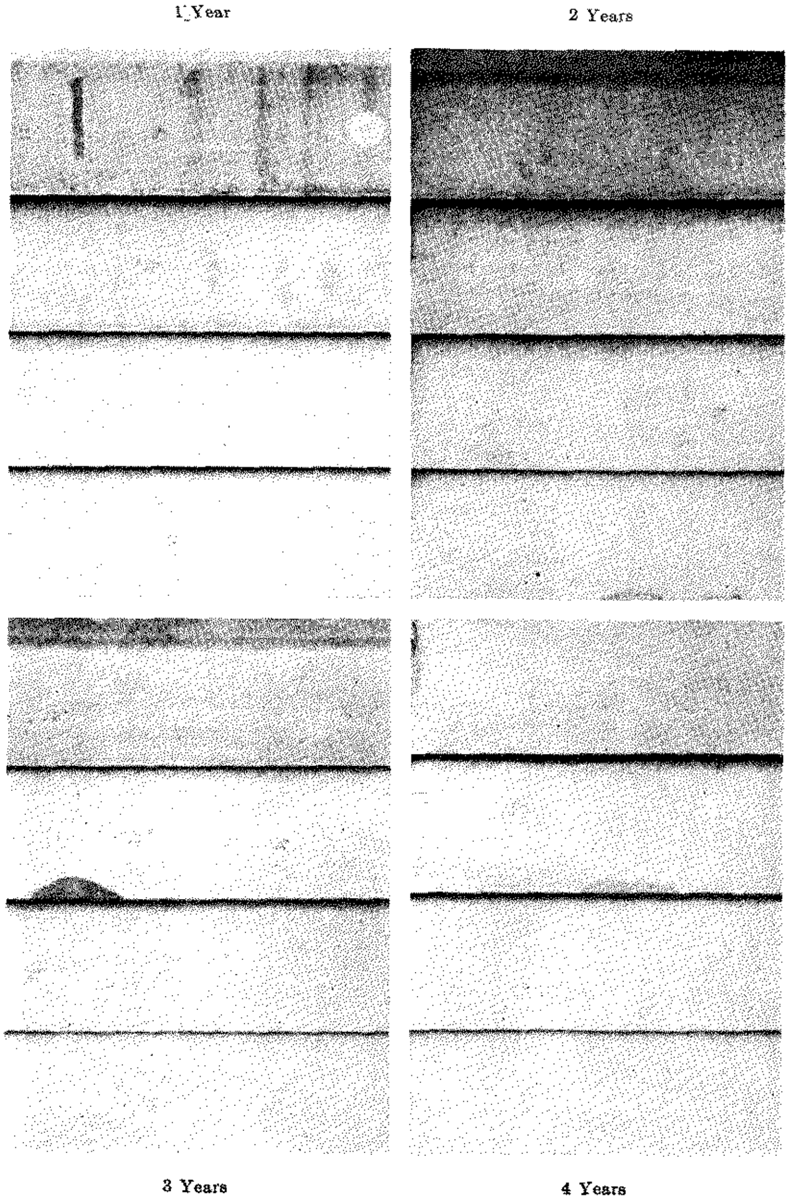
The painting of test houses was carefully controlled to assure that the test paints were applied for each coat strictly in accordance with the above mentioned reductions. Great care was taken to assure that the control paints were applied in accord with the accepted standard procedure and with strict avoidance of any contamination of one paint with another.

These tests houses were also inspected at regular intervals, and records made of the condition of each paint on each side of the house. Particular attention was directed to defects as they became evident. Comparisons between the test paints and the control paints were regarded as highly important.

Throughout this study of exterior exposures, every effort was made to obtain a complete and unbiased record of the relative merits of various pigment and vehicle combinations used by the paint industry. A wide range of pigment and extender combinations, both those long used and those newly developed, was investigated. There was a constant effort to develop new and better exterior paints.

Exposure Conditions and Effects

The information obtained indicates marked differences in type and rapidity of failure as the result of various climatic conditions, and it is therefore necessary to correlate, intercompare, and interpret individual observations as received, in order to arrive at reliable conclusions. Similar results were reported by Marshall, Iliff, and Young (*4*) and by Broeker (*1*). The variations in climatic conditions from year to year in any locality are sufficient to change somewhat the durability of any particular paint. It was therefore found desirable to repeat tests in any given exposure area before



Lead-in-oil	
Lead	60
Zinc	30
Inert	10
Lithopone	45
Leaded zinc	40
Inert	15
Ti-Mg pigment	37.3
Leaded zinc	45.0
Inert	17.7
Lead-in-oil	
Lead	60
Zinc	30
Inert	10
Lithopone	45
Leaded zinc	40
Inert	15
Ti-Mg pigment	37.3
Leaded zinc	45.0
Inert	17.7

FIGURE 2. APPEARANCE OF FOUR PAINTS AFTER DIFFERENT PERIODS OF EXPOSURE ON THE DELAWARE SOUTH VERTICAL FENCE

drawing final conclusions. Further, there are likely to be differences between panel exposures and house tests, to say nothing of the differences which develop between 45° and vertical panels, although the south vertical panels usually give results in close agreement with house tests. Repeated tests on numerous panels are also necessary to differentiate between wood failure and paint failure.

Exposures in Florida show more rapid chalking and erosion with less evidence of checking and cracking failures than are exhibited by the same paints exposed in the same manner in Delaware. This indicates that paints prepared for use in Florida and in similar climates should be slightly harder than paints prepared for such climates as prevail in Delaware and the Middle West.

A climate such as that in Texas produces earlier checking and cracking, with a greater degree of cracking and flaking, than does the Florida or Delaware climate. It therefore seems evident that paints designed for a Texas type of climate should be of the softer and more flexible type.

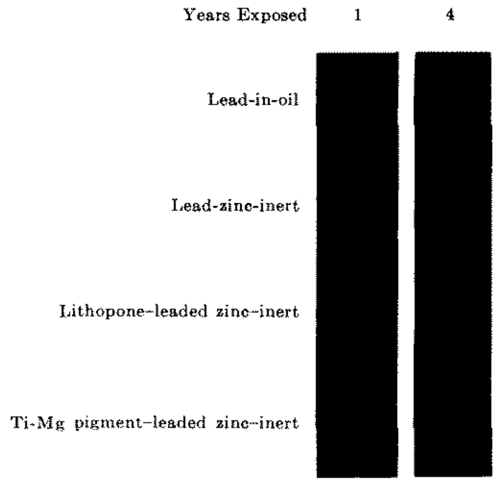


FIGURE 3. CHALKING CHARACTERISTICS OF FOUR PAINTS AFTER 1 AND 4 YEARS ON THE DELAWARE SOUTH VERTICAL FENCE

Panels inclined 45° to the south exhibit such an acceleration of failure that they can often be used to provide helpful preliminary evaluations in a limited time, but this acceleration indicates that the results obtained from 45° exposures should not be accepted as final without reservations. It is often true that the durability results, as well as information on dirt collection and general appearance as obtained from 45° south panels, are misleading (Figure 1). Exposures at 45° south may show widely different relative dirt collection as compared to the same paints exposed on south vertical panels. This affects durability and makes the 45° results unreliable. With experience, however, the 45° exposures can be read and interpreted properly to provide early information which may prove helpful.

North vertical exposures are particularly helpful in making accurate evaluations of dirt collection, mildew, and variations in paint appearance. These phenomena are usually accentuated and prolonged on such exposures.

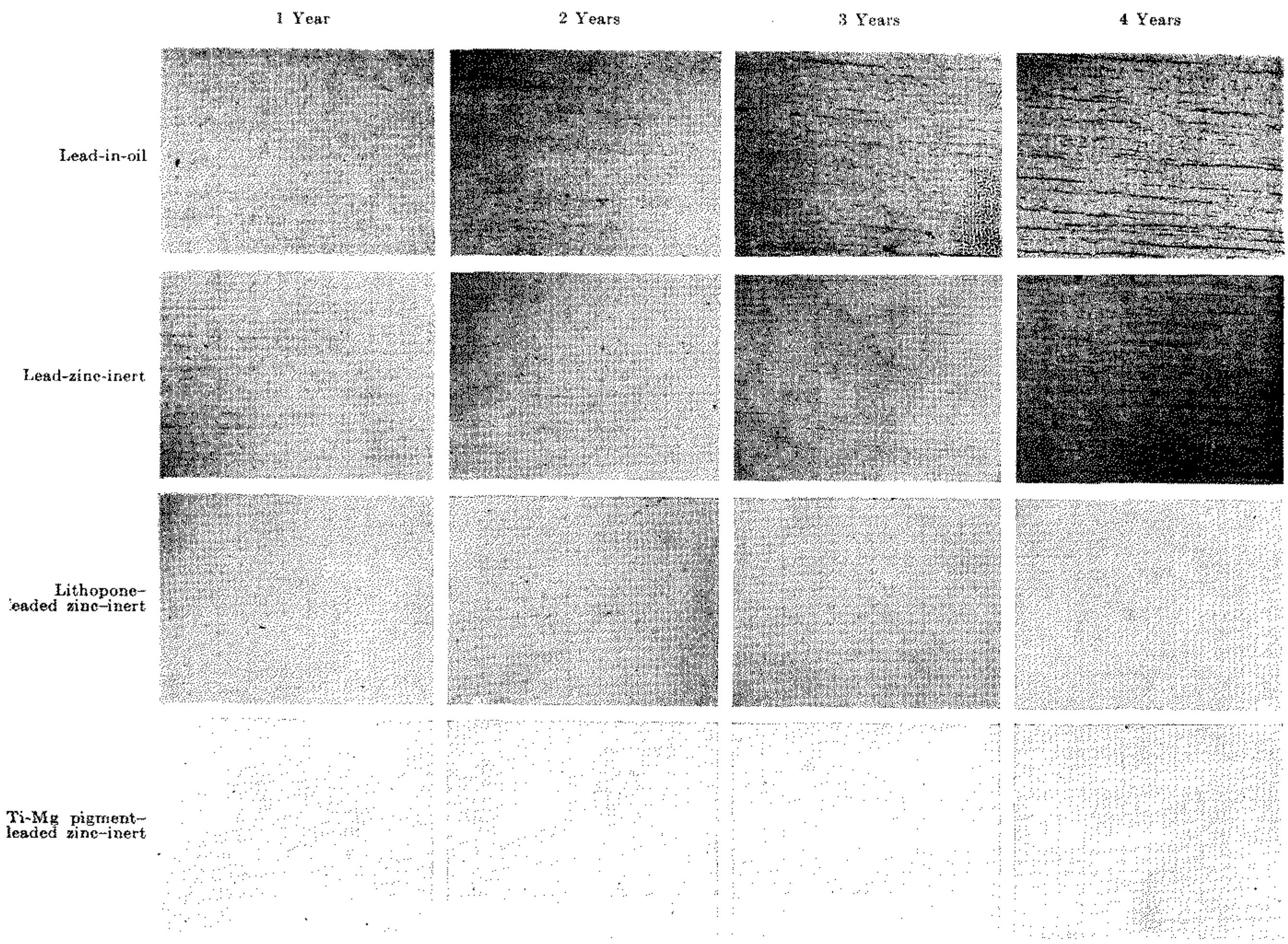
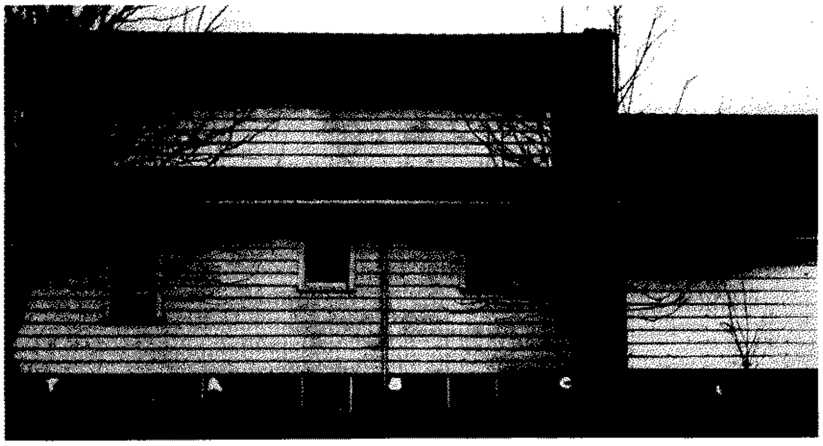


FIGURE 4. DURABILITY CHARACTERISTICS OF FOUR PAINTS THROUGHOUT 4 YEARS OF DELAWARE SOUTH VERTICAL EXPOSURE (ACTUAL SIZE)



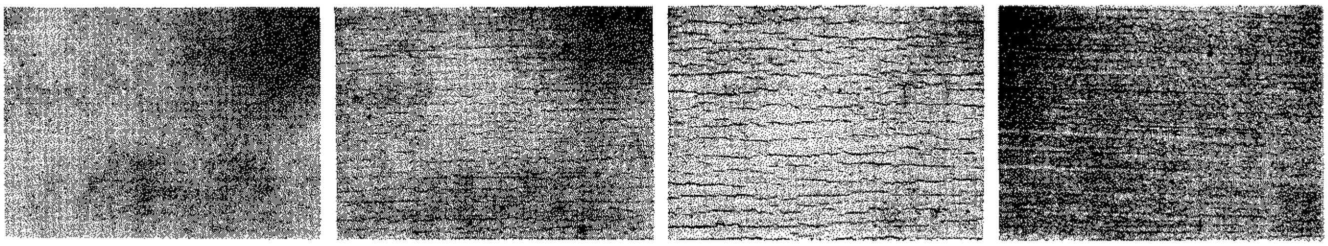


FIGURE 5. DURABILITY OF FOUR PAINTS EXPOSED FOR 33 MONTHS ON THE SOUTH VERTICAL SIDE OF A HOUSE; AND ACTUAL-SIZE PRINTS OF THE PAINTS AFTER 4 YEARS

T Ti-Mg pigment/leaded zinc/inert = 37.3/45/17.7

A Ti-Ba pigment/lead/zinc/inert = 30/30/30/10

B Lead/zinc/inert = 60/30/10

C Lead-in-oil

Experience indicates that data from prolonged vertical exposures, supplemented by repeated tests on both test fences and test houses, are required before it is possible to obtain a reliable evaluation of any exterior paint.

House Paint Evolution

In the construction of exterior house paints there has been a gradual evolution activated by the constant desire of manufacturers to produce improved products having better durability and lower cost, with greater consumer satisfaction. The evolution of these paints has carried them from lead-in-oil to lead-zinc paints, subsequently to lithopone exterior paints, and finally to those carrying titanium pigments.

The lead-zinc paints, in comparison with lead-in-oil paints, show less dirt collection, greater resistance to mildew, and improved tint retention. The advantage achieved in the way of reduction of dirt collection is not adequate, however, to counterbalance the sacrifices in durability which result from the greater tendency of lead-zinc paints to fail by cracking and flaking, since this type of failure results in poor repaint surfaces.

FIGURE 6. COMPARISON OF WHITE "TI-PURE" O PAINT WITH OTHER WHITE PAINTS, EXPOSED 1 YEAR ON THE SOUTH VERTICAL FENCE IN DELAWARE

The adoption of lithopone or zinc sulfide type paints, in which these pigments are combined with leaded zinc oxide and extender in the optimum proportions, gives improvements in hiding power, cleanness, and whiteness, as compared with lead-zinc paints; at the same time they exhibit durability characteristics essentially equal to those shown by lead-in-oil paints. Actually the lithopone paints retain the good tint-retention characteristics of lead-zinc paints and offer at the same time significantly superior durability, with better surface for repainting.

The titanium-type paints, which are the latest stage of this evolution, give still further improvements in hiding power, whiteness, and freedom from dirt collection, with still better durability than is exhibited by the lithopone paints. Paints containing titanium pigment properly combined with other pigments and extenders have exhibited properties far superior to those of any of the older types. Recent developments in house paint technology have dealt primarily with the production of improved titanium pigments and the methods of incorporating them most advantageously into exterior paints.

Figure 2 shows the appearance of these four types of paints after 1-, 2-, 3-, and 4-year exposure on the Delaware south vertical fence. The dingy appearance of the lead-in-oil and the fair appearance of lead-zinc and lithopone paints, as well as the clean white appearance of the titanium type paints, are readily discernible throughout the 4 years of exposure. The unusual cleanness of the titanium type paints is a result of the inherent self-cleaning characteristic of these films. Titanium pigments possess this characteristic to a marked degree; and when outside house paints are properly formulated with such pigments, it is possible to obtain this desirable property along with exceptionally good durability.

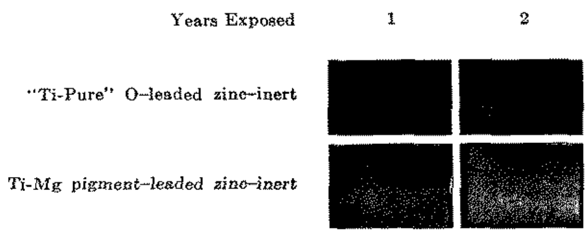


FIGURE 7. CHALKING PROPERTIES OF "TI-PURE" O OUTSIDE PAINT, COMPARED WITH REGULAR TITANIUM DIOXIDE AFTER 1 AND 2 YEARS ON THE DELAWARE SOUTH VERTICAL FENCE

The chalking properties of these four paints after 1 and 4 years, Delaware south vertical exposure, are shown by Figure 3. These chalking differences were recorded by drawing black velvet across the paint films with a light even pressure and taking special care to maintain the conditions as uniform as possible. It is evident that the lead-zinc paint chalks more freely than the lead paint; the lithopone and titanium type paints, in turn, chalk more than the lead-zinc paint. These data, together with the appearance differences previously shown, indicate that chalking and self-cleaning are closely related; the latter is probably a direct result of the former. Accordingly, when properly controlled, the chalking properties of a paint are made to serve a useful purpose.

The durability characteristics of these same four paints are shown throughout the 4 years of exposure by Figure 4. The lead and lead-zinc paints show visible film failure at 2 years, whereas the lithopone and titanium type paints show no failure even at 4 years. Actually the lithopone paint is checking and cracking slightly; this can be discerned only with difficulty.

The appearance and durability differences are apparent also on actual house tests (Figure 5). Here again the titanium paints are exceptionally clean and white. The darker portion of the house shows the dingy appearance common to many paints which collect dirt excessively and which do not have this inherent self-cleaning property characteristic of titanium type paints.

Properly formulated titanium type paints under normal conditions of exposure give excellent durability and a clean white appearance. Ultimate failure is by slow chalking and erosion, which leave an excellent surface for repaint work. These advantages are coupled with markedly superior hiding power because of the high refractive index of titanium dioxide.

Fade-Resistant Titanium Dioxide House Paints

The use of white titanium dioxide in tinted outside house paints has not been feasible until recently because of excessive fading (*2*). This difficulty has been recognized for a number of years, and extensive research and development work have been carried out in order to solve the problem. As a result, white titanium dioxide pigments are now avail-

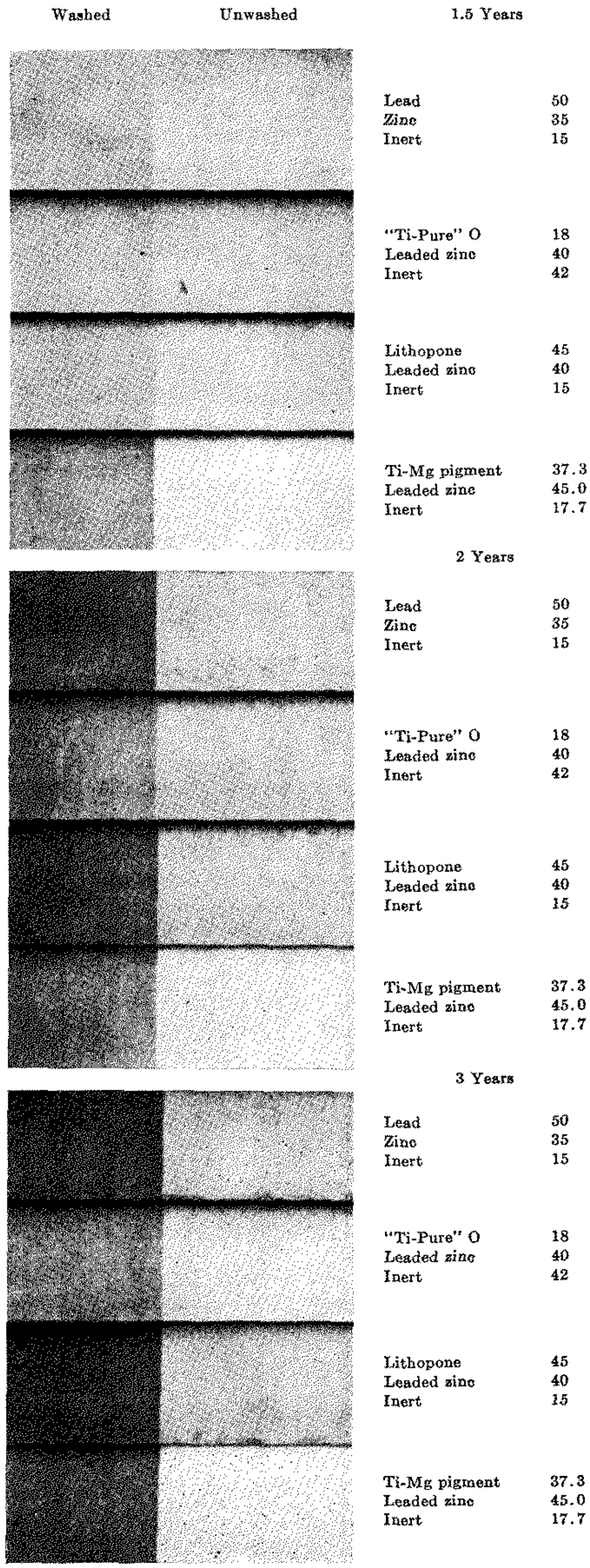


FIGURE 8. TINT RETENTION (GRAY EXPOSURES) OF "TI-PURE" O AND OTHER PAINTS EXPOSED VERTICALLY TO THE SOUTH IN DELAWARE

able showing inherently slower chalking and greatly improved tint retention properties, yet retaining to a marked degree the self-cleaning and excellent durability characteristics generally associated with titanium type pigments. These pigments are marketed under the trade names "Ti-Pure" Y-CR titanium dioxide, and "Ti-Pure" O titanium dioxide.

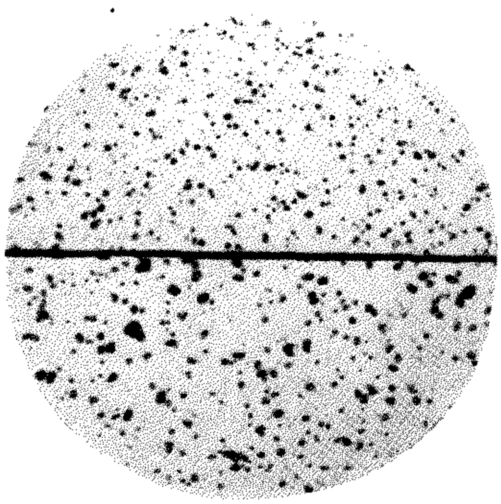


FIGURE 9. ULTRAVIOLET PHOTOMICROGRAPH (×1500) OF REGULAR TITANIUM DIOXIDE (*above*) AND "TI-PURE" O (*below*)

"Ti-Pure" Y-CR is a commercially pure white titanium dioxide manufactured by a process which provides improved resistance to chalking during exterior exposure. It gives the paint manufacturer an opportunity to obtain slightly better gloss and gloss retention as well as fade resistance without sacrificing color or hiding power. The special field for "Ti-Pure" Y-CR is enamels and lacquers, both interior and exterior, where it can be used to advantage. The fade resistant characteristics of this pigment, however, are not marked in house paint. Accordingly, it is not generally recommended for use in tinted exterior house paints. Minor improvements, however, in gloss, chalking, and fade resistance may be realized in outside house paints by the use of "Ti-Pure" Y-CR in place of the regular grades of titanium dioxide.

"Ti-Pure" O is a white pigment with a slightly yellow undertone. It is decidedly more chalk resistant than regular titanium dioxide and considerably more chalk resistant than "Ti-Pure" Y-CR. It possesses tint retention characteristics markedly superior to other titanium dioxide pigments, and is comparable in this respect to zinc sulfide or lead-zinc pigmentations. It provides the paint manufacturer with an opportunity to produce a single-base paint for whites and a full line of tints, although it is recognized that in whites it does not yield the clear brilliant outstanding white of ordinary titanium dioxide. "Ti-Pure" O can be used throughout a wide range of percentages in exterior paint formulas, which gives considerable leeway in meeting hiding power and cost requirements. In preparing "Ti-Pure" O exterior paints sufficient cofumed 35 per cent leaded zinc oxide should be incorporated to inhibit mildew. Generally 40 to 45 per cent of cofumed 35 per cent leaded zinc oxide has given adequate protection. Sufficient extender should be used to give the paint a satisfactory pigment volume. Under these conditions paints will be produced which are decidedly better than lead-in-oil in durability, tint retention, and cleanness, and markedly superior to lead-zinc paints in durability.

Figure 6 shows the appearance of white "Ti-Pure" O paint as compared with other white paints. In general, the "Ti-Pure" O paint shows about the same appearance as the lead-zinc paint; both are better than lead-in-oil but noticeably less clean and white than similar paints made with regular titanium dioxide.

Outside house paints made with "Ti-Pure" O show chalking properties which are delayed in time and degree as compared with similar paints made with regular titanium dioxide. This is indicated by chalking tests on such paints after 1 and 2 years of exposure on the Delaware south vertical fence (Figure 7).

The tint retention and durability characteristics of "Ti-Pure" O paints are outstanding. Figure 8 shows "Ti-Pure" O paints equal or slightly superior to lead-zinc or lithopone and decidedly superior to regular titanium dioxide type paints in tint retention characteristics. The durability advantage for "Ti-Pure" O is in line with the excellent durability characteristics which are generally realized with properly formulated titanium type house paints.

Theoretical Aspects

In an attempt to explain why "Ti-Pure" O is superior to regular titanium dioxide in nonchalking and nonfading properties, certain considerations appear pertinent: The primary pigment particles of "Ti-Pure" O are larger than the regular titanium dioxide particles (Figure 9). The individual crystals of "Ti-Pure" O are believed to be more regular in shape and better developed than the regular titanium dioxide crystals. Regular pigment-grade titanium dioxide possesses stronger adsorptive properties, possibly due to irregular crystal growths or areas of rough or incomplete lattice structure on the surface.

Assuming these considerations to be true, it becomes plausible that "Ti-Pure" O would tend to be held on the surface of a paint film to a less degree than would the smaller, more strongly adsorptive particles of regular titanium dioxide. This condition would allow easy removal or washing away of the "Ti-Pure" O particles, and thus result in less chalk retention and in the markedly superior nonfading properties which are characteristic of "Ti-Pure" O.

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(3) Dawson, D. H., and Nutting, R. D., IND. ENG. CHEM., **32**, 112 (1940).
(4) Marshall, John, Iliff, J. W., and Young, H. R., *Ibid.*, **27**, 147–52 (1935).

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