

# THE HANDBOOK



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**TITANIUM PIGMENT CORPORATION**

*Subsidiary of*

**NATIONAL LEAD COMPANY**

NLI 121234

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**F**ACTUAL information regarding TITANOX\* titanium pigments and their fields of application has won for the HANDBOOK many readers who have come to cherish it. If you are among these, you will find this latest revised edition even more valuable than its predecessor.

Your inquiries concerning any of the discussions or data in the HANDBOOK will be gladly answered. Any opportunity to help you work out your specific problems involving TITANOX pigments is welcome at any time.

**TITANIUM PIGMENT CORPORATION**  
 111 Broadway  
 New York 6, New York



\* Trade Mark, reg.

April, 1964

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When it is realized that titanium pigments used in many products in many different industries, the difficulty of generally predicting the exact effect of the pigment in use, can be readily understood. Moreover within a given industry producing a single line of products, manufacturing conditions may vary a great deal. Therefore no warranty can be attached to items appearing in the HANDBOOK, such as formulae, results of paint exposure tests, or results of experimental or testing work which depend upon a particular set of conditions not necessarily duplicated by the user of the pigment.

Nevertheless all such data offered possess the inherent reliability naturally associated with intensive study and carefully conducted and verified experimental work.

But any recommendations or suggestions are made without guarantee, inasmuch as the conditions of use are beyond our control.

Nothing contained herein shall be construed as a recommendation to use any product or material which may conflict with patents covering any material or use.

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## PART I

### INTRODUCTORY

#### Discovery of Titanium

**A** REMARKABLE clergyman—William Gregor—reported in 1791 that some magnetic black sand which he had found in the parish of Menaccan in Cornwall, England, consisted mainly of iron oxide and a white oxide which had not previously been described. Gregor also noticed that solutions of this new oxide turned milky on heating. No name was given to the new oxide nor its element, but later the sand was called "Menaccanite" after the parish.

A few years later in 1795, M. H. Klaproth in Austria separated a white oxide from solution of the mineral now known as rutile. He noticed the similarity of this oxide to that described by Gregor, and also observed the milkiness developed on heating its solutions. The name "Titanic Earth" given to the new oxide by Klaproth in honor of the Titans, the fabled giants of mythology, finally evolved into the name "titanium" for the element.

During the entire 19th century, the idea of utilizing the reaction which caused the milkiness of titanium solutions, as a means of separating titanium dioxide for pigment purposes apparently occurred to no one. This, in spite of much work on the chemistry of titanium by eminent chemists of the time who recognized that the separation of titanium was due to hydrolysis and that hydrated titanium dioxide or titanate acid was the product separated. In this period, Gregor's "Menaccanite" was superseded by the name ilmenite after the Ilmen Mountains of Russia where deposits of the mineral were found. During this time, two attempts were made to use titanium minerals as material for paint. In about 1869, J. W. Ryland brought a boat load of crude ilmenite from Norway to Birmingham, England. Some of this material after grinding and heating to remove moisture, was milled into a paint vehicle. In 1870, John Overton of Louisville, Kentucky, patented a coating composition containing ground rutile mineral in a bituminous composition. But nowhere, apparently, was white titanium dioxide considered.

## Development of Titanium Pigments

In the latter part of the 19th century interest in titanium was restricted to its use as a ferro alloy in steel manufacture, but after production of such an alloy was launched in 1907 interest turned to the possibilities of titanium as a pigment. A. J. Rossi who guided the metallurgical development, observed about 1908 that some impure titanium dioxide which he had prepared, when mixed with oil gave remarkable opacity. At about the same time Jebsen, Farup and others in Norway working on the utilization of the limenite deposit at Egersund, Norway, recognized that titanium dioxide possessed value as a pigment.

In 1912, L. E. Barton joined Rossi in research on the pigment possibilities of titanium. Their processes involved finally the reaction which Gregor and Klapproth had observed, but obtaining the titanium solution to be hydrolyzed was a tedious affair. Limenite was fused with nitre cake (sodium bisulphate) and coke in an electric furnace, before a solution of titanium in sulphuric acid could be obtained. This process was applicable to both limenite and rutile. At this time, however, in Norway, work centered on the reaction of limenite ore directly with concentrated sulphuric acid without going through a fusion process. Rossi and Barton found that the introduction of finely divided calcium sulphate or barium sulphate into the titanium solution facilitated hydrolysis and gave a composite pigment having as high opacity as that of any pure titanium dioxide which they could produce. For this reason the first titanium pigments were composites.

In 1916, the Titanium Pigment Company was organized to produce the products developed by Rossi and Barton, but due to the war it was not until 1918 that production could be started. In 1920, National Lead Company, realizing the great value of titanium pigments as concluded from research, purchased an interest in the Titanium Pigment Company. The new pigment proved attractive to the paint industry to the extent that a second plant had to be put into operation in 1923 at St. Louis, Missouri, to meet the growing demand, and as a result of extensive research a process for reacting limenite directly with sulphuric acid was developed. Composite pigments were still

being produced in preference to straight titanium dioxide, but within a few years processes were developed for the production of straight titanium dioxide having tinting strength appreciably higher than that of the composite pigments.

By 1932, pure titanium dioxide had established itself as a pigment along with the composite titanium pigments and late in that year National Lead Company acquired the entire stock of Titanium Pigment Company, Inc. In 1935, an additional pigment plant was put into operation at Sayreville, New Jersey. In 1936, the Titanium Pigment Company was dissolved and the National Lead Company—Titanium Division—became the manufacturer while a new company—TITANIUM PIGMENT CORPORATION—was formed as sole sales agent for TITANOX pigments.

## Titanium Ore for Pigment Manufacture

Although titanium was considered for years a rare element it is estimated to be ninth in abundance of the chemical elements making up the earth's crust.

Table I  
The 25 Most Abundant Elements in the Earth's Crust\*

| Estimated Weight Percent |         | Weight Percent     |         |
|--------------------------|---------|--------------------|---------|
| Element                  | Percent | Element            | Percent |
| 1 Oxygen                 | 46.60   | 13 Sulfur          | .052    |
| 2 Silicon                | 27.72   | 14 Carbon          | .032    |
| 3 Aluminum               | 8.13    | 15 Chlorine        | .031    |
| 4 Iron                   | 5.00    | 16 Rubidium        | .030    |
| 5 Calcium                | 3.63    | 17 Fluorine        | .030    |
| 6 Sodium                 | 2.83    | 18 Strontium       | .025    |
| 7 Potassium              | 2.59    | 19 Barium          | .022    |
| 8 Magnesium              | 2.09    | 20 Zirconium       | .020    |
| 9 Titanium               | .44     | 21 Chromium        | .015    |
| 10 Hydrogen              | .14     | 22 Vanadium        | .013    |
| Total of 1st 10. 99.17   |         | 23 Zinc            | .008    |
|                          |         | 24 Nickel          | .007    |
|                          |         | 25 Copper          | .007    |
|                          |         | Total of 25. 99.70 |         |
| 11 Phosphorus            | .118    |                    |         |
| 12 Manganese             | .100    |                    |         |

\* From Mason, Brian, 1932, Principles of Geochemistry, page 41, New York, John Wiley and Sons.  
See also: Geological Survey Circular 285, Recent Estimates of the Abundances of the Elements in the Earth's Crust by Michael Fleischer, Washington, D. C., 1953, Geological Survey, Washington 25, D. C.

There is more titanium than lead, zinc, antimony, tin, nickel and chromium combined. Only oxygen, silicon, aluminum, iron, calcium, sodium, potassium and magnesium are more abundant than titanium. See Table I. This abundance of titanium is due to its widespread occurrence in small amounts in practically all rocks and many minerals, but rutile, ilmenite and alteration products of ilmenite are the only important titanium ores.

So far as titanium pigment production is concerned, because of relative scarcity and insolubility, rutile does not lend itself readily to conversion to pigment by the sulfate process in spite of the fact that rutile concentrates may contain 92-98%  $\text{TiO}_2$ . Ilmenite is often considered an iron titanate  $\text{FeTiO}_3$  or  $\text{FeO} \cdot \text{TiO}_2$ , but iron is apparently always present in both valences. In the usual commercial ores the titanium dioxide ( $\text{TiO}_2$ ) content may vary from 35-60%, ferrous oxide ( $\text{FeO}$ ) from 5-40%, and ferric oxide ( $\text{Fe}_2\text{O}_3$ ) from 5-32%. These ranges in composition are explained as resulting from the effects of weathering—oxidation and removal of some of the iron leaving residues higher in titanium dioxide but lower in total iron content than unaltered ilmenite. The fresh mineral is black, but its alteration products may be much lighter in color—brown, yellow, or gray.

In rock formations, ilmenite is generally associated with iron ore, usually magnetite although occasionally with hematite, which accounts for the designation titaniferous iron ore. The MacIntyre deposit in New York State which is being worked by National Lead Company as a source of ilmenite for TIRANOX pigments is titaniferous iron ore also yielding magnetite. The ilmenite produced at MacIntyre contains about 45%  $\text{TiO}_2$ , 39%  $\text{FeO}$ , and 5%  $\text{Fe}_2\text{O}_3$ , and like other ilmenites from rock deposits, is essentially unweathered and black in color. Titaniferous iron ore is being mined in Canada, and is known to occur in India, Russia, Wyoming, Minnesota and California. The titaniferous iron ore of Norway has been the main source of ilmenite for titanium pigments manufactured in Europe, along with the more recently worked deposit at Otamaki, Finland.

In titaniferous iron ore mined near Allard Lake, Que-

bec, Canada, hematite and ilmenite are so closely intergrown that separate concentrates of each mineral cannot be produced. As a result, the winning of titanium values from this ore involves the manufacture of pig iron by electric smelting with coke to yield a high titanium slag (70-75%  $\text{TiO}_2$ ). This slag is starting material for the production of titanium dioxide pigments. Pure ilmenite unassociated with iron ore in a rock body has come from Nelson County, Virginia, where the body consists mainly of ilmenite and apatite or rutile and apatite.

In beach and dune sands, ilmenite occurs along with monazite, zircon, silica and rutile. The most extensive of the sand deposits are near Qutlon, in the state of Kerala (formerly Travancore), India. The beach sand deposit near Jacksonville, Florida, afforded the first ilmenite used in this country for the volume production of TIRANOX pigments. An ilmenite sand deposit has recently been developed near Lakewood, New Jersey. Other sand deposits of importance are at Trail Ridge, Florida, in South Africa, Australia, Malaya, Senegal, and Spain. The ilmenite in sand deposits is usually an altered product so that the concentrate may contain as high as 65%  $\text{TiO}_2$ .

It is believed that all ilmenite has come from igneous rocks, and as a result, the beach sands are accounted for by the breaking up of rocks on weathering. Fragments of the rocks are carried to the beaches by rainfall. This theory has been applied particularly to the beach sands of India. Zircon, monazite and ilmenite are carried along by the rivers arising from flood waters which are held back by the Arabian Sea—the rivers spread out into lagoons, thus causing the sands to be deposited. Of course, very long periods of time elapsed during this process. The deposition and concentration of ilmenite and other heavy minerals in certain localities is apparently the result of a number of forces acting singly or in combination, such as streams, ocean currents, waves, or wind.

Production of ilmenite concentrates from rock deposits involves blasting, crushing and grinding, followed by magnetic separation of magnetite, gravity separation of gangue, and final high intensity magnetic separation, or flotation, of ilmenite.

Production of ilmenite concentrates from sand deposits usually requires no grinding. A combination of gravity, magnetic and electrical high tension separations is used.

### **MacIntyre Development of National Lead Company**

In 1942, National Lead Company opened up its mine in the Adirondack Mountains for the concentration of ilmenite from titaniferous iron ore—an inclusion in anorthositic rock. By far the largest proportion of domestic production of ilmenite comes from this deposit. The operations are centered at Tahawus, which is located on the edge of Sanford Mountain and the other mountains in the area. Open-pit mining methods are used. The rock is drilled with churn drills for the blast holes, after which the rock is blasted out. The broken rock is removed by large power shovels loaded into trucks and transported to the crushing mill where a huge jaw crusher, in combination with cone crushers, reduce the rock to  $-\frac{1}{2}$ " size.

The outstanding development at this point is "cobbing" or the utilization of a magnetic pulley separator which eliminates 10 to 20% of ore which is low in ilmenite and magnetite. The product from the crushing plant is further ground to  $-20$  mesh in rod mills in closed circuit with vibrating screens. From this point on, the whole operation is essentially one of employing varied magnetic intensity to separate magnetite, ilmenite, and siliceous residue. Magnetite is readily extracted over wet magnetic separators after which it is conveyed to the magnetic sintering plant. The conglomeration of ilmenite and gangue materials left after the removal of magnetite presents a difficult problem in separation because of the similarity in specific gravity and magnetic properties of the ilmenite and the gangue. But the problem is solved through close, wet gravity separation carefully controlled on a large series of gravity concentration tables. Final magnetic separation is made on dry magnetic separators yielding con-

centrated ilmenite. A flow sheet on the next page which may be folded out presents graphically the essential steps in the winning of ilmenite at Tahawus.

The value of this project cannot be stressed too much. It literally saved the paint industry and this is evident when some statistics are considered. Thus, in 1940, some 222,000 tons of ilmenite were imported into the United States practically all from India, but of this year, only about 21,000 tons were produced domestically. By 1942, total imports of ilmenite for titanium pigment production had fallen to about 7,000 tons, but when the Adirondack material came into production late in 1942, the total domestic output was increased to about 77,000 tons. By 1943, while imports rose to about 75,000 tons, due to 65,000 tons from Canada, there was a pressing demand for ilmenite to maintain the supply of titanium pigments. This was met by domestic production of about 204,000 tons, mostly from Tahawus, to be boosted to a total of 278,000 tons in 1944. Further increases in production of ilmenite at Tahawus keep pace with the growth in production and use of titanium pigments.

### **MacIntyre Development Not Sole Source of Titanium Ore for TITANOX Pigments**

National Lead Company is not dependent solely upon its MacIntyre development as a source of titanium ore for TITANOX pigments. Not only does this company own and operate mines in other places, but it regularly uses ilmenite from other sources. A policy that stabilizes the present and looks to the future provides long range planning of reserves in the ground at present and future mining sites plus proper control of inventories of ore from several sources at all times.

Titanium ore reserves of the Company have been strongly supplemented by discoveries of new deposits at its properties in Tahawus and in Norway and by the purchase of titanium-bearing land in north central Florida.



## Process of Titanium Pigment Manufacture

The ilmenite concentrate shipped by rail, or as ballast by water to lower shipping cost, is first dried and ground to a fineness less than 200 mesh. The ground ore is reacted with concentrated sulphuric acid, giving rise to an exothermic reaction which can be made to carry itself along economically. Sulfates of titanium and iron are formed which are carefully brought into solution with water and dilute sulfuric acid.

Any ferric iron in the solution is reduced to ferrous usually by the addition of metallic iron in the form of scrap. In addition, a small proportion of the titanium is reduced to guard against reoxidation of the iron. The undissolved ore is removed—incidentally this is one of the most vital steps of the process inasmuch as this residue must not remain in solution to contaminate later the titanium dioxide which is precipitated.

In the manufacture of titanium dioxide pigments the solution is carefully nucleated, there being many patents covering this step. The nuclei may be added separately or formed in the solution, after which the solution is boiled, resulting in its hydrolysis and the precipitation of hydrous titanium dioxide. The precipitate is separated by filtration and is washed during continuous filtration to free it from the mother liquor. The washed precipitate is calcined in rotary kilns in order to drive off moisture and to develop opacity. Prior to calcination, additives may be employed to insure proper development of pigment properties. Here again, the patent literature is replete with suggestions for this step. The calcined product is ground under the most carefully controlled conditions, employing the types of grinding required for the properties of ease of dispersion to a high degree of dispersion in the products for which the pigment is intended. For some types, roller mills of the Raymond type are used; also wet milling in closed circuit with hydro separation and also in combination with fluid pressure mills of the latest type.

On the next page which may be folded out there is a flow chart depicting the essential steps in the manufacture of "pure" titanium dioxide pigments.

Whether anatase or rutile titanium dioxide is to be produced will depend largely upon two steps in this process; namely, nucleation where the type of nuclei will determine, to a large extent, the crystal structure of the hydrolyzate and in calcination where conditions also govern crystal structure. Rutile may also be produced by employing chloride solutions instead of sulfate solutions. It must be remembered that the name rutile when applied to titanium dioxide pigment simply indicates crystal structure and does not mean that the pigment has been derived from the mineral rutile.

In making composite Titanox pigments, the extender in finely divided form is added to the solution of titanium prior to hydrolysis. Very finely divided calcium sulfate (anhydrite) is the extender of the rutile-calcium pigments and is proportioned for 50% of the composition of Titanox-C-50 and 70% of Titanox-RCHT, Titanox-RCHTX and Titanox-RC corresponding to  $TiO_2$  contents respectively of about 50% and 30% by weight.

From the boiling titanium solution, hydrous titanium dioxide is precipitated, by hydrolysis, upon the extender. So precipitated, the titanium dioxide is tightly held by the extender, resulting in a true composite pigment. After washing, the precipitate is calcined, then milled.

A flow sheet follows which shows graphically the steps in this process.

## Other Processes for Manufacturing Titanium Pigments

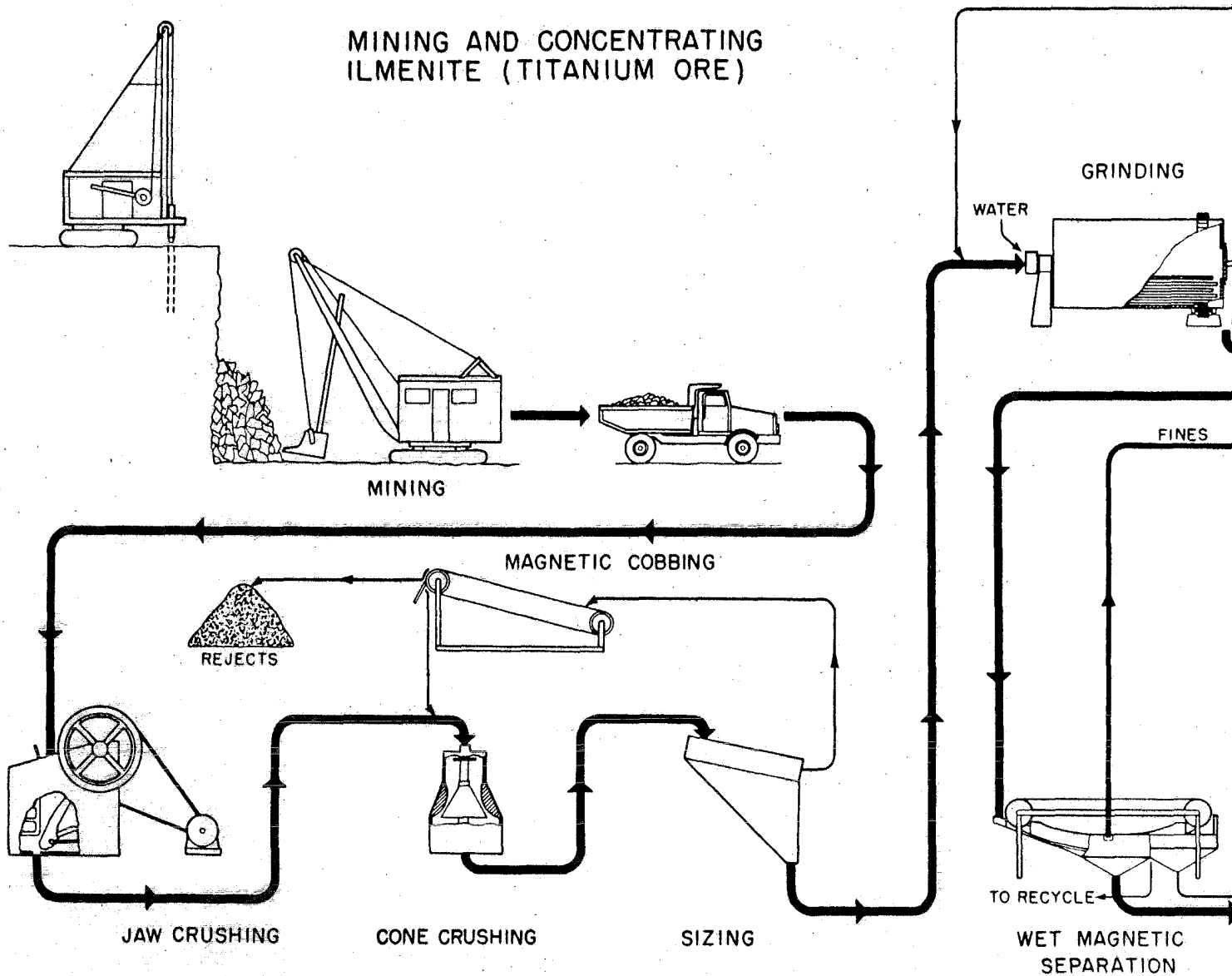
Many processes for manufacturing titanium pigments have been described and patented. Some of these have been studied, used and abandoned by the industry. Processes that have been abandoned because of inefficiency and high cost, involved either fusion of the ore or reaction with fluorides. Other than the sulfate processes used in the manufacture of Titanox pigments the only other processes that are always under consideration are those involving the manufacture of titanium tetrachloride and its conversion, either

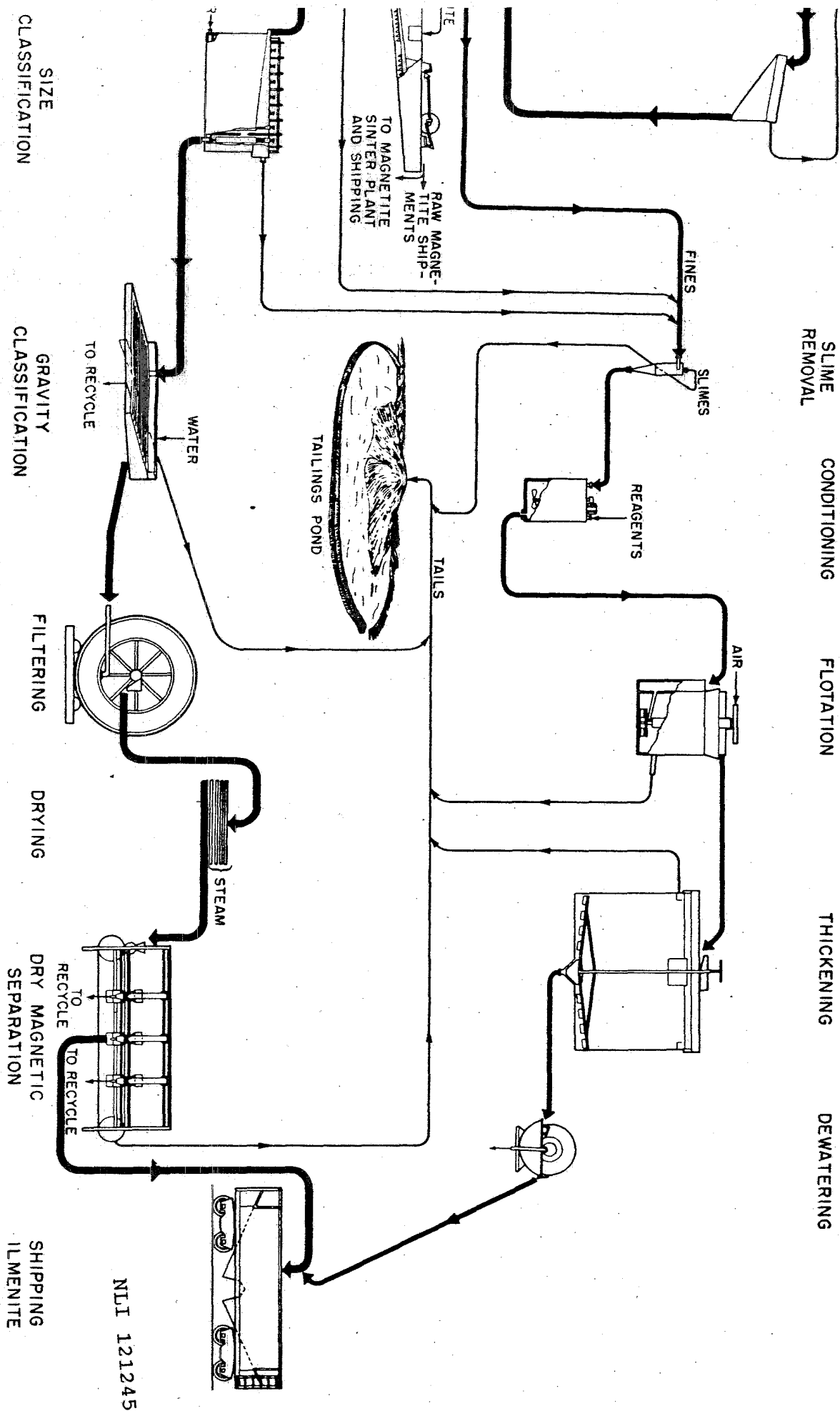


in the liquid or vapor phase, to titanium dioxide. The sulfate process being highly economically stable has been preferred by National Lead Company. Chloride processes are naturally receiving intensive study partly because of the rise of the titanium metal industry which must utilize under present processes titanium tetrachloride for conversion to titanium metal. In manufacturing titanium tetrachloride for titanium metal production the mineral rutile is the starting point. Use of this ore (rutile) obtained mainly from beach and dune sands of Australia and Florida, in no way affects the supply of ilmenite from which Titanox pigments are made by the sulfate process.

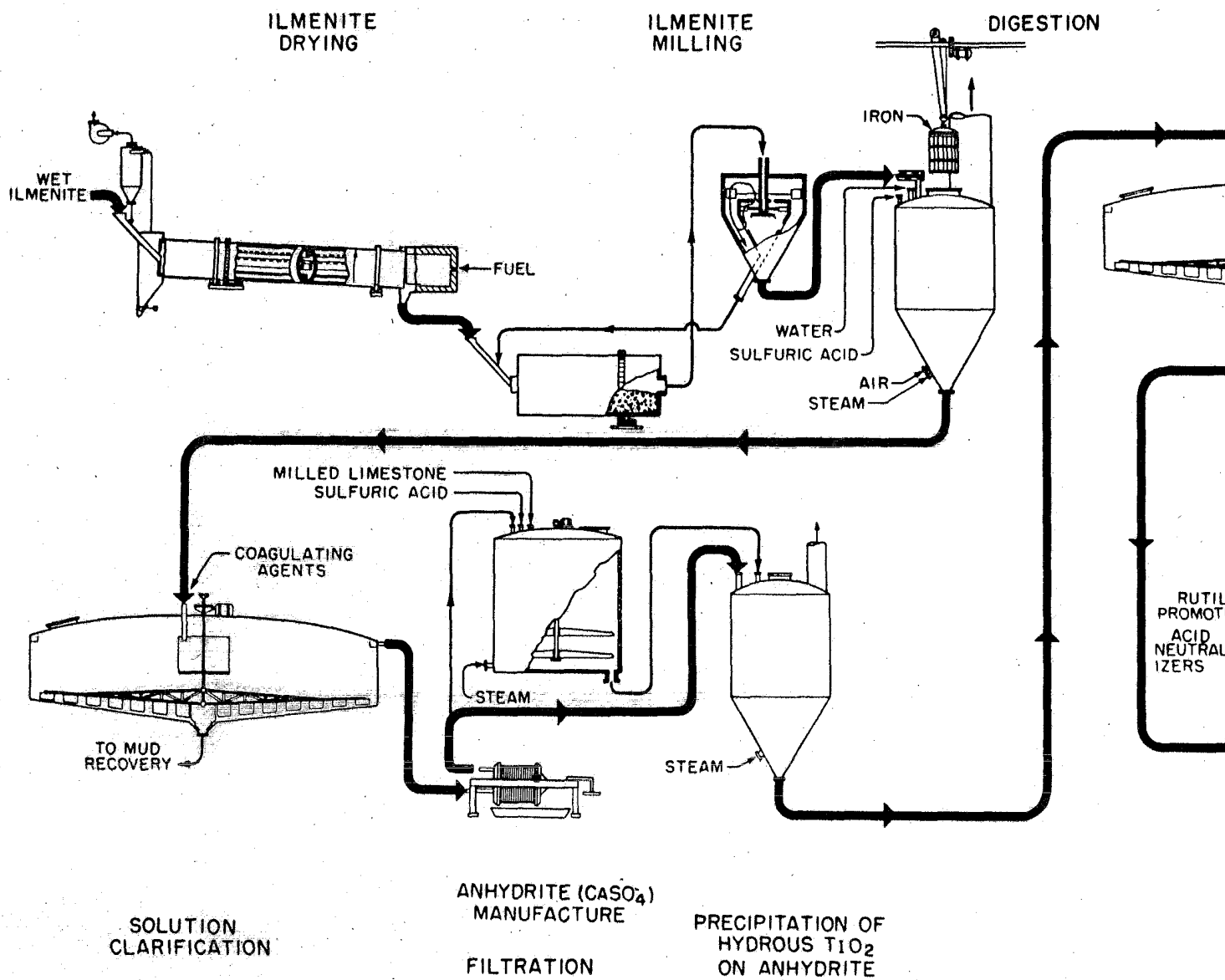
It must be remembered that titanium dioxide pigment owes its value to its properties, particularly the combination of high refractive index with optimum particle size. A particular process for the manufacture of this pigment may be looked upon as one route to these properties. And there are many routes. Yet no single one will necessarily produce titanium dioxide superior to that from any other.

MINING AND CONCENTRATING  
ILMENITE (TITANIUM ORE)

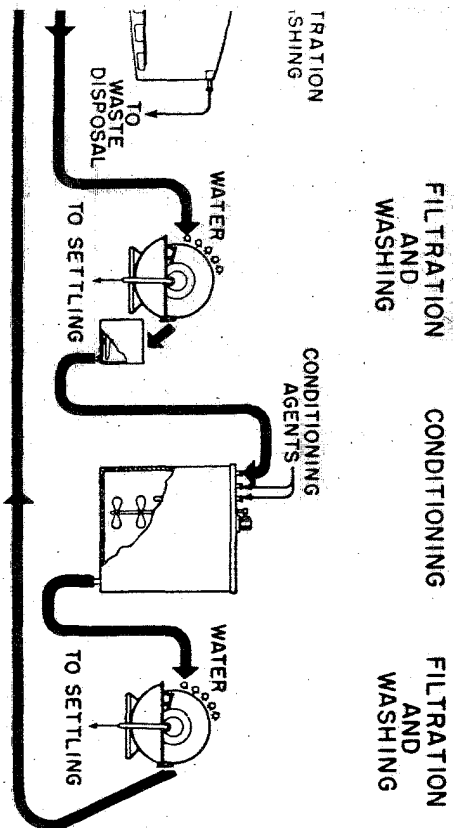




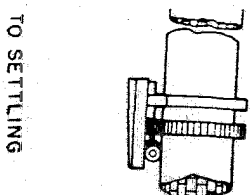
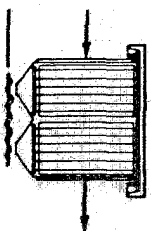
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# MANUFACTURE OF TITANOX TITANIUM-CALCIUM PIGMENTS

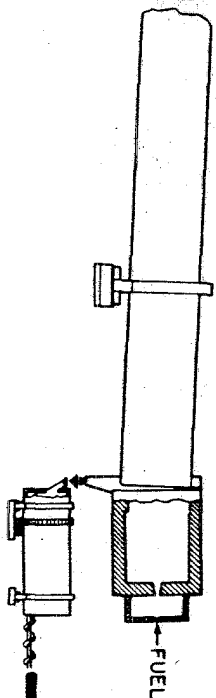


DUST COLLECTION

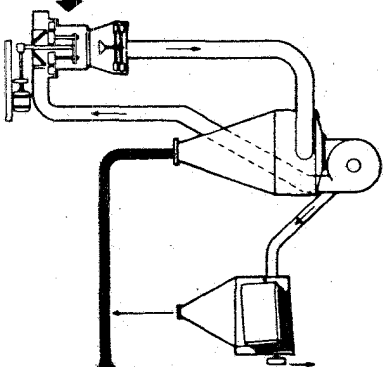


TO SETTLING

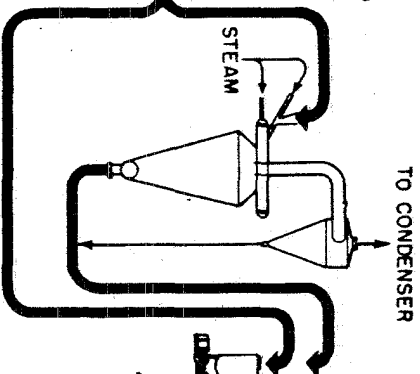
CALCINATION OF PIGMENT



ROLLER MILLING



FLUID ENERGY  
MILLING



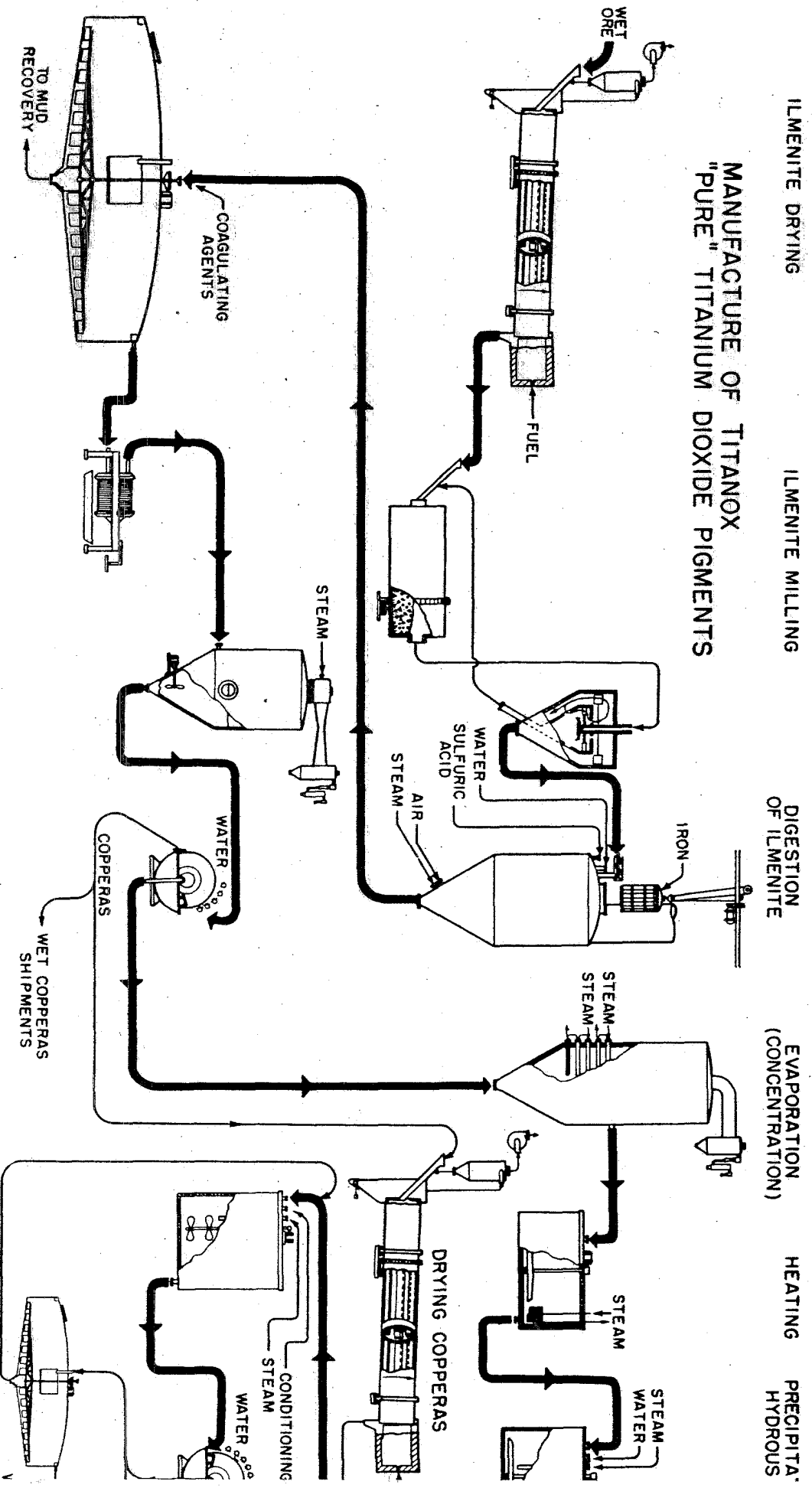
PACKING  
FINISHED  
PIGMENT



NLI 121247

ILMENITE DRYING      ILMENITE MILLING

# MANUFACTURE OF TITANOX "PURE" TITANIUM DIOXIDE PIGMENTS

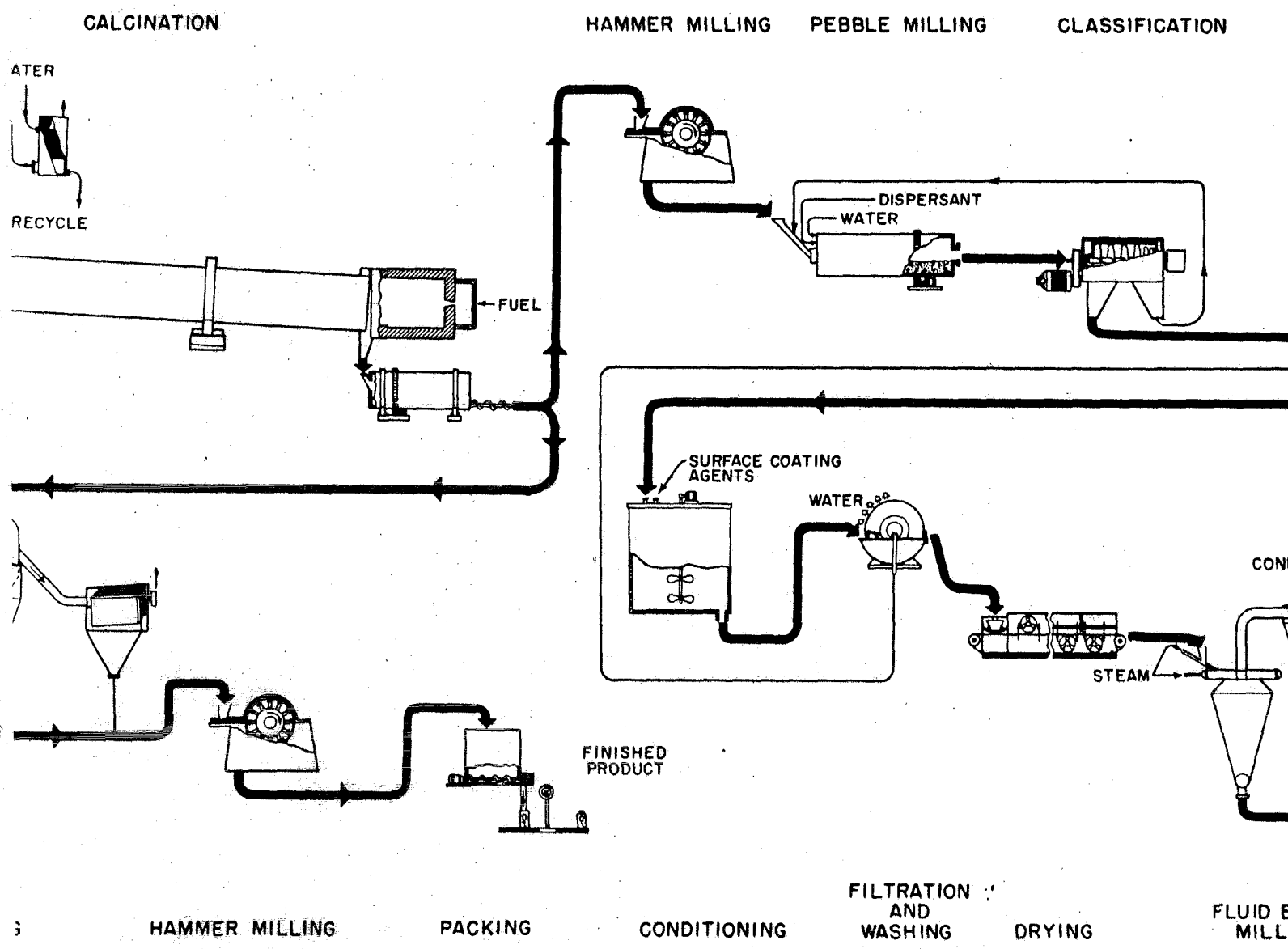
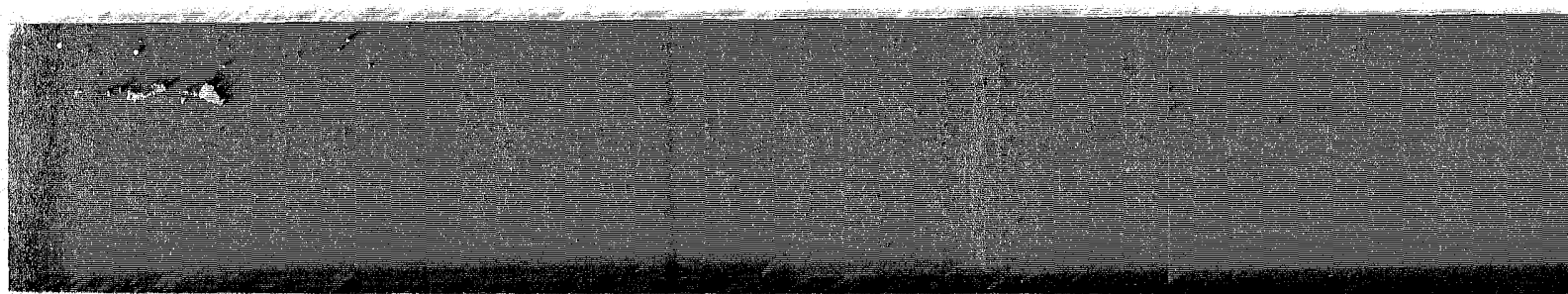


NLI 121248

SOLUTION CLARIFICATION      FILTRATION      IRON SULPHATE (COPPERAS) CRYSTALLIZATION      FILTRATION      CONDITIONING      SETTLING







## PART I

### PROPERTIES OF TITAN

**A**N UNDERSTANDING of titanium dioxide itself is helpful in determining the worth of TITANOX pigments.

#### Physical and Chemical

In the first place, why was the foundation of these pigments? Titanium dioxide is the most stable combination of titanium and oxygen. Titanium peroxide,  $TiO_2$ , is highly stable. The lower oxides,  $TiO$  and  $Ti_2O_3$ , are unstable. All lower oxides are dark in color. Titanium dioxide in finely divided form is white.

Physical stability of titanium dioxide is due to its high melting point of  $1830^\circ C$ . It is very stable when heated to very high temperatures. As a result, titanium dioxide pigments are stable at temperatures encountered in most pigmented materials. Although at high temperatures, the color of titanium dioxide may change, it usually reverts to white on cooling.

Chemical stability is indicated by its insolubility. Insoluble in water, dilute acids, dilute alkalis and peroxide. Titanium dioxide compound at ordinary temperatures may be brought into solution by concentrated sulfuric acid or hydrofluoric acid with sodium or potassium carbonate. In the latter case, the fate must often be employed to bring it into solution, the melt being dissolved. Titanium dioxide is unaffected by atmospheric conditions, such as sulfur oxides, etc.

Titanium dioxide is difficultly reduced in a vacuum at very high temperatures. The color and consequent darkening may be eliminated and brightness restored by heating. Ordinarily very high temperatures are not required. Reaction of  $TiO_2$  with other coloring agents.

21 This stability of titanium dioxide is the result of the strong bond between titanium and oxygen—often explained by the screening of titanium ions by six oxygen ions in the crystal structure.

### Crystal Structure

Three crystal types or polymorphs of titanium dioxide exist, namely, anatase, brookite and rutile, and in each, the titanium ion is surrounded by six oxygen ions. Anatase and rutile are tetragonal while brookite is orthorhombic. Inasmuch as brookite has not been prepared on any significant scale and apparently occurs only in nature, and sparsely, it is not of primary interest here.

With the titanium ion at the centre surrounded by six oxygen ions, the arrangement is an octahedron. In anatase the octahedra are packed so that four of the twelve edges of each octahedron are shared with other octahedra, whereas in rutile two are shared. These arrangements are illustrated in Figures 1 and 2 along with the unit cells and their dimensions.

While anatase has four molecules per unit cell with<sup>(1)</sup>  $a = 3.758 \pm .001\text{\AA}$  and  $c = 9.514 \pm .003\text{\AA}$ , rutile has two molecules per unit cell with<sup>(1)</sup>  $a = 4.5929 \pm .0005\text{\AA}$  and  $c = 2.9591 \pm .0003\text{\AA}$ , and is therefore less complex and more compact.

Typical X-ray diffraction patterns of anatase and rutile are shown in Figures 3 and 4 respectively. The intensity of the diffracted ray is plotted against the diffraction angle. The interplanar spacing in Angstrom units associated with each diffracted ray is marked adjacent to it. X-ray diffraction patterns are a most positive means of identifying anatase and rutile.

Rutile is apparently the more stable form at all temperatures. As heat is applied to anatase it transforms to rutile over the temperature range  $700^{\circ}$  to  $950^{\circ}\text{C.}$ <sup>(2)</sup> which is well below the melting point of  $1830 \pm 15^{\circ}\text{C.}$  of rutile.

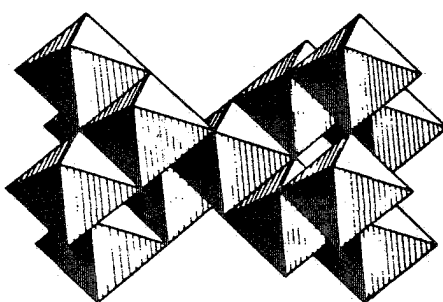
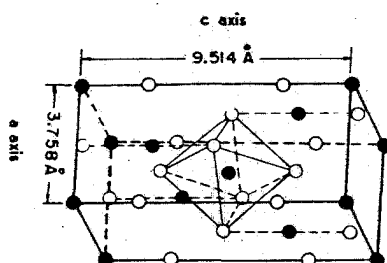
The difference in crystal structure between anatase and rutile is often considered the basis for differences in their physical properties. These properties, in general, are of the same order of magnitude in the two

(1) Cromer, D. T. and Herrington, K., J. Am. Chem. Soc. 77, 4708 (1955)

(2) Sullivan, W. F. and Cole, S. S., J. Am. Cer. Soc. 42, 127-133 (1956)

# CRYSTAL STRUCTURE OF ANATASE

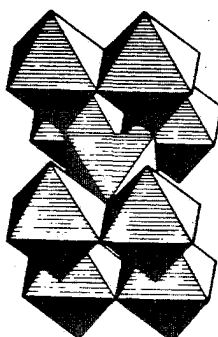
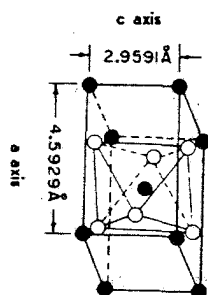
● TITANIUM  
○ OXYGEN



12a

# CRYSTAL STRUCTURE OF RUTILE

● TITANIUM  
○ OXYGEN



12b

NLI 121253

Figure 3

X-RAY DIFFRACTION PATTERN OF ANATASE POWDER

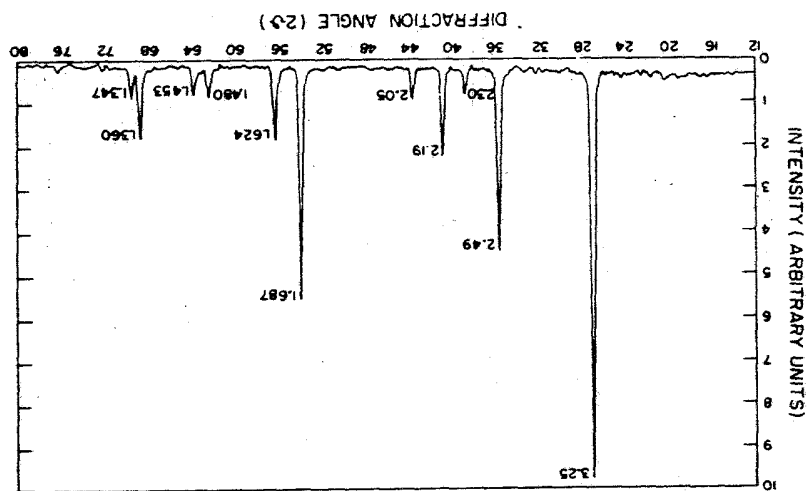
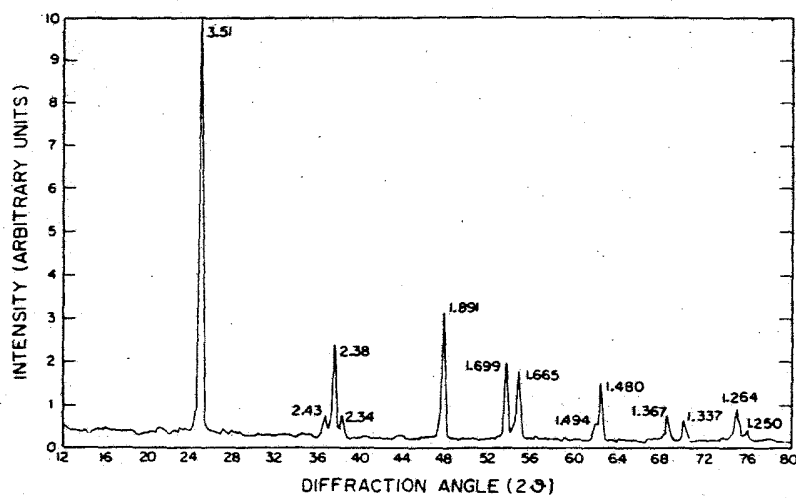


Figure 4

X-RAY DIFFRACTION PATTERN OF RUTILE POWDER

12c

12d

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types, but the differences can be of practical importance. The more compact structure of rutile, for example, is considered to account for its higher refractive index. This can be the basis for selection between the two crystal types in finely divided form for pigment purposes.

### Refractive Index

Among colorless substances, the average refractive index of titanium dioxide is the highest known. For anatase it is 2.52(3) and for rutile 2.76(4). This property accounts for the great light scattering ability of finely divided titanium dioxide when dispersed in various media with consequent high reflectance and opacity. As refractive index varies with wave length, it is not surprising that the refractive index of titanium dioxide is higher at the shorter wave length or blue region, and lower at the longer wave length or red region of the visible spectrum as shown in Table I.

TABLE I

### Refractive Index of Titanium Dioxide Synthetic Rutile Crystal(s)

| Wave Length<br>Micron | $n_D$<br>(ordinary ray) | $n_D$<br>(extraordinary ray) |
|-----------------------|-------------------------|------------------------------|
| 0.4358                | 2.8499                  | 3.1969                       |
| 0.4861                | 2.7305                  | 3.0473                       |
| 0.5461                | 2.6503                  | 2.9473                       |
| 0.5891                | 2.6126                  | 2.9004                       |
| 0.6563                | 2.5720                  | 2.8500                       |
| 1.0140                | 2.4842                  | 2.7418                       |
| 1.5295                | 2.4461                  | 2.6954                       |

other data(5) extend the above range to 8 microns.

### Natural Anatase Crystal(s)

| Wave Length<br>Micron | $n_D$<br>(ordinary ray) | $n_D$<br>(extraordinary ray) |
|-----------------------|-------------------------|------------------------------|
| 0.43583               | 2.7688                  | 2.6576                       |
| 0.54607               | 2.5948                  | 2.5161                       |
| 0.5893                | 2.5612                  | 2.4880                       |
| 0.69075               | 2.5097                  | 2.4447                       |

- (3) Int. Critical Tables, McGraw-Hill, N. Y., 1, 113 (1926)  
 (4) Herrington, K., *Optical Digest* 34, 453, p. 1069, Oct. 1962.  
 See also DeVore, J. K., *J. Opt. Soc. Am.*, 41, 416-419 (1951)  
 (5) Schroeder, A., *Zeit. Krist.* 67, 485-542 (1928)



The transparent large single crystal form of rutile titanium dioxide, early made by National Lead Company Titanium Division(6a) has provided not only for reliable determination of refractive index but also of other optical properties. For example, transmission(6) expressed as optical density ( $\log \frac{1}{\text{transmission}}$ ) is shown in Figure 5.

### High Reflectance and Whiteness

Titanium dioxide while transparent in large single crystals, is highly reflective in finely divided form, and is intensely white because its high reflectance is uniform throughout the visible spectrum. Yet its whiteness is not perfect.

As indicated by transmission of the single crystal, absorption in the far blue region is also characteristic of the finely divided material. In this respect rutile is more absorptive than anatase as may be noted from Figure 6 showing the reflectance of compresses of finely divided anatase and rutile measured against fumed magnesium oxide as a standard(7). Anatase is innately the less yellowish or more bluish white form. As a result, under strictly comparable conditions, not involving colored additives, anatase titanium dioxide is the whitest type of titanium pigment. At longer wavelengths(7) and extending into the infrared as shown in Figure 7 rutile is more highly reflective.

### Integrated Solar Reflectance

Based on solar intensities over the wavelength range of 0.3 to 2.5 microns and adjusted to a value of 0.966 for fumed  $\text{MgO}$ (7), the integrated solar reflectance of a compress of finely divided anatase is 0.929 and of a similar compress of rutile is 0.946. (The spectral energy distribution of sunlight(8), at an air mass of two, on which these figures are based, is shown in Figure 8). Because titanium dioxide has much higher refractive index than the binders of coatings such as paints, its high solar reflectivity is readily utilized in coatings.

- (6) Cronmeyer, D. C., *Phys. Rev.* 87, 876-86 (1952)
- (6a) *Science News Letter*, Oct. 18, 1947; A.I.M.E. Mining Transactions 184, 194 (1949)
- (7) Herrington, K., Unpublished Data, Res. Labs., National Lead Company, Titanium Division
- (8) Moon, P., *J. Franklin Inst.* 230, 583-617 (1940)

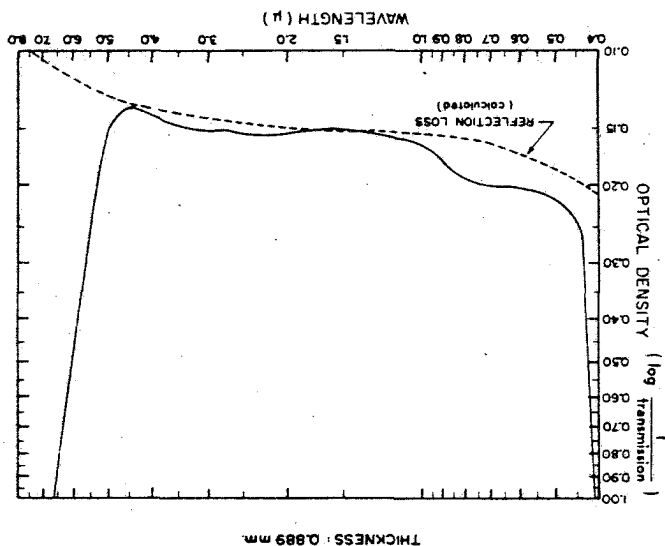
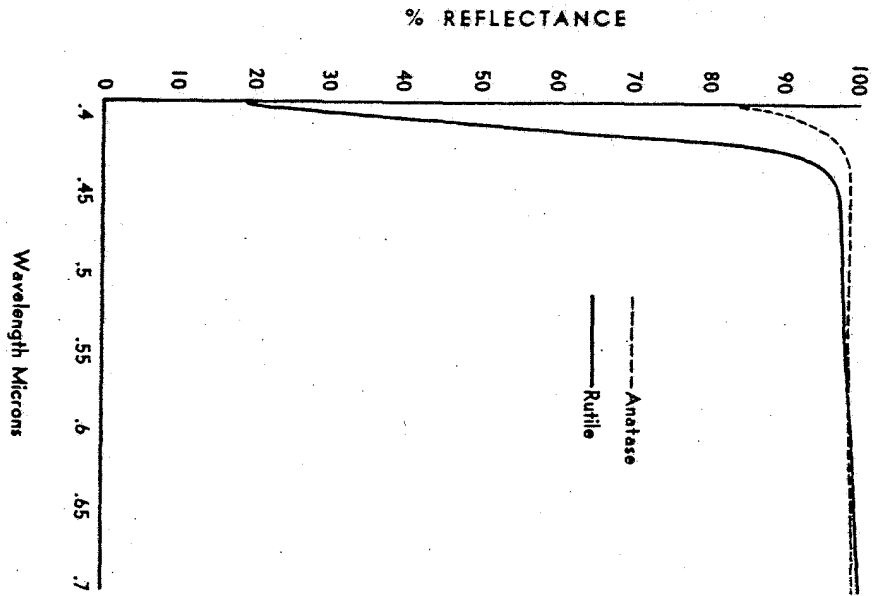


Figure 5  
TRANSMISSION OF SYNTHETIC RUTILE SINGLE CRYSTAL,  
THICKNESS: 0.889 mm.

Figure 6

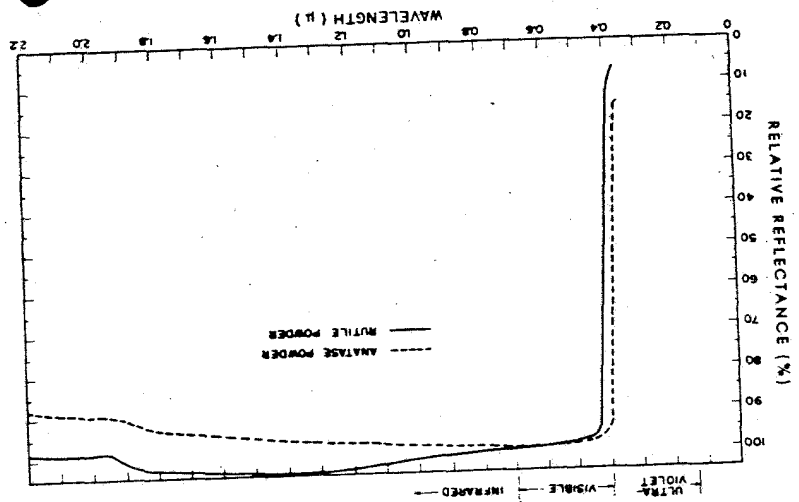
REFLECTANCE OF  $TiO_2$  POWDERS  
(AGAINST FUMED  $MgO$ ) OVER  
VISIBLE PORTION OF SPECTRUM



14b

REFLECTANCE OF TITANIUM DIOXIDE  
AGAINST FUMED MAGNESIUM OXIDE  
WHICH IS ASSIGNED A VALUE OF 100%

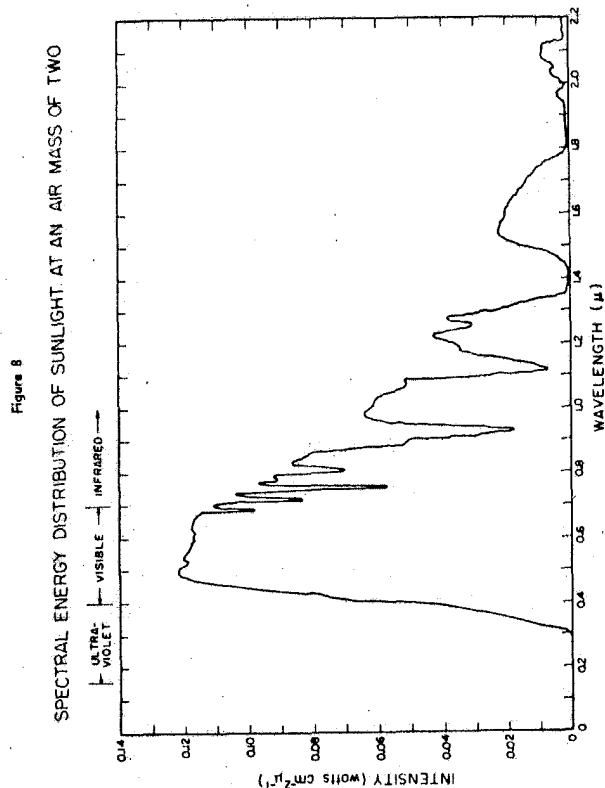
Figure 7



14c

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ON



This is in contrast to other low refractive index materials carrying appreciable p

### Emissiv

The emissive power of a various wavelengths is shown

TAB

Some Mechanical Properties

Density g.cm.<sup>-3</sup>

Hardness—Mohs'

Knoop Hardness Number with 500 gram load

- \* single crystal
- † rutile powder
- ‡ anatase powder

Among other mechanical properties of TiO<sub>2</sub> powder pres moduli (14b) and bending rutile crystal; compressibility crystal have been determined coefficient calculated (14, 15) kg.-1.

- (9) Res. Lab. National Lead C.
- (10) Shomate, C. H., J. Am. Chem. Soc., 41, 1000 (1919).
- (11) Schossberger, F., Z. Krist., 100, 1 (1937).
- (12) Moore, C. H., Trans. A.I.E.E., 56, 1000 (1937).
- (13) Combes, L. S., Ballard, J. Opt. Soc. Am., 41, 215-216 (1921).
- (14) Madelung, E. and Fuchs (1921)
- (14a) Bridgman, P. W., Proc. Nat. Acad. Sci., 16, 100 (1920).
- (14b) Vick, G. L. and Holland, J. B., J. Appl. Phys., 32, 947-9 (1960).
- (14c) Bridgman, P. W., Am. J. Sci., 26, 30 (1950-51).
- (15) Dayal, B., et al., J. Sci. Ind. Res., 10, 263 (1951).
- (16) Wachtman, J. B., Jr. and nical Report, 53-265, July 1951.

TABLE III  
Some Thermal Properties of Titanium Dioxide

|                                       | Rutile                               | Anatase                           |
|---------------------------------------|--------------------------------------|-----------------------------------|
| Melting Point                         |                                      |                                   |
| in Air                                | 1830 ± 15°C. (17)                    | .....                             |
| At higher O <sub>2</sub>              | 1870 ± 15°C. (17)                    | .....                             |
| Thermal Conductivity                  |                                      |                                   |
| cal/sec.-1 cm.-1 °C.-1                |                                      |                                   |
| at 44°C. in c-dir.                    | .0256(18)                            | .....                             |
| at 48°C. in a-dir.                    | .0204(18)                            | .....                             |
| rutile powder                         |                                      |                                   |
| 100°C. to 1200°C. 0.015 to 0.0079(18) |                                      | .....                             |
| Linear Therm. Expans.                 |                                      |                                   |
| (°C.-1)                               |                                      |                                   |
| a axis                                | *7.19 × 10 <sup>-6</sup> (6, 20)     | *-2.88 × 10 <sup>-6</sup> (6, 20) |
| c axis                                | *9.94 × 10 <sup>-6</sup> (6, 20)     | *6.64 × 10 <sup>-6</sup> (6, 20)  |
| 0 to 1000°C.                          | †9.0-9.1 × 10 <sup>-6</sup> (21, 22) | .....                             |
| -130 to 50°C.                         | †8.0 × 10 <sup>-6</sup> (23)         | .....                             |
| * Natural single crystals             |                                      |                                   |
| † Powders                             |                                      |                                   |

Specific Heat,  $c_p$ , (cal. °C.<sup>-1</sup>g.<sup>-1</sup>)

TiO<sub>2</sub> powder—crystal structure not specified (24), where  $t$  varies from about 37 to 400°C.,

$$c_p = 0.1512 + 2.45 \times 10^{-4} t - 2.22 \times 10^{-7} t^2$$

Anatase powder (25), where  $t$  varies from 307 to 728°C.,

$$c_p = 0.1692 + 1.602 \times 10^{-4} t - 1.53 \times 10^{-7} t^2$$

Rutile powder (26), where  $t$  varies from 304 to 1009°C.,

$$c_p = 0.1680 + 1.281 \times 10^{-4} t - 7.84 \times 10^{-8} t^2$$

Specific Heat at Low Temperatures (10)

| Temp., °K. | Rutile  | Anatase |
|------------|---------|---------|
| 298.16     | 0.1646  | 0.1653  |
| 240.9      | 0.1446  | 0.1419  |
| 160.7      | 0.1021  | 0.0990  |
| 79.5       | 0.03911 | 0.03746 |
| 52.5       | 0.01966 | 0.01682 |

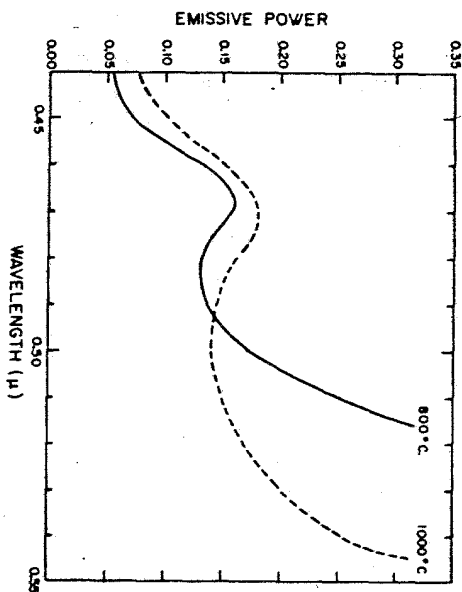


Figure 9  
EMISSIVE POWER OF TITANIUM DIOXIDE  
(ratio of emitted light to that emitted by a black body)  
Ref.: Smyth, G. I., Zhur. Eksp. Terost. Fiz. 12 581.3 (1949)

TABLE IV

## Some Electrical Properties of Titanium Dioxide

|                                   | <i>Rutile</i>                                              | <i>Anatase</i>                                  |
|-----------------------------------|------------------------------------------------------------|-------------------------------------------------|
| Dielectric Constant ..            | 114(26a)                                                   | 48(27)                                          |
| a-direction .....                 | *170(26)                                                   | .....                                           |
| c-direction .....                 | *86(26)                                                    | .....                                           |
| Temp. Coeff. of Diel. Const. .... | *-0.18 °C. <sup>-1</sup> (26)                              | .....                                           |
| Loss Tangent                      | .....                                                      | 1.40 × 10 <sup>-3</sup> °C. <sup>-1</sup> (27a) |
| a-direction .....                 | .0110 to 0.0002(26b)                                       | .....                                           |
| c-direction .....                 | 0.35 to 0.0016(26b)                                        | .....                                           |
| Conductivity                      | .....                                                      | .....                                           |
| room temp.                        | .....                                                      | .....                                           |
| a-direction .....                 | *10 <sup>-10</sup> ohm <sup>-1</sup> cm <sup>-1</sup> (12) | .....                                           |
| c-direction .....                 | *10 <sup>-18</sup> ohm <sup>-1</sup> cm <sup>-1</sup> (12) | .....                                           |
| 500°K.                            | .....                                                      | .....                                           |
| a-direction .....                 | *10 <sup>-7</sup> ohm <sup>-1</sup> cm <sup>-1</sup> (26c) | .....                                           |
| c-direction .....                 | *10 <sup>-6</sup> ohm <sup>-1</sup> cm <sup>-1</sup> (26c) | .....                                           |
| Breakdown Voltage ..              | 600-700 volts mil <sup>-1</sup> (26d)                      | .....                                           |
| Dipole Moment .....               | 2.8-3.3 debyes(26e)                                        | .....                                           |
| Magnetic Susceptibility .....     | 0.078-0.089 × 10 <sup>-6</sup> (26)                        | .....                                           |

\* on single crystals

- (17) Bruner, G. and Litke, W., *J. Inorg. Nucl. Chem.*, **16**, 67-76 (1960)
- (18) McCarthy, K. A. and Ballard, S., *J. Opt. Soc. Am.*, **41**, 228 (1951)
- (19) Kingery, W. D., Prancel, J., Coble, R. L. and Vashita, T., *J. Am. Cer. Soc.*, **37**, 107-110 (1954)
- (20) Schrauf, A., *Z. Krist.*, **9**, 433-485 (1884)
- (21) VonHippel, A., Breckenridge, R. G., Chesley, F. G. and Tisza, L., *Ind. Eng. Chem.*, **38**, 1097-1109 (1946)
- (22) Maurer, F. A. and Holz, I. H., WADC Technical Report, 55-473 (1955); Supplement 1 (1957)
- (23) Day, J., *Bull. Soc. Sci. Bretagne*, **24**, 13-19 (1949)
- (24) Arthur, J. S., *J. Appl. Phys.*, **21**, 732-733 (1950)
- (25) Lietz, J., *Hamburger Beitr. Angew. Mineral Kristall Phys.*, **1**, 229-238 (1956)
- (26) Parker, K. A., *Phys. Rev.*, **124**, 1719-22 (1961)
- (26a) Bencherch, L. J. and Bell, M. E., *J. Appl. Phys.*, **11**, 681-92 (1940)
- (26b) VonHippel, A. R., "Dielectric Materials and Applications", John Wiley & Sons, Inc., New York (1954)
- (26c) Grant, F. A., *Revs. Mod. Phys.*, **31**, 646-74 (1959)
- (26d) Wainer, E., *Trans. Electrochem. Soc.*, **80**, 331-56 (1946)
- (26e) C. A. 45, 406f (1951)
- (27) Errera, J. and Ketelaar, H., *J. Phys. Rad.*, **3**, 239-47 (1943)
- (27a) Eucken, A. and Buchner, A., *Z. Phys. Ch.*, **B27**, 321-29 (1935)
- (28) Ryerson, L. H. and Honig, J. M., *J. Am. Chem. Soc.*, **75**, 3920-22 (1953)

## Attainment of Pigmentary Value

The purest titanium dioxide, as a result of atomic and internal crystal structure, may possess imminently high refractive index and chemical and physical stability, but may have no value whatsoever as pigment. Particle size and particle size distribution must be optimum so as to contribute with high refractive index, to efficient scattering of light and consequent high reflectance and opacity. On the basis of Mie theory (29), one can calculate (4) that maximum scattering efficiency for green light by titanium dioxide results when the particle diameter is about 0.25 micron. Excessive proportions of extremely small particles such as under 0.1 micron diameter and of relatively large such as above 1.0 micron diameter must be excluded. As a result, a typical median particle diameter of titanium dioxide pigment is 0.2 micron.

From the practical viewpoint, particles of titanium pigment are of interest in relation to their surface which is not only subject to modification itself but offers the entrance for modifiers which control pigmentary effects. The simplest type of titanium pigment is one which provides high reflectance, whiteness and remarkable hiding power. Such a pigment however may lack certain qualities required for special uses and therefore will be modified for these. That is why a number of types of titanium dioxide pigments have been made available to meet different needs. Thus as an example, for tinted exterior paints, the tendency of the simplest type of pigment toward chalking and resultant fading of the paint must be reduced. Such modification may be secured through acting upon or through the surface of the pigment.

In Part III, the salient qualities of TITANOX pigments are discussed. A comprehensive table of the properties of the pigments is presented as well as a separate data sheet devoted to each type.

(29) Mie, Gustave, *Annalen der Physik*, 25, p. 377 (1908)

## PART III

### TITANOX

#### The original Titanium Pigments

**W**HITE pigments which owe their unusual whiteness and unsurpassed hiding power to titanium dioxide are either substantially titanium dioxide itself or titanium dioxide extended with calcium sulfate. Unextended titanium dioxide is known as "pure" pigment, whereas extended titanium dioxide is known as composite pigment. These classes are distinguished in TITANOX—the original line of titanium pigments—by the letter following the word TITANOX. Thus, the letter A as suffix denotes "pure" titanium dioxide, while C indicates calcium sulfate as extender. So widely has this brand been accepted that titanium pigments are commonly mentioned as falling into classes A and C.

Increased tinting strength and opacity brought the rutile crystal structure of titanium dioxide into the picture with the established anatase crystal structure. To identify the rutile form, the letter R was added to the suffix so that rutile titanium dioxide is identified TITANOX-RA, whereas anatase titanium dioxide is called simply TITANOX-A. Similarly, rutile titanium dioxide-calcium sulfate pigment is called TITANOX-RC. Thus, there are two general classes of titanium pigments according to titanium dioxide content and two additional classes according to crystal structure of titanium dioxide.

Specific types within the broad classes have been developed mainly to provide one or more of the following:

1. Greater ease of mixing and grinding in coating or other compositions.
2. Reduction of after-yellowing of vehicles or retention of whiteness.
3. Increased tinting strength and hiding power.
4. Reduction of chalking in exterior organic coatings.

## TITANOX Pigments

### Titanium Dioxide (rutile)

- TITANOX-RA—general utility
- TITANOX-RA-10—unmodified
- TITANOX-RA-40—rubber and plastic, especially floor covering grade
- TITANOX-RA-45—High gloss enamel grade
- TITANOX-RA-46—Latex flat and paper grade
- TITANOX-RA-50—Multi-purpose
- TITANOX-RA-51—Higher strength multi-purpose
- TITANOX-RA-NC—"Non-chalking" for coatings and compositions exposed to weathering
- TITANOX-PL—stabilized for use in plastic laminating paper

### Titanium Dioxide (anatase)

- TITANOX-A-MO (and -LO)—general utility; chalking type for white house paints; white rubber; viscose delustering.
- TITANOX-A-168 (-MO and -LO)—retards after yellowing; uses similar to above, also white plastic compositions; inks
- TITANOX-AA—"semi-chalking" for white house paints; acetate rayon delustering
- TITANOX-A-CG—paper coating grade (CG)
- TITANOX-A-WD—water dispersible; paper filling
- TITANOX-A-WG—"Welding Grade" for coatings of arc-welding rods

### Titanium-Calcium (rutile $\text{TiO}_2$ on $\text{CaSO}_4$ 30% $\text{TiO}_2$ )

- TITANOX-RCHT—general utility; flat wall paints, etc., traffic paints
- TITANOX-RCHTX—enamel grade of RCHT
- TITANOX-RC—"non-chalking" for tinted coatings exposed to weathering

### 50% $\text{TiO}_2$

- TITANOX-C-50—multi-purpose; flat wall, semi-gloss, gloss paints and enamels

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## Improvement in Mixing and Grinding Qualities

### Progress in Dispersion paralleled Trend to Rutile

The primary "pure" titanium dioxide pigment is TITANOX-A. Of substantially anatase crystal structure, this original titanium dioxide pigment was early improved in ease of mixing and grinding accompanied by lowered vehicle requirement, or low oil absorption—hence the suffix LO—TITANOX-A-LO. To assure distinction between the regular pigment and the improved type, the letters MO signifying medium oil absorption were added to the regular name so familiarly known as TITANOX-A-MO. As new types of TITANOX-A were developed, these also possessed low oil absorption.

With the exception of TITANOX-RA-46, the TITANOX rutile "pure" pigments have low oil absorption and low organic vehicle requirements for mixing and grinding. The high oil absorption of TITANOX-RA-46 is a characteristic that accompanies its high hiding in flat latex paints, but is not a determinant of its ease of incorporation in latex vehicles.

A typical comparison of the percentage of pigment by weight in pastes for grinding through a roller mill illustrates differences among these pigments:

| Anatase "pure" pigments            | Relative % Pigment by Weight in Paste for Grinding |
|------------------------------------|----------------------------------------------------|
| TITANOX-A-MO, and A-168 MO.        | 50-55                                              |
| TITANOX-A-LO, and A-168 LO.        | 62-64                                              |
| TITANOX-AA                         | 60-62                                              |
| TITANOX-A-CG                       | 62-64                                              |
| Rutile "pure" pigments             |                                                    |
| TITANOX-RA-46                      | 50                                                 |
| TITANOX-RA                         | 66                                                 |
| TITANOX-RA-50, RA-51, RA-NC, RA-45 | 68-72                                              |

Improvement in the dispersibility of the TITANOX pigments paces the need for maximum rate of production of milled suspensions having the degree of dispersion or fineness of grind desired.

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Thus the general utility rutile-calcium (30% TiO<sub>2</sub>) pigment TITANOX-RC-HT readily provides the degree of dispersion usually needed in flat wall paints, exterior house paints, traffic paints, and many other suspensions. Further ease of mixing and grinding\* of this type of pigment has been denoted by the suffix X, thus TITANOX-RC-HT-X. This pigment is applicable to systems requiring the ultimate in pigment dispersibility. Exceptional ease of mixing and grinding has always characterized the chalk-resistant rutile-calcium pigment, TITANOX-RC, and is an outstanding feature of TITANOX-C-50 (50% TiO<sub>2</sub>, 50% CaSO<sub>4</sub>)—the exceptionally high hiding composite pigment. These pigments may be shown to differ from TITANOX-RC-HT in speed of wetting and fineness of grind as in the following comparison:

|                 | Relative<br>Wetting Time | Fineness*<br>of Grind |
|-----------------|--------------------------|-----------------------|
| TITANOX-RC-HT   | 60                       | 5                     |
| TITANOX-RC-HT-X | 40                       | 6 1/2                 |
| RC, C-50        | 40                       | 6 1/2                 |

\* Hegman gauge readings of special test paint for comparison purposes only.

These easy dispersing rutile-calcium pigments have long been readily dispersible in equipment of the high speed mixer or colloidal mill type that operate on suspensions of relatively low consistency and high volatile content, as well as in older types of equipment such as pebble and roller mills.

### Ease of Dispersion of Newer TITANOX rutile Pigments

At comparable constant pigment concentration, the newer TITANOX rutile titanium dioxide pigments in speed of wetting on the average fall in about this order:

|                            |       |
|----------------------------|-------|
| TITANOX-RA-45              | 18    |
| TITANOX-RA-50, -51, -RA-NC | 23-30 |
| TITANOX-RA-46              | 45    |

As would be expected from differences in oil absorption, other factors being equal, a higher loading of TITANOX-RA-45, generally about 8% as compared with RA-50, -RA-51, and RA-NC and a lower loading of RA-46 may be handled in a given dispersing vehicle when maximum concentration of pigment in relatively viscous grinding suspensions is desired. In equipment of the high speed mixer type, such as the Cowles dis-

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solver, these pigments may be dispersed readily to 7-8 fineness of grind. Despite the fact that the rutile pigments are harder than the anatase types, abrasion traceable to hardness is minimized by lack of large particles plus rapidity of mixing and grinding. For the production of whites and delicate tints prolonged grinding in steel ball mills is avoided.

### Dispersibility and Consistency

In the rutile "pure" pigments at high pigment content of pastes there may be differences in consistency related to efficacy of dispersion in critical cases. In finished paint products, there is usually no appreciable difference in consistency among the TITANOX "pure" pigments, except that the higher oil absorption types may produce slightly higher consistency than the low oil absorption types in organic solvent type systems. Among the newer rutile "pure" pigments, TITANOX-RA-46 will give slightly heavier consistency than the others; the difference is more pronounced at higher total pigment concentration, as in pastes and in organic solvent flat wall paints. A typical relationship in consistency effects of the newer "pure" pigments follows:

### Average Consistency Some organic solvent type coatings

| Pigment       | Stormer Units |
|---------------|---------------|
| TITANOX-RA-45 | 85            |
| TITANOX-RA-46 | 90            |
| TITANOX-RA-51 | 88            |

In finished organic solvent type paints which do not contain aqueous bodying agents, there is usually only slight difference in consistency among the rutile-calcium pigments. In critical cases, TITANOX-RC-HT will produce heavier consistency and less flow in highly pigmented pastes.

| Pigment         | Paste<br>Consistency <sup>(1)</sup> | Paint<br>Consistency <sup>(2)</sup> |
|-----------------|-------------------------------------|-------------------------------------|
| TITANOX-RC-HT   | 40                                  | 69                                  |
| TITANOX-RC-HT-X | 30                                  | 68                                  |
| TITANOX-RC      | 28                                  | 68                                  |
| TITANOX-C-50    | 25                                  | 67                                  |

(1) Relative consistency using paste consistometer under parallel conditions.  
(2) Typical difference in brushing consistency in Stormer Units.

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### Dispersion and Consistency in Water

Ease of dispersion in water was early attained in anatase titanium dioxide—Tiranox-A-WD (WD—water dispersible). With the trend to rutile for use in aqueous systems, such as latex paints, and the need for a high degree of dispersion in such systems, the newer rutile pigments are readily dispersible at high solids in water with the dispersants universally used.

Oil absorption and consistency in organic solvent type vehicles are generally not indicators of dispersibility and consistency in aqueous systems. Thus, water slurries of Tiranox-RA-46 at relatively high concentration have low viscosity over a range of dispersant concentration.

*Example of Approximate Viscosity in Centipoises*  
70% Pigment by Weight in Water for % Dispersant\*

| Pigment           | 0.2 | 0.4 | 0.6 |
|-------------------|-----|-----|-----|
| Tiranox-RA-45 ... | —   | 125 | 290 |
| Tiranox-RA-46 ... | 100 | 50  | 100 |
| Tiranox-RA-51 ... | 30  | 50  | 125 |

\* Potassium tripolyphosphate

### Improved Retention of Whiteness of Coatings

The yellowing with age of white organic finishes was early found to be lessened by the high tinting strength of the original Tiranox-A. But in addition to masking discoloration, modern Tiranox titanium dioxide pigments also retard the color change of many vehicles. This additional whiteness-retentive effect, largely the result of treatment with hydrated alumina, was first applied by the suffix "168," thus Tiranox-A-168. This feature also characterizes the newer types of rutile "pure" pigments with the exception of Tiranox-RA-10. Generally, white coatings made with the rutile pigments, although not quite as white, retain whiteness to a greater degree as compared with anatase pigments. The higher brightness generally produced by the rutile pigments compensates for their slightly lesser whiteness which can be corrected through the use of toners.

Using reflection values obtained with the Hunter reflectometer, and the color index\* calculated therefrom, following is a typical difference in whiteness and its retention between anatase and rutile and also Tiranox-

\* Color Index =  $\frac{\% \text{ Reflected Amber} - \% \text{ Reflected Blue}}{\% \text{ Reflected Green}}$  X 100  
Brightness =  $\frac{\% \text{ Reflected Green}}{\% \text{ Reflected Green (with green filter)}}$

RA and Tiranox-A-168 whiteness retentive types compared with Tiranox-RA-10 and Tiranox-A. The lower the color index, the less yellowish is whiteness.

### Example of Whiteness and its Retention

Air Dry Alkyd Enamel

| Pigment           | Initial Color<br>% of film |                 | Color of film after<br>exposure to<br>diffused light<br>for eight months |                 |
|-------------------|----------------------------|-----------------|--------------------------------------------------------------------------|-----------------|
|                   | Bright-<br>ness            | Color*<br>Index | Bright-<br>ness                                                          | Color*<br>Index |
| Tiranox-A-168 ... | 89.0                       | 3.7             | 87.0                                                                     | 11.0            |
| Tiranox-A ...     | 89.0                       | 4.2             | 86.0                                                                     | 16.0            |
| Tiranox-RA ...    | 90.0                       | 5.5             | 87.5                                                                     | 13.0            |
| Tiranox-RA-10 ... | 90.0                       | 5.9             | 87.5                                                                     | 16.0            |

In addition to Tiranox-RA, the following rutile pigments generally inhibit after yellowing—Tiranox-RA-45; -RA-46; -RA-50; -RA-51; -RA-NC.

The Tiranox rutile-calcium pigments have long been notable for promoting color retention, although in whiteness effect, Tiranox-RC, the chalk-resistant type has a slightly yellower tone than -RCHT or -C-50. As an example, an enamel with Tiranox-RC had color index of 5.5 as compared with 4.4 for Tiranox-RCHT.

### Improvement in Hiding Power

Increase in tinting strength and correspondingly in hiding power and opacity is the result mainly of the rutile crystal structure in the composite and "pure" pigments and increase in the titanium dioxide content of the composite as may be noted from the following:

#### Tinting Strength of Tiranox Pigments

(Reynolds' constant volume method—  
ultramarine blue—see page 87)

|                                                                                     |                     |
|-------------------------------------------------------------------------------------|---------------------|
| Rutile Titanium Dioxide<br>the Tiranox-"RA" pigments, .....                         | Tinting<br>Strength |
| Anatase Titanium Dioxide<br>the Tiranox-"A" pigments, .....                         | 1650-1850           |
| 50% TiO <sub>2</sub> (rutile)-calcium pigment<br>Tiranox-C-50, .....                | 1200-1250           |
| 30% TiO <sub>2</sub> (rutile)-calcium pigments<br>Tiranox-RC; -RCHT; -RCHT-X, ..... | 1000                |
| Zinc sulfide, .....                                                                 | 600                 |
| Other White Pigments <sup>(1)</sup> , .....                                         | 640                 |
|                                                                                     | 90-300              |

<sup>(1)</sup> Excludes extenders such as aluminum, magnesium and alkali earth carbonates, sulfates, silicates, etc. which are non-hiding or non-opacifying in the great majority of pigmented systems.

Hiding Power Calculated from Tinting Strength\*

|                                   | Hiding Power<br>square feet<br>per pound | Relative<br>weight<br>for equal<br>hiding |
|-----------------------------------|------------------------------------------|-------------------------------------------|
| TIRANOX-RA (rutile $TiO_2$ types) | 147                                      | 1.00                                      |
| TIRANOX-A (anatase $TiO_2$ types) | 115                                      | 1.28                                      |
| TIRANOX-C-50                      | 82                                       | 1.79                                      |
| TIRANOX-RCHT                      | 57                                       | 2.58                                      |
| Zinc sulfide                      | 58                                       | 2.53                                      |
| Lithopone                         | 27                                       | 5.44                                      |
| Zinc oxide                        | 20                                       | 7.35                                      |
| White Lead                        | 15                                       | 9.80                                      |

The above hiding power values are valuable as a guide to the relationship in hiding power among white pigments, and illustrate the exceptional hiding afforded by the TIRANOX pigments, especially the composites when the relative weights for equal hiding are compared. These values are applicable, however, only to a single content by volume of pigment in the paint film. Inasmuch as hiding power of a pigment depends mainly upon the proportion of pigment by volume in the paint film, pigment volume must be taken into account when considering the hiding power of white pigments.

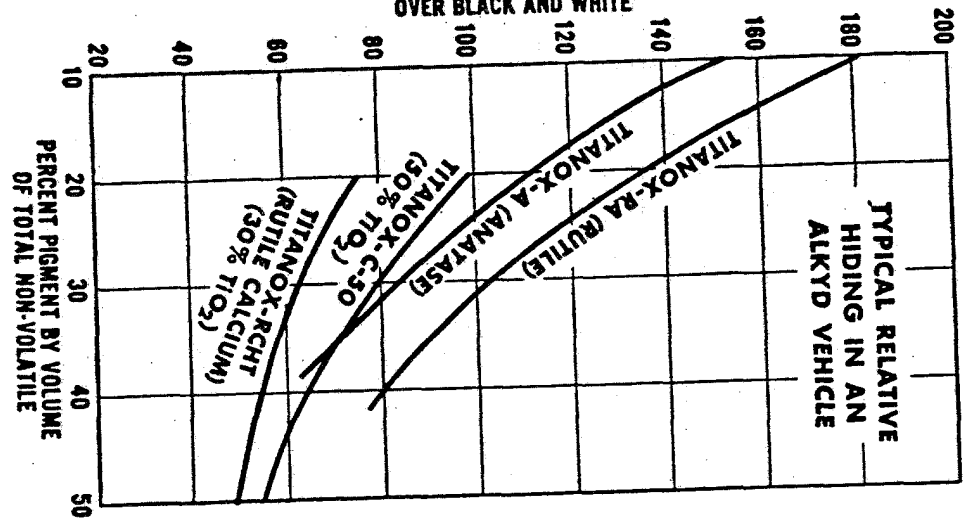
The chart on page 27 is a typical example of the variation of pigment hiding power with pigment volume concentration. The exceptionally high hiding of titanium dioxide at low pigment volume often required in gloss finishes is contrasted with the relatively high hiding of the composite pigments at higher pigment volumes applicable to semi-gloss and flat finishes. These composite pigments usually produce more hiding power for their titanium dioxide content than do the "pure" pigments in highly pigmented coatings such as flat wall paints. As a result, fewer pounds of TIRANOX-RCHT or TIRANOX-C-50 than would be expected of their titanium dioxide content, give maximum hiding at minimum cost. In some comparable flat wall paints, this relationship was found:

| For equal Hiding Power of some Flat Wall Paints     |                                |                                |
|-----------------------------------------------------|--------------------------------|--------------------------------|
| Average Pounds of Prime Pigment per Gallon of Paint |                                |                                |
| Rutile "pure"<br>Titanium Dioxide                   | TIRANOX-C-50<br>(50% $TiO_2$ ) | TIRANOX-RCHT<br>(30% $TiO_2$ ) |
| 1.5                                                 | 2.5                            | 3.9                            |
| 2.0                                                 | 3.4                            | 4.5                            |
| 2.5                                                 | 3.8                            | 5.0                            |

All factors comparable—constant total non-volatile content. Selected extenders, of course, present with prime pigment to raise pvc to 60-70%.

\* Proc. ASTM 30 Part II 895 (1930).  
\* Hiding Power = (Tinting strength with black X .1) + 3.

HIDING POWER - SQUARE FEET PER POUND (98 % CONTRAST RATIO)  
OVER BLACK AND WHITE



The decrease in hiding power of "pure"  $\text{TiO}_2$  pigment as its concentration by volume is increased is the result of crowding of its particles and consequent reduction of light scattering. The use of extenders with this type of pigment thus reducing its concentration while maintaining total pigment volume, reduces the crowding and increases the hiding power of the  $\text{TiO}_2$ . But generally, the increase is not enough to equal the hiding power per pound of the Titanox composite pigments. With "pure"  $\text{TiO}_2$  and added extenders great care must be exercised in establishing the ratio of  $\text{TiO}_2$  to total extender and in the combination of extenders suitable for the total pigment volume concentration. In the Titanox composite pigments the titanium dioxide is integral with the extender and the whole is controlled at manufacture, and in use, functions largely as a pigmentary unit.

### Higher Tinting Strength of Newer TITANOX Rutile Pigments

At high total pigment volume concentrations, the hiding effects of mixtures of "pure" pigment and extenders, while greatly influenced by the extenders can also be affected by relatively slight differences in the "pure" pigment. As a result, for use in flats that do not utilize the Titanox "C" pigments, new grades of "pure" pigment have been developed. These generally have higher oil absorption than the type ordinarily used, such as Titanox-RA-50. Such higher oil absorption is probably due to higher pore volume which may accommodate the extenders while the pigment also resists flocculation. The result is pigment dispersity that contributes to greater scattering of light with resultant higher reflectance and hiding power. Examples of the new type, are Titanox-RA-46 and Titanox-RA-51. In a typical latex flat these pigments gave higher hiding than Titanox-RA-50 as shown below:

| Pigment                                                                                                                     | Hiding Power of Paint<br>(sq. ft./U. S. gal.)<br>for 95% contrast ratio<br>over black and white |
|-----------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| TITANOX-RA-46 .....                                                                                                         | 520                                                                                             |
| TITANOX-RA-50 .....                                                                                                         | 460                                                                                             |
| TITANOX-RA-51 .....                                                                                                         | 490                                                                                             |
| The higher tinting strength of these pigments in a similar flat is illustrated by the higher brightness of their blue tint: |                                                                                                 |
|                                                                                                                             | % Brightness<br>Blue Latex Flat                                                                 |
| TITANOX-RA-46 .....                                                                                                         | 41.1                                                                                            |
| TITANOX-RA-50 .....                                                                                                         | 38.6                                                                                            |
| TITANOX-RA-51 .....                                                                                                         | 39.4                                                                                            |

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At low pigment volume concentrations of titanium dioxide at which crowding of the particles may not be involved, the pigment must also be capable of the dispersity that gives sufficient scattering to yield high reflectance and opacity or hiding power. Improvement of Titanox rutile "pure" pigment for this effect, is most pronounced in Titanox-RA-45.

This pigment can be dispersed most readily to a high degree of dispersion in low pigment volume systems such as high gloss enamels. It exerts higher tinting strength and gives higher hiding in such products than does a regular pigment such as Titanox-RA-50:

| Pigment             | Comparable White Enamels<br>Example of Hiding Power<br>in sq. ft./U. S. Gal.<br>for 98% contrast ratio<br>over black and white |     |
|---------------------|--------------------------------------------------------------------------------------------------------------------------------|-----|
|                     | 10 % pvc                                                                                                                       | 15  |
| TITANOX-RA-45 ..... | 310                                                                                                                            | 375 |
| TITANOX-RA-50 ..... | 225                                                                                                                            | 330 |

| Pigment             | Comparable Grey Enamels<br>Example of High Tinting<br>Strength of High Tinting<br>Titanox-RA-45<br>11% pvc |  |
|---------------------|------------------------------------------------------------------------------------------------------------|--|
|                     | % Brightness                                                                                               |  |
| TITANOX-RA-45 ..... | 43.0                                                                                                       |  |
| TITANOX-RA-50 ..... | 41.8                                                                                                       |  |

While it is recognized that hiding power of a white pigmented coating may depend upon factors peculiar to the specific coating, on the average, the newer Titanox rutile "pure" pigments bear the following relationship in relative hiding power—Titanox-RA-50 as 100.

| Pigment             | Low pvc | High pvc |
|---------------------|---------|----------|
| TITANOX-RA-45 ..... | 110     | 90       |
| TITANOX-RA-46 ..... | 95      | 113      |
| TITANOX-RA-50 ..... | 100     | 100      |
| TITANOX-RA-51 ..... | 107     | 106      |

In general, the multi-purpose "pure" pigments Titanox-RA-50 and Titanox-RA-51 yield high hiding in both low and highly pigmented goods, with Titanox-RA-51 being superior to Titanox-RA-50 in this respect.

In addition, Titanox-RA-51 in hiding power and tinting strength can equal Titanox-RA-45 in many gloss finishes. And in flats, Titanox-RA-51 can provide the highest hiding compatible with color uniformity (of tints over surfaces of varying porosity) and cleanliness.

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## Higher Tinting Strength for Rubber and Plastic Compositions

In compositions such as floor-tile stocks in which the titanium dioxide concentration is very low, the remainder consisting of binder, fillers and colors, slight differences in "pure" titanium dioxide pigment, as in flat wall paints, may affect brightness and tone of tints. The titanium dioxide should be capable of being dispersed in such systems so as to provide the scattering needed for the color effects desired. TIRANOX-RA-40, developed especially for this purpose, exerts higher tinting strength than regular rutile "pure" pigment such as TIRANOX-RA, in many floor-tile and similar compositions. As a result, if desired, a lower concentration of TIRANOX-RA-40 may replace the regular pigment. Following is an example of this higher tinting strength of TIRANOX-RA-40:

| Pigment       | Approx. % | Brightness of Green Vinyl Tile |
|---------------|-----------|--------------------------------|
| TIRANOX-RA-40 | 3.0       | 45.2                           |
| TIRANOX-RA    | 3.3       | 44.7                           |
| TIRANOX-RA-40 | 3.3       | 45.8                           |
| TIRANOX-RA    | 3.3       | 44.7                           |

TIRANOX-RA-40 at even lower concentration may replace anatase titanium dioxide as in the following example of a white and grey rubber tile composition. Such replacement is feasible also because of the tint clarity and clean whiteness produced by TIRANOX-RA-40.

| TiO <sub>2</sub> Pigment | Approx. %<br>of total batch | White Rubber Tile<br>Colormaster Reflectorimeter<br>% reflected with Filler<br>(bright. ness) |      |      |
|--------------------------|-----------------------------|-----------------------------------------------------------------------------------------------|------|------|
|                          |                             | Green                                                                                         | Red  | Blue |
| TIRANOX-RA-40            | 4.2                         | 66.3                                                                                          | 69.4 | 52.5 |
| TIRANOX-A<br>(anatase)   | 6.0                         | 66.3                                                                                          | 69.4 | 53.2 |
| TiO <sub>2</sub> Pigment | Approx. %<br>of total batch | Grey Rubber Tile<br>Colormaster Reflectorimeter<br>% reflected with Filler<br>(bright. ness)  |      |      |
|                          |                             | Green                                                                                         | Red  | Blue |
| TIRANOX-RA-40            | 4.2                         | 38.0                                                                                          | 37.5 | 38.0 |
| TIRANOX-A<br>(anatase)   | 6.0                         | 38.4                                                                                          | 37.9 | 38.7 |

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## Improvement in Chalking Characteristics

### Evolution of Chalk-resistant Pigments

Along with improved retention of whiteness, TIRANOX-A-168 possessed slightly less tendency than TIRANOX-A to chalk, but in the light of later knowledge both pigments are chalking types. The need for less chalking in industrial product finishes was first met by titanium dioxide treated with titanium phthalate, but on account of increased cost and poor color in some finishes as well as slowing up of drying of others, this type of pigment was abandoned. TIRANOX-AA, an antimony oxide-alumina treated pigment first presented improved resistance to chalking accompanied by all other desirable properties of anatase titanium dioxide including the whiteness retention feature of TIRANOX-A-168. In many tinted finishes TIRANOX-AA was equivalent in ability to reduce chalking-fading to a combination of 60% TIRANOX-A-168 plus 40% antimony oxide.

Still further increase in resistance to chalking was secured in TIRANOX-A-NC, the letters "NC" signifying "non-chalking." In this relatively coarse titanium dioxide, extremely high chalk-resistance was accompanied by relatively low tinting strength and low brightness. Yet TIRANOX-A-NC filled a most important place in many tinted coatings including marine paints, especially for Navy use during World War II. At the end of the war this pigment was discontinued and is no longer manufactured.

Although TIRANOX-AA was a step forward in resistance to chalking, improvement in this quality was needed without sacrificing other qualities.

Accordingly, a further modification of TIRANOX-AA, yielded such a large increase in chalk-resistance as to warrant a new designation for the improved pigment—TIRANOX-A-24. But this pigment had to give way to

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rutile which offers not only high resistance to fading-chalking but also higher opacity.

### **Rutile Titanium Dioxide**

Rutile titanium dioxide, thus far, has inherently greater chalk-resistance, type for type, than anatase titanium dioxide. Thus, TIRANOX-RA-10, the primary rutile titanium dioxide pigment is not as free-chalking as the corresponding anatase type—TIRANOX-A-MO. Similarly TIRANOX-RA reduces chalking as much as does TIRANOX-AA and is distinctly more chalk-resistant than its anatase prototype TIRANOX-A-168-LO. Thus, TIRANOX-RA while primarily intended as a high hiding rutile titanium dioxide possessing the whiteness retention feature of TIRANOX-A-168 is also a chalk-resistant pigment in the class of TIRANOX-AA. As a result, the rutile pigment TIRANOX-RA has replaced the anatase TIRANOX-AA generally. An interesting example of this replacement is the Federal Specification for Titanium Pigments in which semi-chalking anatase of the type of TIRANOX-AA was replaced by rutile of the type of TIRANOX-RA.

### **High Hiding "Non-Chalking" Rutile Titanium Dioxide**

A great deal of experience, through years of research and development followed by periodic manufacture during the war years, of chalk-resistant rutile pigment for war purposes laid a firm basis for the production of high hiding rutile titanium dioxide combining in one pigment maximum chalk-resistance along with attractive color and ease of mixing and grinding. This pigment is TIRANOX-RA-NC.

Since its introduction, TIRANOX-RA-NC while maintaining its maximum resistance to chalking, has been improved in color, tinting strength, tint clarity and in its ability to produce sharp gloss in critical formulations.

The improved tinting strength and tint clarity of TIRANOX-RA-NC approach closely those of the multipurpose TIRANOX-RA-50 and TIRANOX-RA-51, so that where greater chalk-resistance is needed without significant loss in color properties, TIRANOX-RA-NC may be specified.

Where highest gloss and minimum pigmentation is

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of greatest importance and the durability of the binder tolerates less than maximum resistance to chalking in the pigment, TIRANOX-RA-45 may be preferred.

### **Composite pigments**

In 1934, there appeared what was probably the most chalk-resistant and durable titanium pigment ever produced—lead titanate, a compound of lead oxide and titanium dioxide called TIRANOX-L. Possessing opacity comparable to zinc sulfide, TIRANOX-L found its greatest use in tinted exterior finishes which did not demand the concentrated hiding power of "pure" titanium dioxide. Thus the way was open to replace TIRANOX-L eventually with a composite pigment having comparable qualities and at a lower price.

In the meantime, the original titanium-barium pigment, TIRANOX-B-30 had received the antimony oxide-alumina modification to be analogous to TIRANOX-AA and designated TIRANOX-B-30-AA. At the end of 1948, these titanium barium pigments were discontinued, inasmuch as in the majority of uses titanium-calcium pigment, TIRANOX-RC, or TIRANOX-RCHT could readily replace the barium sulfate extended titanium pigment.

Rutile-calcium pigment for durable exterior paints

In 1941, after extensive research and development, a combination of rutile titanium dioxide and calcium sulfate, (the oxide having been precipitated upon and coalesced with calcium sulfate [anhydrite]) was introduced as TIRANOX-RC. Combining low specific gravity, high hiding power, ease of mixing and grinding, low cost per pound and high chalk-resistance, this pigment—TIRANOX-RC—is firmly established in tinted exterior paints and enamels. It proved an advantageous replacement for TIRANOX-L (lead titanate) in house paint tint bases, architectural trim paints and enamels, floor and deck enamels and combination interior-exterior tinted paints and enamels.

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# TITANOX Pigments According to Chalking

## Titanium Dioxide

Free chalking types—indicated for use in exterior white house paints, usually plus a proportion of "RA" or "C" pigment—

- TITANOX-A (anatase)
- TITANOX-A-168 (anatase)

Chalking type—

- TITANOX-RA-10 (rutile)

Chalk-resistant—sometimes termed "semi-chalking"—

- TITANOX-RA (rutile)
- TITANOX-AA (anatase)

Highly chalk-resistant—

- TITANOX-RA-50, also -RA-51; -RA-45; -RA-46

Very highly chalk-resistant—"non-chalking"—

- TITANOX-RA-NC (rutile)

## Rutile-Calcium Pigment

Chalking type—

- TITANOX-RCHT; -RCHTX; -C-50

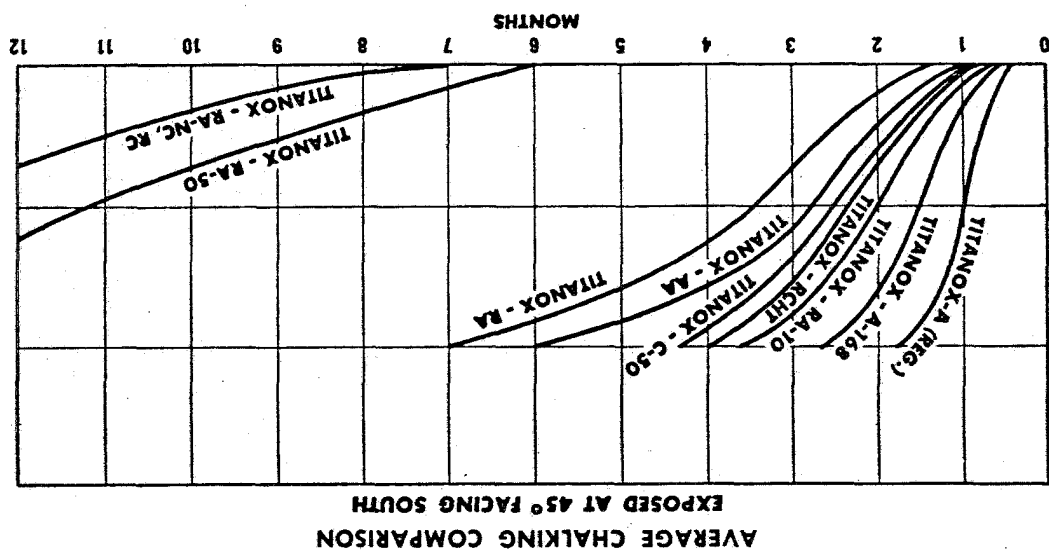
In white exterior house paints, these pigments are used with a proportion of free chalking anatase titanium dioxide.

Very highly chalk-resistant—"non-chalking"—

- TITANOX-RC

In general, these pigments differ in chalking as shown in the chart on page 35 for which comparable exposures have been averaged. Although an exact relationship between the pigments and the chalking of a specific paint cannot be predicted from this chart, it should serve as a valuable guide to the selection of the type of TITANOX pigment in relative rate of chalking.

FIGURE III  
SLIGHT CONS.



## TITANOX PIGMENTS

| Average Values                                                                   |                                 |         |                              |                                 |                     |                    |                                 |                                                                                             |                                                   |
|----------------------------------------------------------------------------------|---------------------------------|---------|------------------------------|---------------------------------|---------------------|--------------------|---------------------------------|---------------------------------------------------------------------------------------------|---------------------------------------------------|
|                                                                                  | %<br>TiO <sub>2</sub><br>(min.) | Sp. Gr. | 1 lb.<br>Bulk<br>Per<br>Gal. | 1 lb.<br>Tinting<br>Per<br>Gal. | Washing<br>Strength | Opt.<br>Absorption | Relative<br>Refractive<br>Index | Principal Use                                                                               | Applicable to<br>Paint Specifications             |
| <b>Rutile Titanium Dioxide</b>                                                   |                                 |         |                              |                                 |                     |                    |                                 |                                                                                             |                                                   |
| TITANOX-RA                                                                       | 97                              | 4.2     | .0286                        | 34.99                           | 1700                | 19                 | Medium                          | General utility; interior enamels; plastics;.....                                           | TT-P-442, Type II; ASTM D476-48, -11-1; 52MC-19   |
| TITANOX-RA-40 and RA-41                                                          | 98-97                           | 4.2     | .0286                        | 34.99                           | 1600-1650           | 18                 | .....                           | Plastics and rubber (RA-40 mainly floor tile);                                              |                                                   |
| TITANOX-RA-45                                                                    | 95                              | 4.1     | .0293                        | 34.15                           | 1850                | 20                 | High                            | High gloss enamels, industrial and architectural.                                           |                                                   |
| TITANOX-RA-46 and RA-42                                                          | 93-92                           | 4.1     | .0293                        | 34.15                           | 1675-1700           | 32                 | .....                           | RA-46 flat emulsion paints; RA-42 paper.....                                                |                                                   |
| TITANOX-RA-50                                                                    | 95                              | 4.1     | .0293                        | 34.15                           | 1700                | 23                 | High                            | Multi-purpose.....                                                                          | TT-P-442, Grade B, Type III; ASTM D476-48, -11-11 |
| TITANOX-RA-51                                                                    | 93                              | 4.1     | .0293                        | 34.15                           | 1850                | 26                 | High                            | All types of paints; multi-purpose.....                                                     | TT-P-442, Grade B, Type III                       |
| TITANOX-RA-NC                                                                    | 93                              | 4.1     | .0293                        | 34.15                           | 1700                | 21                 | High                            | All types of exterior coatings and compositions                                             | TT-P-442, Grade A, Type III; ASTM D476-48; 52MC-9 |
| <b>Rutile-calcium Pigment (50% TiO<sub>2</sub> rutile; 50% CaSO<sub>4</sub>)</b> |                                 |         |                              |                                 |                     |                    |                                 |                                                                                             |                                                   |
| TITANOX-C-50                                                                     | 49.0                            | 3.47    | .0345                        | 28.94                           | 975                 | 20                 | Medium                          | Semi-gloss and flat paints; general utility.....                                            |                                                   |
| <b>Rutile-calcium Pigment (30% TiO<sub>2</sub> rutile; 70% CaSO<sub>4</sub>)</b> |                                 |         |                              |                                 |                     |                    |                                 |                                                                                             |                                                   |
| TITANOX-RC                                                                       | 29.5                            | 3.25    | .0369                        | 27.07                           | 600                 | 21                 | High                            | Exterior tinted paints.....                                                                 | ASTM D476-48                                      |
| TITANOX-RCHT                                                                     | 29.5                            | 3.25    | .0369                        | 27.07                           | 600                 | 23                 | Medium                          | Interior paints (flat, semi-gloss, gloss); general utility.....                             | ASTM D476-48; 52-MA-521a; MIL-T-15195A            |
| TITANOX-RCHTX                                                                    | 29.5                            | 3.25    | .0369                        | 27.07                           | 600                 | 21                 | Medium                          | As RCHT but exceptional ease of dispersion...                                               | ASTM D476-48; 52-MA-521a; MIL-T-15195A            |
| <b>Anatase Titanium Dioxide</b>                                                  |                                 |         |                              |                                 |                     |                    |                                 |                                                                                             |                                                   |
| TITANOX-A-MO                                                                     | 98                              | 3.9     | .0308                        | 32.49                           | 1250                | 25                 | Low                             | White house paints; general utility; rubber.....                                            | TT-P-442, Type I; ASTM D476-48, Type I            |
| TITANOX-A-LO                                                                     | 98                              | 3.9     | .0308                        | 32.49                           | 1250                | 21                 | Low                             | Interior gloss enamels and lacquers; rubber.....                                            | TT-P-442, Type I; ASTM D476-48, Type I            |
| TITANOX-A-168-MO                                                                 | 97                              | 3.8     | .0316                        | 31.65                           | 1250                | 25                 | Low                             | Plastics; inks; white house paints.....                                                     | ASTM D476-48, Type I                              |
| TITANOX-A-168-LO                                                                 | 97                              | 3.8     | .0316                        | 31.65                           | 1250                | 21                 | Low                             | White interior air dry and baked enamels and lacquers (see Titanox-RA); inks; plastics..... | ASTM D476-48, Type I                              |
| TITANOX-AA                                                                       | 96                              | 3.9     | .0308                        | 32.49                           | 1250                | 22                 | Medium                          | Acetate rayon; white house paints.....                                                      | ASTM D476-48, Type I                              |
| TITANOX-A-CG                                                                     | 97                              | 3.8     | .0316                        | 31.65                           | 1250                | 20                 | Medium                          | Coatings for paper; white house paints.....                                                 | ASTM D476-48, Type I                              |
| TITANOX-A-WD                                                                     | 98                              | 3.9     | .0308                        | 32.49                           | 1200                | .....              | .....                           | Paper filling.....                                                                          | ASTM D476-48, Type I                              |

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<sup>1</sup> Tinting Strength: Reproduce constant volume method—0.5 grams acid, Titanox-A plus 1.25 gm. ultramarine blue (6 parts by weight, 1 part ultramarine blue) plus 0.515 ml. refined linseed oil has tinting strength 1250. Although an exact general relationship cannot be shown, tinting strength is generally indicative of relative hiding power.

<sup>2</sup> Opt. Absorption: Spectra method expressed as lb. of per 100 lb. pigment—determined in relation to standard sample under controlled conditions.

<sup>3</sup> TT-P-442 is Federal Spec. for Titanium Dioxide dated August 10, 1961, superseding TT-T-423a dated December, 1951.

In addition to the pigments listed above, these highly specialized products are offered: Titanox-PL, rutile TiO<sub>2</sub> pigment for plastic laminating papers; Titanox-A-WG, anatase TiO<sub>2</sub> for welding rod coatings; non-pigmentary or chemical grade titanium dioxides; Titanox-RA-10 rutile TiO<sub>2</sub> pigment.

TITANIUM PIGMENT CORPORATION, 111 Broadway, New York 6, N. Y.

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# Federal Specification for Titanium Dioxide

TT-P-442, August 10, 1961  
Superseding TT-T-425a—December 1951

Titanox  
Applicable

Type I Free Chalking (anatase) .. A-MO

Type II Semi-chalking—aluminum  
treated (rutile) ..... RA

Type III Chalk resisting (rutile)  
Grade A—silicon-alumi-  
num-zinc  
treated .....

RA-NC  
Grade B—aluminum treated RA-45;  
RA-46; RA-50; RA-51

## Chemical Composition Requirements

Type I % TiO<sub>2</sub>, min. 98.0

Type II % TiO<sub>2</sub>, min. 96.0  
% Al<sub>2</sub>O<sub>3</sub>, 0.5-2.5

Type III Grade A  
% TiO<sub>2</sub>, min. 93.0  
% Al<sub>2</sub>O<sub>3</sub>, 1.8-2.4  
% SiO<sub>2</sub>, 0.6-2.0  
% ZnO, 0.5-1.4

Grade B  
% TiO<sub>2</sub>, min. 94.0  
% Al<sub>2</sub>O<sub>3</sub>, 2.5-3.5

## A.S.T.M. Specification

For Titanium Pigments—D 476-48

Titanox  
Applicable

### Titanium Dioxide

Type I anatase ..... A reg.;  
A-108;  
AA

Type II rutile  
Class I ..... RA-10;  
RA

Class II—Chalk resistant .. RA-NC  
RCHT;  
RCHTX;  
RC

Titanium-Calcium .....

2N1

TITANOX  
Applicable

### Military Specification

for

Titanium-Calcium Pigment

(rutile)

MIL-T-15195A

July 9, 1951

..... RCHT

### U. S. Maritime Commission

Spec. for Rutile  $TiO_2$

52-MC-19

Mar. 31, 1943

..... RA

Spec. for Rutile  $TiO_2$

Chalk-Resisting

52-MC-9

Nov. 23, 1942

..... RA-NC

Spec. for Titanium-Calcium Pigment

(rutile)

52-MA-521a

..... RCHT, RCHTX

# Types of TITANOX for U. S. Government Paint Specifications

| U. S. Govt. Agency | TITANOX — A reg.                                                                                                         | TITANOX — RA                                                                                                                                                                                                                       | TITANOX — RA-45                            | TITANOX — RA-46        | TITANOX — RA-50          | TITANOX — RA-NC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | TITANOX — RCHT                                                                                                                                                                                                           |
|--------------------|--------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|------------------------|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Federal            | TT-P-18; TT-P-0019a; TT-P-21; TT-P-22; TT-P-23a; TT-P-24a; TT-P-0035a; TT-P-0067; TT-P-88a; TT-P-91a; TT-P-102; TT-P-103 | TT-P-18; TT-P-91a; TT-P-98; TT-P-00115b; TT-E-500c                                                                                                                                                                                 | TT-L-26; TT-L-0054a; TT-E-503a; TT-E-545a; | TT-P-29b               |                          | TT-P-0019a; TT-P-24a; TT-P-25a; TT-L-26; TT-L-31b; TT-P-0033; TT-P-34a; TT-L-0050b; TT-P-0055a; TT-P-0085a; TT-P-91a; TT-P-95; TT-P-0099a; TT-P-102; TT-E-489c; TT-E-401; TT-E-527a; TT-E-529a; TT-L-558b; TT-L-559b; TT-P-659a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | TT-P-0026b; TT-P-30b; TT-P-47a; TT-P-51d; TT-P-56b; TT-P-00015b; TT-E-500c; TT-E-508; TT-E-543                                                                                                                           |
| Military           | MIL-P-4812; MIL-P-15149                                                                                                  | JAN-E-480; MIL-E-1115a; MIL-P-4812; MIL-P-6884b; MIL-L-10287a; MIL-L-11195b; MIL-P-15123a; MIL-P-15151a; MIL-E-17136b; MIL-P-17970; MIL-P-17971c; MIL-P-17972c; MIL-P-17973a; MIL-P-17974a; MIL-L-18389; MIL-C-52032; MIL-L-52043a | MIL-L-13815a;                              | JAN-E-480; MIL-P-52108 | MIL-L-2638b; MIL-P-6884b | MIL-L-73a; MIL-E-74b; JAN-E-480; JAN-P-630; MIL-P-00699a; JAN-R-700; MIL-P-00735a; MIL-E-1264c; MIL-E-1265c; MIL-D-5550a; MIL-D-5551a; MIL-D-5554a; MIL-D-5555; MIL-E-5556b; MIL-E-5558a; MIL-L-6805c; MIL-L-7128a; MIL-E-7729a; MIL-E-10164; MIL-L-10182; MIL-E-10242; MIL-E-10687b; MIL-L-11195b; MIL-E-12507a; MIL-P-12742a; MIL-P-13340; MIL-P-13983c; MIL-E-13690b; MIL-P-13128c; MIL-E-13129c; MIL-E-13130c; MIL-P-15150a; MIL-C-15159; MIL-E-15181c; MIL-P-15182a; MIL-E-15935b; MIL-E-15936b; MIL-P-16188b; MIL-P-16502b; MIL-E-16663; MIL-P-16738b; MIL-E-17133a; MIL-E-17134a; MIL-E-17138a; MIL-E-17139a; MIL-E-17140a; MIL-E-17325a; MIL-E-17327; MIL-E-17328; MIL-E-17329; MIL-E-17330; MIL-E-17466a; MIL-P-18210; MIL-P-18214a; MIL-R-18708a; MIL-L-19538a; MIL-E-19603b; MIL-P-22808; MIL-C-27227; MIL-P-27316; MIL-P-52108 | MIL-P-2852; MIL-E-15090b; MIL-P-15183a; MIL-E-17136b; MIL-E-17140a; MIL-E-17325a; MIL-E-17327; MIL-E-17328; MIL-E-17329; MIL-E-17330; MIL-E-17466a; MIL-P-17970c; MIL-P-17971c; MIL-P-17972c; MIL-P-17973a; MIL-P-17974a |
| Navy               |                                                                                                                          |                                                                                                                                                                                                                                    |                                            |                        |                          | 52E13 (ORD)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                          |
| Coast Guard        |                                                                                                                          |                                                                                                                                                                                                                                    |                                            |                        |                          | CGS-52P-5b                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                          |
| Maritime           |                                                                                                                          |                                                                                                                                                                                                                                    |                                            |                        |                          | MAP-48; 52-MC-103; 52-MA-106a; 52-MC-107a; 52-MA-121; 52-MA-152a; 52-MA-154b; 52-MA-155; 52-MA-156; 52-MA-251                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | MAP-48; 52-MC-120; 52-MA-210                                                                                                                                                                                             |

### TITANOX-RA-45

|                                                       |         |
|-------------------------------------------------------|---------|
| Minimum % TiO <sub>2</sub> .....                      | 95      |
| (Additive Al <sub>2</sub> O <sub>3</sub> principally) |         |
| Crystal Structure of TiO <sub>2</sub> .....           | Rutile  |
| Refractive Index (mean).....                          | 2.7     |
| Average Particle Size                                 |         |
| Mean Dia., micron.....                                | 0.2-0.3 |
| Specific Gravity .....                                | 4.1     |
| Lb. per Solid Gal.....                                | 34.15   |
| 1 Lb. bulks Gal.....                                  | .0293   |
| Tinting Strength .....                                | 1850    |
| Oil Absorption lb. oil/100 lb. pigment...             | 19-22   |
| Relative Resistance to Chalking.....                  | High    |

Titanox-RA-45 is rutile titanium dioxide pigment having maximum tinting strength, but otherwise most closely related in properties to Titanox-RA-50. In most pigmented compositions, with few exceptions such as some flat latex paints, Titanox-RA-45 exerts higher tinting strength and higher hiding power than the other Titanox rutile titanium dioxide pigments. Higher brightness of cleaner whites, greater clarity of brighter tints plus higher gloss are associated with Titanox-RA-45.

#### Uses

Titanox-RA-45 is particularly suitable for use in high gloss industrial product finishes and high gloss architectural finishes. But with few exceptions, Titanox-RA-45 is applicable to the many uses of Titanox-RA and of Titanox-RA-50 which are discussed on pages 43 to 46.

Where brightness and opacity of a paint or other pigmented composition may be at a satisfactory level with ordinary rutile titanium dioxide pigment, a lesser amount of Titanox-RA-45 will often give the desired hiding at resulting lower pigment cost. Outstanding exceptions are highly pigmented flat latex paints in which Titanox-RA-51 or Titanox-RA-46 give higher hiding.

**TITANOX-RA-46** (rutile titanium dioxide pigment—primarily for use in flat emulsion paints having total pigment volume— $\text{TiO}_2$  plus extenders)

**TITANOX-RA-42** (rutile titanium dioxide pigment—primarily for use in paper to achieve higher blue or TAPPI brightness)

Both of these pigments have these average properties:

|                        |       |
|------------------------|-------|
| Specific Gravity ..... | 4.1   |
| Lb. per Solid Gal..... | 34.15 |
| 1 Lb. bulks Gal.....   | .0293 |
| Tinting Strength ..... | 1700  |
| Oil Absorption .....   | 32    |

Particle size distribution determinations of Titanox-RA-42 indicate an average mean particle diameter of 0.2 micron. The value indicated for Titanox-RA-46 is 0.2-0.3 micron. Minimum %  $\text{TiO}_2$  is 93 in Titanox-RA-46, and 92 in Titanox-RA-42.

## Uses

**Water Emulsion Paints:** Titanox-RA-46 imparts maximum hiding and brightness of whites and tints at higher total pigment volumes (see pages 28, 29). Titanox-RA-42 ordinarily is not considered for use in paints.

**Paper:** At higher titanium dioxide content of paper, Titanox-RA-46 (as well as other Titanox rutile pigments) has been found in some cases to impart opacity sufficiently higher than anatase to warrant use on an equal or lower cost basis. Under the same conditions, Titanox-RA-42 yields also blue brightness comparable to anatase. Exceptionally high brightness (99% minimum) of Titanox-RA-42 itself contributes to high brightness in paper.

**Other Uses:** In high dry hiding organic solvent flat wall paints Titanox-RA-46 may be called upon. This pigment should prove interesting wherever high oil absorption and resultant consistency effects of rutile titanium dioxide are desired.

Titanox-RA-42 exhibits low abrasiveness and should prove applicable to inks and other compositions for which this property is of interest.

## TITANOX-RA

|                                                |         |
|------------------------------------------------|---------|
| Minimum % $\text{TiO}_2$ .....                 | 97      |
| (Additive $\text{Al}_2\text{O}_3$ principally) |         |
| Crystal Structure of $\text{TiO}_2$ .....      | Rutile  |
| Refractive Index (mean) .....                  | 2.7     |
| Average Particle Size                          |         |
| Mean Dia., Micron.....                         | 0.3-0.4 |
| Specific Gravity .....                         | 4.2     |
| Lb. per Solid Gal.....                         | 34.99   |
| 1 Lb. bulks Gal.....                           | .0286   |
| Tinting Strength .....                         | 1600    |
| Oil Absorption lb. oil/100 lb. pigment...      | 19      |
| Relative resistance to Chalking.....           | Medium  |

Titanox-RA is rutile titanium dioxide pigment modified for minimum discoloration and after-yellowing of vehicles of organic coatings especially those based on synthetic resins.

## Uses

Titanox-RA is widely used in all products requiring rutile pigment qualities, except high resistance to fading-chalking. Newer Titanox rutile pigments are becoming preferable in the uses listed below.

## Paints

**Interior White and Tinted Enamels**—Low pigmentation of enamels to secure high gloss demands high opacity in a white pigment for high hiding power of the enamel. Titanox-RA meets these conditions ideally, for it also retards after-yellowing.

**White and Tinted Industrial Enamels, Metal-decorating Enamels, Lacquers**—Any white or light tinted finish requiring the optimum in film qualities, especially flexibility afforded by low pigmentation and avoidance of excessive film thickness is best pigmented with Titanox-RA (where high resistance to chalking is not needed). This pigment is particularly adaptable to baking finishes. The metal-decorating field including reflectors for lights is particularly suited to this pigment which will usually yield the highest reflectance per pound of any white pigment at a given film thickness.

**Exterior White House Paints**—Although TITANOX-RA is employed as the sole titanium pigment to boost the reflectance and hiding of exterior white house paints, this usage is not general, for this pigment is a semi-chalking type and as a result may not chalk sufficiently to insure acceptable removal of dirt collection.

Most formulators employ some free chalking anatase—TITANOX-A-MO—along with TITANOX-RA to regulate chalking of this type of paint.

### Plastics

TITANOX-RA whitens, brightens, opacifies and regulates translucency of all types of plastics. For highest whiteness, however, TITANOX-A-168 is sometimes preferred, but, of course, TITANOX-RA is more efficient and is fast replacing the anatase pigment.

## TITANOX-RA-50

and

## TITANOX-RA-51

|                                              |             |             |
|----------------------------------------------|-------------|-------------|
| Minimum % TiO <sub>2</sub> .....             | RA-50<br>95 | RA-51<br>93 |
| Crystal structure of TiO <sub>2</sub> .....  | Rutile      | Rutile      |
| Refractive Index (mean).....                 | 2.7         | 2.7         |
| Average Particle Size                        |             |             |
| Mean Dia., Micron.....                       | 0.3         | 0.2-0.3     |
| Specific Gravity .....                       | 4.1         | 4.1         |
| Lb. per Solid Gal.....                       | 34.15       | 34.15       |
| 1 Lb. bulks Gal.....                         | .0293       | .0293       |
| Tinting Strength .....                       | 1725        | 1850        |
| Oil Absorption lb. oil/100 lb. pigment ..... | 23          | 26          |
| Relative Resistance to Chalking.             | High        | High        |

TITANOX-RA-50 is high hiding rutile titanium dioxide modified not only for fast wetting and extreme fineness of grind but also high whiteness and reduction of after-yellowing of vehicles plus high resistance to chalking without significant loss of tint-clarity.

TITANOX-RA-51 is similar pigment having about 10% higher tinting strength and hiding power.

### Uses

In general, TITANOX-RA-51 shows improved performance in all uses of TITANOX-RA-50.

### Paints

**Latex and Emulsion Flats**—TITANOX-RA-50 because of ease of dispersion and suspension plus color and hiding properties, is firmly established in these products but TITANOX-RA-51 will yield higher hiding without increasing film porosity. Where highest dry hiding is desired TITANOX-RA-46 is preferred.

**High Gloss Industrial Product Finishes, white and light tints**—TITANOX-RA-50 although established in these products may be replaced by TITANOX-RA-51. For maximum gloss at lowest pigmentation, TITANOX-RA-45 may be first choice.

**Trade Sales interior-exterior Enamels, white and light tints**—TITANOX-RA-50 is established in formulations requiring increased chalk-resistance of rutile titanium dioxide for products intended for interior and exterior use. TITANOX-RA-51 shows superior hiding and may be preferred.



## TITANOX-RA-NC

|                                                                      |         |
|----------------------------------------------------------------------|---------|
| Minimum % $\text{TiO}_2$ .....                                       | 93      |
| (Additives $\text{Al}_2\text{O}_3$ , $\text{SiO}_2$ , $\text{ZnO}$ ) |         |
| Crystal Structure of $\text{TiO}_2$ .....                            | Rutile  |
| Refractive Index (mean).....                                         | 2.7     |
| Average Particle Size                                                |         |
| Mean Dia., micron.....                                               | 0.2-0.3 |
| Specific Gravity.....                                                | 4.1     |
| Lb. per Solid Gal.....                                               | 34.15   |
| 1 Lb. bulks Gal.....                                                 | .0293   |
| Tinting Strength.....                                                | 1700    |
| Oil Absorption lb. oil/100 lb. pigment.....                          | 21      |
| Relative resistance to Chalking.....                                 | High    |

Titanox-RA-NC is rutile titanium dioxide pigment modified for maximum resistance to chalking compatible with ease of mixing and grinding, whiteness, high tinting strength and hiding power. It is the type of pigment prescribed by Fed. Spec. TT-P-442, Type III, Grade A.

### Uses

#### Exterior Tinted Coatings of All Types

Finishes requiring white pigment having maximum tinting strength combined with high resistance to chalking are the most logical field of usage for Titanox-RA-NC. Outstanding in this field are automotive finishes, industrial product finishes which will be exposed to the weather, sign enamel, outdoor furniture and fixture enamel.

#### Exterior Tinted House Paints

Titanox-RA-NC is employed in this type of paint where the formulator prefers a combination of rutile titanium dioxide and selected extender to Titanox-RC. However, Titanox-RC is usually first choice. Of course, Titanox-RA-NC is not suggested as sole titanium pigment for white exterior house paints which must retain clean appearance through chalking.

### Plastics

Resistance to sunlight and weather is often imparted by Titanox-RA-NC to white and light colored stocks. Despite its content of zinc oxide, Titanox-RA-NC has improved the light and weather stability of properly stabilized vinyl and other stocks.

*Metal Decorating Coatings—Inks*—Extreme fineness of grind accompanied by high opacity accounted for the application of Titanox-RA-50 to thin high gloss coatings of this class. Titanox-RA-51 will often produce high hiding, but where maximum gloss at minimum pigment content is desired, the use of Titanox-RA-45 is indicated.

*Exterior white House Paints*—Titanox-RA-50 or Titanox-RA-51 are not suggested as sole titanium pigments for white exterior house paints inasmuch as their chalk resistance is conducive to undesirable dirt collection. In white house paints a proportion of free chalking anatase titanium dioxide, such as Titanox-A-MO, must be included to promote chalking.

*Tinted Exterior House Paints, Porch and Deck Enamels, Trim Paints*—Titanox-RA-50 replaced Titanox-A-24 in these products. Generally, Titanox-RC or Titanox-RA-NC are preferable, but of course, Titanox-RA-51 may replace Titanox-RA-50 for equal fading-chalking and higher hiding.

### Paper

The ease of dispersion to a smooth suspension plus the high opacity of Titanox-RA-50 and Titanox-RA-51 adapt these pigments to paper coatings of the latex type especially if the paper is to be waxed. In stocks carrying high titanium dioxide content at which rutile proves sufficiently superior to anatase in opacity, although these pigments (Titanox-RA-50 and Titanox-RA-51) are suitable, Titanox-RA-46 may yield higher opacity and be preferred.

### Plastics

The ease of incorporation of Titanox-RA-50 and Titanox-RA-51 to a high degree of dispersion free from large particles in plastics especially vinyl sheeting, strongly recommends their usage in this field, especially in view of high opacifying power.

### Rubber

In white and light tinted rubber compounds tests indicate that Titanox-RA-50 and Titanox-RA-51 while producing high brightness at relatively low loadings also promote retention of whiteness and color on sunlight exposure.



# **TITANOX-PL**

|                                                       |         |
|-------------------------------------------------------|---------|
| Minimum % TiO <sub>2</sub> .....                      | 92      |
| (Principal Additive, Al <sub>2</sub> O <sub>3</sub> ) |         |
| Crystal Structure of TiO <sub>2</sub> .....           | Rutile  |
| Refractive Index (mean).....                          | 2.7     |
| Average Particle Size                                 |         |
| Mean Dia., micron.....                                | 0.3-0.4 |
| Specific Gravity.....                                 | 4.2     |
| Lb. per Solid Gal.....                                | 34.99   |
| 1 Lb. bulks Gal.....                                  | .0286   |
| Tinting Strength.....                                 | 1575    |

Titanox-PL is highly stabilized rutile titanium dioxide pigment modified to retard the discoloration of amino resin plastic laminates. This pigment is specially produced for absorbent plastic laminating (PL) papers. Titanox-PL embodies the optimum in whiteness, brightness and opacity and the maximum in retardation of discoloration of amino plastic paper laminates upon exposure to light.

## **Uses**

### **Plastic Laminating Papers**

Titanox-PL is superior to all other types of rutile titanium dioxide pigments (which of course, are superior to anatase types), in retarding the discoloration of urea or melamine laminates of paper pigmented with titanium dioxide. In addition, in these impregnated papers, Titanox-PL exerts strong whitening, brightening and opacifying power per pound of pigment.

Titanox-PL is fully adapted to normal paper-making procedures and can be incorporated through regular beater addition. A pigment loading of 20 to 30% of the beater furnish may be needed to give the relatively high TiO<sub>2</sub> content of 15-25% required in the sheet while presenting no unusual problems in retention. Although this will vary with the particular machine and white water system, 3% of alum on the fiber has produced good retention while retention can be adjusted by the usual means.

Titanox-PL, like other Titanox TiO<sub>2</sub> pigments is chemically stable and may be used in the presence of "wet strength" resins and other papermaking chemicals.

# **TITANOX-RA-10**

|                                             |            |
|---------------------------------------------|------------|
| Minimum % TiO <sub>2</sub> .....            | 98.5       |
| Crystal Structure of TiO <sub>2</sub> ..... | Rutile     |
| Refractive Index (mean).....                | 2.7        |
| Average Particle Size                       |            |
| Mean Dia., micron.....                      | 0.3-0.4    |
| Specific Gravity.....                       | 4.2        |
| Lb. per Solid Gal.....                      | 34.99      |
| 1 Lb. bulks Gal.....                        | .0286      |
| Tinting Strength.....                       | 1500-1550  |
| Oil Absorption lb. oil/100 lb. pig.....     | 22         |
| Relative resistance to Chalking.....        | Medium-Low |

Titanox-RA-10 is rutile titanium dioxide pigment analogous to Titanox-A regular. This unmodified rutile "pure" pigment while providing maximum titanium dioxide content does not embody the full whitening, brightening, opacifying and color retentive power of rutile titanium dioxide for organic systems.

## **Uses**

Because Titanox-RA-10 does not have outstanding pigmentary qualities its usage is extremely limited. The uses of Titanox-RA-10 depend upon its minimum content of modifiers, such as alumina, which are believed to be harmful to some systems, such as

*Porcelain Enamels for Aluminum*—in which rutile titanium dioxide as white opacifier is part of the mill addition formula. Titanox-RA-10 is preferred as yielding higher gloss in some cases than do the more highly modified pigments.

**TITANOX-RA-40** (rutile titanium dioxide pigment primarily for rubber and plastic compositions that carry high loadings of fillers or extenders)

**TITANOX-RA-41** (rutile titanium dioxide pigment primarily for rubber and plastic compositions that carry little or no filler or extender)

These pigments have the following properties in common: Specific Gravity 4.2; Lb. per Solid Gal. 34.99; 1 Lb. bulks 0.0286 Gal.; Tinting Strength 1600-1650; Oil Absorption 18; Average Particle Size 0.2 micron.

They differ as follows:

|                                                                                                                 | <i>RA-40</i>        | <i>RA-41</i>                                              |
|-----------------------------------------------------------------------------------------------------------------|---------------------|-----------------------------------------------------------|
| Minimum % TiO <sub>2</sub> .....                                                                                | 98                  | 97                                                        |
| Dispersibility in polymer and plasticizer systems .....                                                         | Easy                | Extremely easy to exceptionally high degree of dispersion |
| Discoloration Resistance                                                                                        |                     |                                                           |
| mill aging .....                                                                                                | High                | Highest                                                   |
| (30' @ 350° F.)                                                                                                 |                     |                                                           |
| mold aging .....                                                                                                | High                | Highest                                                   |
| (60' @ 350° F.)                                                                                                 |                     |                                                           |
| Tinting Strength                                                                                                |                     |                                                           |
| " gum " or unloaded stocks.                                                                                     | High                | Highest                                                   |
| high filler loaded plastics, vinyl asbestos tiling, other floor covering compositions, rubber matting, etc..... | High                | High                                                      |
| Whiteness and Tone (in rubber and plastic systems) .....                                                        | Approaches* anatase | Approaches* anatase                                       |

\* In some compositions anatase whiteness may be preferred. An example of whiteness of TITANOX-RA-40 is given on page 30.

# Some Properties of Rutile-Calcium TITAN

|                                         | TITANOX -RCHT | -R |
|-----------------------------------------|---------------|----|
| % TiO <sub>2</sub> , approximate .....  | 30            |    |
| % CaSO <sub>4</sub> , approximate ..... | 70            |    |
| Oil Absorption: .....                   | 23            |    |
| Relative paste consistency .....        | 40            |    |
| Relative paint consistency .....        | 69            |    |
| Color .....                             | white         | v  |
| Tinting Strength .....                  | 600           |    |
| Specific Gravity .....                  | 3.25          |    |
| Lb. per Gallon .....                    | 27.07         | 2  |
| One lb. bulks Gallon .....              | .0369         | J  |
| Relative Wetting Time .....             | 60            |    |
| Fineness of Grind .....                 | 5             |    |
| Relative Resistance to Chalking .....   | medium        | m  |

*Oil Absorption:* Spatula method expressed as lb. oil per 100 lb. pigment—determined in relation to standard sample under controlled conditions using refined linseed oil acid No. 2-2.5.

*Tinting Strength:* Reynolds constant volume method—0.5 gram Std. TITANOX-A plus 1.25 gm. ultramarine blue (6 parts barytes,

1 part ultramarine blue) plus 0.515 ml. refined linseed oil has tinting strength 1250. Although an exact general relationship cannot be shown, tinting strength is generally indicative of relative hiding power.

*Fineness of Grind:* Hegman gauge readings of special test paint for comparison purposes only.

## TITANOX-RCHT

(30% titanium dioxide [rutile]; 70% calcium sulfate [anhydric])

|                                             |        |
|---------------------------------------------|--------|
| Minimum % TiO <sub>2</sub> .....            | 29.5   |
| Crystal Structure of TiO <sub>2</sub> ..... | Rutile |
| Specific Gravity .....                      | 3.25   |
| Lb. per Solid Gal. ....                     | 27.07  |
| 1 Lb. bulks Gal. ....                       | .0369  |
| Tinting Strength .....                      | 600    |
| Oil Absorption lb. oil/100 lb. pigment ..   | 23     |
| Relative Resistance to Chalking .....       | medium |

Titanox-RCHT is a true composite of rutile titanium dioxide and calcium sulfate (anhydric) resulting from the precipitation of titanium dioxide upon precipitated calcium sulfate. As a result of heat treatment of the composite pigment, maximum physical and chemical stability are assured. Titanox-RCHT presents low specific gravity and the maximum in tinting strength and hiding power attainable at its titanium dioxide content.

### Uses

For coatings or other pigmented products in which extender is needed and which do not require the concentrated opacity of titanium dioxide as the sole white pigment, Titanox-RCHT provides effectively and economically the whiteness, brightness and opacity desired.

### Paints

*Interior Architectural Finishes: Flat Wall Paints, calcicoaters, wall primers, primer-fats, enamel undercoaters*—All other desirable properties accompany high hiding and clean tints in these products pigmented with Titanox-RCHT often further extended for desirable sheen and body effects.

*Semi-gloss*—The intermediate pigment volume of this type of product is a natural for Titanox-RCHT as sole pigment or extended.

**Painters' Enamels and Gloss Paints**—Ease of dispersion of TIRANOX-RCHT assures the degree of gloss required in these products.

**White Exterior House Paints**—Whiteness, brightness, high hiding power and desirable rate of chalking may be secured in these products through TIRANOX-RCHT. This pigment is particularly applicable to white exterior house paints highly pigmented for maximum hiding power. It must be remembered though that TIRANOX-RCHT is not a free chalking type of pigment and for atmospheric conditions conducive to objectionable dirt collection a combination of TIRANOX-RCHT with free chalking pigment such as TIRANOX-A-MO should be employed.

**Traffic Paints**—For concrete or bituminous surfaces, TIRANOX-RCHT furnishes economically, high brightness, high hiding and promotes daylight visibility as well as a base for beaded paints having maximum night visibility.

**Industrial Finishes**—Enamel and lacquer undercoaters especially for application to wood are satisfactorily pigmented with TIRANOX-RCHT. This pigment also applicable to tinted finish coats—gloss or semi-gloss.

**Print Paints for Felt Base Floor Covering**—All of the hiding needed is supplied economically by TIRANOX-RCHT.

**Rubber**  
White and light tinted compounds in which the loading requires the extender of TIRANOX-RCHT.

**Paper Coatings**  
TIRANOX-RCHT provides brightness and opacity in paper coatings. This pigment replaces TIRANOX-B-30 economically.

**Plastics**  
Tinted compounds especially sheeting are economically pigmented with TIRANOX-RCHT.  
*Coated Fabrics*—Ground coats and finish coats for all types. TIRANOX-RCHT especially applicable to shade cloth.

## TIRANOX-RCHTX

(30% titanium dioxide [rutile]; 70% calcium sulfate [anhydrite])

|                                             |        |
|---------------------------------------------|--------|
| Minimum % TiO <sub>2</sub> .....            | 29.5   |
| Crystal Structure of TiO <sub>2</sub> ..... | Rutile |
| Specific Gravity .....                      | 3.25   |
| Lb. per Solid Gal. ....                     | 27.07  |
| 1 Lb. bulks Gal. ....                       | .0369  |
| Tinting Strength .....                      | 600    |
| Oil Absorption lb. oil/100 lb. pigment..    | 21     |
| Relative Resistance to Chalking.....        | medium |

X denotes TIRANOX-RCHT processed for lower oil absorption and greater ease of mixing and grinding to promote increased rate of output of high gloss paint products from all types of paint mixing and grinding equipment.

## Uses

### Points

*High gloss enamels and lacquers*—Where extreme fineness of grind is desired often to the exclusion of extender in the pigmentation, TIRANOX-RCHTX is preferred. In many cases this pigment has been reported to mix and grind twice as fast as TIRANOX-RCHT especially where fine dispersion such as 7 or higher Hegman gauge reading is desired.

## TITANOX-RC

(30% titanium dioxide [rutile]; 70% calcium sulfate [anhydrite])

|                                           |        |
|-------------------------------------------|--------|
| Minimum % $\text{TiO}_2$ .....            | 29.5   |
| Crystal Structure of $\text{TiO}_2$ ..... | Rutile |
| Specific Gravity .....                    | 3.25   |
| Lb. per Solid Gal. ....                   | 27.07  |
| 1 Lb. bulks Gal. ....                     | .0369  |
| Tinting Strength .....                    | 600    |
| Oil Absorption lb. oil/100 lb. pigment..  | 21     |
| Relative Resistance to Chalking.....      | high   |

Titanox-RC is a true composite of rutile titanium dioxide and calcium sulfate (anhydrite) resulting from the precipitation of titanium dioxide upon calcium sulfate. In addition to low specific gravity and the maximum tinting strength attainable in a composite white pigment at its titanium dioxide content, Titanox-RC is highly resistant to chalking in exterior paints and enamels.

## Uses

### Paints

*Exterior Paints*—House paint tint bases properly formulated with Titanox-RC are free from objectionable chalking-fading. For use under conditions conducive to slow chalking, a small proportion of less chalk-resistant pigment may be used along with Titanox-RC to promote removal of dirt collection.

*A note on white house paints*—Under some atmospheric conditions, Titanox-RC despite its high resistance to chalking normally, is used in white exterior house paints. Generally, however, this pigment is considered too chalk-resistant for this purpose.

*Exterior Porch and Deck Enamels, Trim Paints, Maintenance Paints, all purpose paints and enamels*—Any coating which can be whitened, brightened or opacified with an extended pigment and which will be exposed to the weather is a natural for Titanox-RC.

## TITANOX-C-50

50% titanium dioxide [rutile]; 50% calcium sulfate (anhydrite)

|                                           |        |
|-------------------------------------------|--------|
| Minimum % $TiO_2$ .....                   | 49.0   |
| Crystal Structure of $TiO_2$ .....        | Rutile |
| Specific Gravity .....                    | 3.47   |
| Lb. per Solid Gal.....                    | 28.94  |
| 1 Lb. BULKs Gal.....                      | .0345  |
| Tinting Strength .....                    | 975    |
| Oil Absorption lb. oil/100 lb. pigment... | 20     |
| Relative Resistance to Chalking.....      | medium |

Like the other rutile-calcium Titanox pigments, Titanox-C-50 is a true composite of rutile titanium dioxide and calcium sulfate (anhydrite). But the ratio of titanium dioxide to calcium sulfate in Titanox-C-50 is about one to one so that the pigment is composed of about 50% titanium dioxide and 50% calcium sulfate. The tinting strength and hiding power of the pigment are the highest ever attained in a white composite pigment and to these qualities are added low oil absorption and ease of fine dispersion in paint vehicles and other media.

### Uses

#### Paints and Coatings

*Semi-gloss and satin-white and tinted finishes; Flat Wall Paints*—such as the alkyd type in which lowered prime pigment volume is needed; *Enamel Undercoats; Tinted Enamels; General Utility Paints.*

Titanox-C-50 is excellently suited to all compositions in which the concentrated hiding power of the "pure" pigment and the high bulk of the 30% pigment are not required. The lesser volume or bulk plus higher hiding of Titanox-C-50 make it an attractive replacement for Titanox-RCHT where prime pigment volume must be lowered and hiding maintained or increased.

By virtue of its fine extender and high ratio of hiding power to bulk, Titanox-C-50 is a valuable tool for the coating formulator. This unique union of hiding pigment and extender allows where needed the selection of additional extender for best results at optimum total pigment volume.



## TITANOX-A (regular)

|                                                   | MO<br>Medium<br>Oil abs |
|---------------------------------------------------|-------------------------|
| Minimum % $\text{TiO}_2$ .....                    | 98.0                    |
| Crystal Structure of $\text{TiO}_2$ .....         | Anatas                  |
| Refractive Index (mean).....                      | 2.55                    |
| Average particle size, mean dia.,<br>micron ..... | 0.3                     |
| Specific Gravity .....                            | 3.9                     |
| Lb. per Solid Gal. ....                           | 32.49                   |
| 1 Lb. Bulks Gal. ....                             | .0308                   |
| Tinting Strength .....                            | 1250                    |
| Oil abs. lb. oil/100 lb. pigment..                | 24-26                   |
| Relative resistance to chalking...                | low                     |

TITANOX-A (regular) is a general pur titanium dioxide to meet the requiremen ness, opacity, and chemical inertness of ti ide without regard to specialized pigment as reduction of after-yellowing of synthet reduction of chalking.

### Uses

#### Paints

*Exterior White House Paints*—TITANOX-A is usually first choice to help reduce dirt coll promote whiteness through a desirable ra ing. This pigment may supplement the r pigments or rutile "pure" titanium dioxi in order to promote chalking in this type

TITANOX-A regular on account of ch course, not suggested for use as sole titan in tinted exterior paints.

#### Paper

TITANOX-A regular is used in beater paper except where the mill may prefer dispersible type TITANOX-A-WD on acco operating conditions.

### Rubber

TITANOX-A-MO or -A-LO adaptable to all types of compounding. The LO type is often preferred to the MO on account of easier mixing.

### Rayon and other synthetic fibres

TITANOX-A-MO on account of uniformly fine particle size is extensively used for the internal delustering of viscose rayon.

### Miscellaneous

*Welding rod coatings*—TITANOX-A-MO is employed in some cases requiring titanium dioxide having high sodium silicate absorption.

### TITANOX-A-168

|                                                                         |     |
|-------------------------------------------------------------------------|-----|
| Minimum % $\text{TiO}_2$ .....                                          | 97  |
| Additive for whiteness retention effect—% $\text{Al}_2\text{O}_3$ ..... | 0.8 |
| Crystal Structure of $\text{TiO}_2$ .....                               | An  |
| Refractive Index (mean).....                                            | 2.5 |
| Average particle size, mean dia., micron .....                          | 0.3 |
| Specific Gravity .....                                                  | 3.9 |
| Lb. per Solid Gal. ....                                                 | 32  |
| 1 Lb. Bulks Gal. ....                                                   | .03 |
| Tinting Strength .....                                                  | 12  |
| Oil abs. lb. oil/100 lb. pigment..                                      | 24  |
| Relative resistance to chalking...                                      | low |

TITANOX-A-168 is anatase titanium modified for minimum discoloration and use in the coloring of vehicles of organic coatings based on synthetic resins. This pigment is rapidly obsolete due to replacement by TITANOX-RA.

### Uses

Inasmuch as TITANOX-A-168 is a color pigment it is applicable to white exterior

In other applications of this pigment in enamels, plastics, inks, leather—any discoloration is the result of conditions which require the adjustment of whiteness or color. TITANOX-RA which is displacing TITANOX-A-168 because of greater opacifying power plus color retention

## TTANOX-AA

|                                                                 |         |
|-----------------------------------------------------------------|---------|
| Minimum % TiO <sub>2</sub> .....                                | 96      |
| As additives, may be present Al <sub>2</sub> O <sub>3</sub> %.. | 0.8-1.2 |
| Sb <sub>2</sub> O <sub>3</sub> %..                              | 0.8-1.2 |
| Crystal Structure of TiO <sub>2</sub> .....                     | Anatase |
| Refractive Index .....                                          | 2.55    |
| Average particle size, mean dia., micron                        | 0.3     |
| Specific Gravity .....                                          | 3.9     |
| Lb. per Solid Gal. ....                                         | 32.49   |
| 1 Lb. Bulks Gal. ....                                           | .0308   |
| Tinting Strength .....                                          | 1250    |
| Oil abs. lb./100 lb. pigment.....                               | 21-23   |
| Relative resistance to chalking.....                            | medium  |

Titanox-AA is "semi-chalking" anatase titanium dioxide. Representing at its introduction a means of attaining high hiding, attractive appearance and improved durability through reduction of chalking-fading in united exterior finishes such as automotive enamels, this pigment found wide acceptance in these products. On account of further improvement in chalk-resistance resulting in other types, however, Titanox-AA became known as "semi-chalking" in comparison with the greater chalking resistance first afforded by Titanox-A-24 and later by the chalk-resistant rutile pigments.

As a Titanox "first", Titanox-AA was the first titanium dioxide pigment to combine appreciable resistance to chalking with reduction of after-yellowing of vehicles. As a result it was used for interior-exterior and many multi-purpose finishes. But like the other anatase pigments Titanox-AA is being rapidly superseded by the rutile pigments—Titanox-RA and Titanox-RA-50 for all paint and coatings applications.

### Uses

Because anatase titanium dioxide is softer than the rutile type, Titanox-AA is still preferred for the internal delustering of acetate rayon in which this pigment also exerts a stabilizing effect upon dyes.

## TITANOX-A-CG

|                                             |         |
|---------------------------------------------|---------|
| Minimum % $\text{TiO}_2$ .....              | 96.5    |
| Crystal Structure of $\text{TiO}_2$ .....   | Anatase |
| Refractive Index (mean).....                | 2.55    |
| Average Particle Size.....                  |         |
| Mean Dia., micron.....                      | 0.3     |
| Specific Gravity.....                       | 3.9     |
| Lb. per Solid Gal.....                      | 32.49   |
| 1 Lb. bulks Gal.....                        | .0308   |
| Tinting Strength.....                       | 1250    |
| Oil absorption lb. oil/100 lb. pigment..... | 20      |

Titanox-A-CG is anatase titanium dioxide pigment characterized by fine dispersion and freedom from coarse agglomerates especially in paper coating compositions, hence the designation "CG" for "coating grade". This pigment, which embodies the full whitening, brightening and opacifying power of anatase titanium dioxide, is readily dispersed at high total solids to yield smooth, stable suspensions having desirable viscosity.

## Uses

### Paper

**Surface Applications**—Titanox-A-CG is remarkably suited to high solids, high speed coatings applied by the trailing blade coater. It is equally as suitable for coatings applied by all other processes and for application at the size press and calender. In addition to whiteness, brightness and opacity, an outstanding property of coatings readily attainable with Titanox-A-CG is high gloss. In papers that are to be waxed, oiled or varnished, only rutile titanium dioxide such as Titanox-RA-50, will yield higher brightness and opacity. But for all types of paper untreated with waxes, resins and similar substances, the use of Titanox-A-CG is preferred especially for fast continuous production of surfaces of uninterrupted smoothness.

**Beater Addition**—Tests of Titanox-A-CG as beater addition reveal that retention and optical properties are comparable to those of other Titanox anatase titanium dioxide pigments. Thus Titanox-A-CG although primarily intended for coatings, should also be considered for addition at any suitable stage of the papermaking process.

## TITANOX-A-WD

|                                           |         |
|-------------------------------------------|---------|
| Minimum % $\text{TiO}_2$ .....            | 98      |
| Crystal Structure of $\text{TiO}_2$ ..... | Anatase |
| Refractive Index (mean).....              | 2.55    |
| Average Particle Size.....                |         |
| Mean Dia., Micron.....                    | 0.3     |
| Specific Gravity.....                     | 3.9     |
| Lb. per Solid Gal.....                    | 32.49   |
| 1 Lb. Bulks Gal.....                      | .0308   |
| Tinting Strength.....                     | 1250    |
| Water Absorption.....                     | Low     |

Titanox-A-WD is anatase titanium dioxide pigment characterized by ease of dispersion and suspension in water and water systems ("WD" signifies water dispersible). In this respect it is usually superior to types of titanium dioxide pigment primarily intended for non-aqueous systems. The ease of mixing Titanox-A-WD with water is evidenced by its low water absorption. For example, on the order of 30 parts distilled water will form a paste with 100 parts Titanox-A-WD, but on the order of 200 parts distilled water will be required by 100 parts Titanox-A-MO.

## Uses

### Paper Filling and Coating

Titanox-A-WD is usually the preferred type of titanium dioxide for beater addition where the pigment is first slurried with water. The easy dispersion and low water absorption of the pigment provide slurries which can be handled due to sufficient flow at high pigment content. However, the water dispersibility of Titanox-A-WD has by no means restricted the pigmentation of paper with titanium dioxide to this type of pigment. Titanox-A-MO is also effectively used.

In paper coatings, Titanox-A-WD is often preferred on account of ready dispersion to a uniform suspension to provide smooth coatings.

## Paints

Tiranox-A-WD has been used in water paints of the casein type and also in alkyd-resin emulsion paints, but generally in the newer types of latex and emulsion paints Tiranox-RA or Tiranox-RA-50 is preferred.

The use of Tiranox-A-WD in organic coatings generally is not suggested inasmuch as the pigment does not disperse as easily as other types for high gloss enamels and does not retard the after-yellowing of vehicles. However, in emergency Tiranox-A-WD may be used in exterior white house paints inasmuch as it is a chalking type of pigment and may be dispersed suitably in this type of paint.

## Other Water Systems

Rubber latex, tanner's leather finishes, textile coatings such as external dullers or delusterants, shoe whiteners and similar products have been pigmented with Tiranox-A-WD, but for most of these the rutile pigments Tiranox-RA and Tiranox-RA-50 are preferred.

## TIRANOX-A-WG

|                                                                                       |         |
|---------------------------------------------------------------------------------------|---------|
| Minimum % $TiO_2$ .....                                                               | 98      |
| Crystal Structure of $TiO_2$ .....                                                    | Anatase |
| Average Particle Size                                                                 |         |
| Mean Dia., micron.....                                                                | 0.6     |
| Specific Gravity .....                                                                | 3.9     |
| Ave. Tinting Strength.....                                                            | 1100    |
| Tiranox-A-WG was formerly called Tiranox A ceramic grade, a designation discontinued. |         |

Tiranox-A-WG is titanium dioxide pigment having particle size not as fine as the usual pigment types. As a result, pigment qualities are not fully developed but rather physical and chemical properties pertinent to the use of Tiranox-A-WG in coatings for steel arc-welding rods or electrodes. Tiranox-A-WG, (Welding Grade) is made specifically for this use.

## Uses

### Welding Rod Coatings

For the coatings of steel arc-welding electrodes such as the E-6010 type Tiranox-A-WG combines uniformity of the following properties: Apparent density higher than that of pigment grade, low and uniform sodium silicate absorption and ease of dispersion in sodium silicate and other binders, high titanium dioxide content and low content of objectionable impurities such as sulfur and phosphorus.

The whitening and lightening of the color of a welding rod coating because of the tinting strength of Tiranox-A-WG is purely accidental and not related to the functioning of the coating but only to its appearance.

Compared to Tiranox-A-WG, although lacking sufficient tinting strength to lighten visibly the color of the coating, Tiranox-TG the "technical grade" or non-pigmentary titanium dioxide, presents the highest titanium dioxide content available plus ease of handling and freedom from harmful amounts of harmful impurities. Tiranox-TG is the logical titanium dioxide of high purity for welding rod coatings in which color appearance is not a factor.

## TIRANOX-TG

Minimum % TiO<sub>2</sub>..... 99.0  
Specific Gravity ..... 3.9-4.1

Particle Size Range, Microns..... 7-20

Tiranox-TG is free-flowing titanium dioxide of high purity. TG stands for "technical grade" in the sense of usage for general technical, technological or chemical purposes instead of pigment purposes.

The relatively coarse particle size of Tiranox-TG (20 to 40 times larger than pigment type) mainly accounts for its free-flowing nature. While relatively coarse, the particles or "fine granules" are still fine enough for Tiranox-TG to be classified as a *fine mesh material free from large hard aggregates*.

Although pigment properties such as tinting strength and opacity do not characterize Tiranox-TG it is a highly refined titanium dioxide having maximum titanium dioxide content and controlled purity.

### Uses

#### Porcelain Enamels

*Titania Porcelain Enamels*—Tiranox-TG is the form of titanium dioxide especially applicable to titania porcelain enamels because this suitability was a prime objective in the development of Tiranox-TG. Enamels made with this titanium dioxide as the sole type have highest reflectance and opacity attainable. Lowered reflectance but greater blue-whiteness are achieved with Tiranox-TG-400.

*Dry Process Enamels for Cast Iron*—Tiranox-TG smelted into the frit batch, is first choice to impart acid resistance to this type of enamel.

*Enamels for Aluminum*—Smelted into the frit of these enamels of the lead borosilicate type Tiranox-TG is first choice to impart acid resistance. In the type of enamel first developed for application to aluminum, white opacification is through additions to the mill. For this purpose Tiranox-RA-10, Tiranox-RA-50 and Tiranox-RA-NC are employed.

*Enamels for Glass Decorating*—As in enamels for aluminum, Tiranox-TG is smelted into the frit to impart acid and chemical resistance, while the pigment grades, especially Tiranox-RA, are added to the mill or paste for whitening, brightening and opacifying.

## Glazes

Extensive research indicates that through smelting Tiranox-TG into the batch clayware glazes can be made which are self-opacified by titania that precipitates on firing. Such glazes have outstanding whiteness, brightness and opacity without excessive thickness and are suitable for wall tile and other bodies.

## Glass

Tiranox-TG added to the glass melt for viscosity, optical or durability effects assures satisfactory results because of its high  $\text{TiO}_2$  content and uniform purity. Tiranox-TG is the preferred titanium dioxide for glass owing its peculiar color to this oxide in combination with others such as cerium oxide.

## Ceramic Colors

Tiranox-TG is the best source of  $\text{TiO}_2$  for co-calcination with other oxides and compounds.

## Electrical Porcelain

The constancy of composition and physical properties such as shrinkage qualify Tiranox-TG for titania as well as titanate (by reaction) bodies.

## Chemical Compounds

**Doble fluorides**—such as sodium and potassium titanium fluorides used in the alloying of aluminum are best made from Tiranox-TG as the most reliable source of highly concentrated  $\text{TiO}_2$ .

**Carbides**—Tiranox-TG is an ideal starting point of titanium dioxide to be converted to titanium carbide by reduction.

**Titanium Metal**—Tiranox-TG because of its uniformly high  $\text{TiO}_2$  content and lack of disturbing impurities is the ideal starting material in processes for the production of metallic titanium from titanium dioxide.

## Welding Rod Coatings

High  $\text{TiO}_2$  content, low sulphate and phosphate content, high purity, low binder absorption, free-flow, all recommend Tiranox-TG as a most attractive form of titanium dioxide for coatings of steel arc-welding rods.

## TIRANOX-TG-400

|                                   |         |
|-----------------------------------|---------|
| Minimum % $\text{TiO}_2$ .....    | 99.0    |
| Specific Gravity .....            | 3.9-4.1 |
| Particle Size Range, Microns..... | 7-20    |

Tiranox-TG-400 is Tiranox-TG modified to yield blue-white titania porcelain enamels. The number "400" denotes increased relative reflectance in the 400-500 millimicron or blue range of the visible spectrum of white titania porcelain enamels.

In the production of Tiranox-TG-400 the ideal titanium dioxide base—Tiranox-TG—is carefully processed to provide constant bluing effect. Thus, Tiranox-TG-400 has its color effect positively controlled during its manufacture.

## Use

### Titania Porcelain Enamels

In those frit compositions in which color tone of the white enamel—whether blue-white or cream-white—is determined largely by the type of titanium dioxide employed, Tiranox-TG-400 is used to secure blue-white tone. In such compositions Tiranox-TG yields higher reflectance and opacity along with a less blue or creamy tone.

Gradations in opacity and color tone may be secured through mixtures of these two titanium dioxides. Thus through the simple expedient of varying the ratio between Tiranox-TG and Tiranox-TG-400 in the frit batch, exact requirements for reflectance and color tone may be readily met.

Tiranox-TG-400 like Tiranox-TG is not recommended as a mill addition for opacity because these titanium dioxides do not function themselves as pigments but act through precipitation or crystallization from the frit on firing the enamel.



### List of Uses of TITANOX Pigments

Recognition of the multiple functions of pigments is helpful in accounting for the large number of products in which titanium pigments are used. In addition to whitening films or other organic compositions, white pigments are also capable of brighten colors, to opacify—especially at low levels of reflectance and to regulate translucency. The efficacy of TITANOX pigments in performing these functions is enhanced by compatibility with a wide kind of composition—those based on drying oils, plastics, rubber, cellulose—to mention a few. This broad adaptability, largely the result of low chemical reactivity, has also stimulated impetus in the formulation of many compositions especially in the paint field.

Paints and related products, because they constitute the largest task in whitening, brightening, opacifying are naturally by far the largest field of usage of TITANOX pigments. Paper, rubber, coated fabrics, floor coverings, leather, and building materials are some of the other fields in which the outstanding qualities of titanium pigments are preferred when a white pigment is required.

In addition, the "pure" titanium dioxide, TITANOX has been chosen to furnish titanium pigmentary functions, for example as a catalyst in the coating of electric arc-welding electrodes to stabilize the arc. The importance of this application, spurred by the development of porcelain enamel led to the production of "non-pigmentary" titanium dioxide. This grade is made exclusively for ceramics and other products that require titanium dioxide as chemical pigment. Some examples, in addition to porcelain enamels, are glasses and titanium coatings.

The following list of uses of TITANOX presents first the field of paint and organic compositions, a group with products listed alphabetically, followed by the field of paper and products in alphabetical order. The remainder of the list is alphabetical by product.

## Paints and Organic Finishes

| Product                        | TITANOX Applicable<br>(First mentioned is<br>usually first choice) |
|--------------------------------|--------------------------------------------------------------------|
| Acid resistant paints.....     | any                                                                |
| Aircraft finishes .....        | RA-NC                                                              |
| Alkyd resin Enamels            |                                                                    |
| white .....                    | RA-45;<br>other "RA";<br>A-168-LO                                  |
| White exterior .....           | RA-NC; RA-50                                                       |
| White and tint exterior .....  | RA-NC; RA-50                                                       |
| tint exterior .....            | RA-NC; RA-50;<br>RC                                                |
| Architectural Enamels          |                                                                    |
| Interior .....                 | RA-45; other<br>"RA"; C-50<br>A-168-LO;<br>RCHTX<br>RA-NC; RC      |
| Artists' colors                |                                                                    |
| oil and water .....            | RA-45; RA-46;<br>A-168; others                                     |
| Automotive finishes            |                                                                    |
| white .....                    | RA-NC; RA-45                                                       |
| white and tinted .....         | RA-NC; RA-45;<br>RA-51                                             |
| tinted .....                   | RA-NC                                                              |
| Baking Enamels                 |                                                                    |
| white .....                    | RA-45;<br>other "RA";<br>A-168-LO                                  |
| white (interior & exterior) .. | RA-NC; RA-45                                                       |
| white & tint (exterior) .....  | RA-NC                                                              |
| tint (exterior) .....          | RA-NC                                                              |
| Concrete & Stucco paints       |                                                                    |
| white .....                    | A-MO; RCHT;<br>RA                                                  |
| tint .....                     | RC; RA-NC                                                          |

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## Paints and Organic Finishes

| Product                         | TITANOX Applicable<br>(First mentioned is<br>usually first choice) |
|---------------------------------|--------------------------------------------------------------------|
| Enamels                         |                                                                    |
| Appliance .....                 | RA-45; others                                                      |
| exterior exposure .....         | RA-NC                                                              |
| industrial products .....       | RA-45; RA-51;<br>C-50                                              |
| Flat Wall Paints .....          | RCHT or<br>RCHTX; C-50                                             |
| Floor Enamels .....             | RC; RA-NC;<br>RA-45; others                                        |
| Gas resistant paints .....      | any                                                                |
| Highway paints                  |                                                                    |
| white .....                     | RCHT; C-50;<br>RA; A-MO<br>RC; RA-NC                               |
| tints .....                     | RA-NC; RA-45;<br>RA-51; RC                                         |
| Household Enamels .....         | RC; RA-NC;<br>RA-51; A-MO<br>RCHT                                  |
| House paint primers .....       |                                                                    |
| House Paints                    |                                                                    |
| white .....                     | A or A-168<br>usually plus<br>some "RA" or<br>"C" pigment          |
| White and tint .....            | RC; RCHT;<br>C-50; RA-50<br>RC; RA-NC;<br>RA-51                    |
| tint .....                      |                                                                    |
| Industrial Product Finishes     |                                                                    |
| white .....                     | RA-45; RA-50;<br>RA-NC                                             |
| tint .....                      | RA-NC; RA-50                                                       |
| exterior exposure .....         | RA-NC                                                              |
| white & tint .....              | RA-NC; RA-45;<br>RA-51                                             |
| Interior-exterior Enamels ..... |                                                                    |

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## Paints and Organic Finishes

| Product                                            |       | TITANOX Applicable<br>(First mentioned is<br>usually first choice)    |
|----------------------------------------------------|-------|-----------------------------------------------------------------------|
| Lacquers                                           | ..... | RA-45; RA-51;<br>RA-NC;<br>C-50; RCHTX<br>RA-NC; RC<br>RCHT; C-50; RC |
| exterior tint                                      | ..... |                                                                       |
| undercoaters                                       | ..... |                                                                       |
| Latex Paints—see water base and<br>emulsion paints | ..... |                                                                       |
| Marine Paints                                      | ..... | RA-NC; RA-50;<br>RC<br>RA-NC; RA-50;<br>RC                            |
| tints                                              | ..... |                                                                       |
| Mill Whites                                        | ..... | RCHTX; C-50;<br>RA-45;<br>RA-51; RA-46                                |
| gloss and flat                                     | ..... |                                                                       |
| Painter's Enamels and<br>Gloss Paints              | ..... | RCHTX; C-50                                                           |
| Painters' Paste and<br>Semi-paste Paints           | ..... | RA; RA-50; RC;<br>C-50; RCHT                                          |
| Porch and Deck<br>Paints and Enamels               | ..... | RC; RA-NC;<br>RA-50                                                   |
| Primers                                            | ..... | RA; RA-50;<br>A-168                                                   |
| metal                                              | ..... |                                                                       |
| wood                                               | ..... | RCHT                                                                  |
| house paint                                        | ..... | RCHT; RC                                                              |
| Interior wall                                      | ..... | RCHT; C-50                                                            |
| Reflector Enamels                                  | ..... | RA-51; RA-45;<br>RA; RA-50                                            |
| Refrigerator Enamels                               | ..... | RA-45; RA-51;<br>RA-NC                                                |
| Semi-gloss                                         | ..... |                                                                       |
| interior                                           | ..... | C-50; RCHT or<br>RCHTX<br>RA-46; others                               |

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## Paints and Organic Finishes

| Product                             |       | TITANOX Applicable<br>(First mentioned is<br>usually first choice)                     |
|-------------------------------------|-------|----------------------------------------------------------------------------------------|
| Sign Enamels                        | ..... | RA-NC; RC;<br>RA-51                                                                    |
| Stencil Paints                      | ..... | RA-NC; RC;<br>RA-51                                                                    |
| exterior                            | ..... |                                                                                        |
| Stipple flats                       | ..... | RCHT; or<br>RCHTX; C-50                                                                |
| Synthetic resin coatings            | ..... | any<br>RA-NC; RC;<br>others                                                            |
| exterior                            | ..... |                                                                                        |
| Traffic Paints                      | ..... | RCHT; C-50;<br>RA; A-MO<br>RA-NC; RC;<br>others                                        |
| white                               | ..... |                                                                                        |
| tint                                | ..... |                                                                                        |
| Trim and Trellis Paints             | ..... | RC; RA-NC;<br>others                                                                   |
| Venetian blind and similar coatings | ..... | RA-45; RA-50;<br>RA-NC; others                                                         |
| Vinyl coatings                      | ..... | RA-45; others<br>RA-NC                                                                 |
| exterior                            | ..... |                                                                                        |
| Wall primers and sealers            | ..... | RCHT or<br>RCHTX; C-50                                                                 |
| Water base and emulsion paints      | ..... | RA-46; also C-50<br>or RCHT under<br>controlled<br>conditions; others<br>RA-NC; others |
| exterior                            | ..... |                                                                                        |

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## Paper

| <i>Product</i>                                               | <i>Titanox Applicable</i> |
|--------------------------------------------------------------|---------------------------|
| <b>Fine Papers</b>                                           |                           |
| Airmail, bond, cigarette, ledger, manifold, writing, etc.    | A-WD; A-CG; RA-46         |
| <b>Printing Paper, uncoated</b>                              |                           |
| Bible, book, catalog, coating raw stock, label, offset, etc. | A-WD; A-CG; RA-46; C-50   |
| <b>Printing Papers, coated all types</b>                     | A-CG; RA-46; others       |
| <b>Label</b>                                                 | RA-46; others             |
| <b>Packaging Stocks</b>                                      |                           |
| Wrapping, uncoated, waxed.                                   | RA-46; others             |
| Glassine                                                     | RA-46; others             |
| Grease proof                                                 | RA-46; others             |
| Parchment                                                    | RA-46; others             |
| Breadwrap, coated                                            | RA-46; others             |
| Gift wrap                                                    | RA-46; others             |
| Plastic coated                                               | RA-46; others             |
| <b>Paperboards</b>                                           |                           |
| patent coated                                                | A-WD; others              |
| folding boxboard, coated                                     | A-CG; others              |
| <b>Foodboards</b>                                            |                           |
| cup                                                          | RA-46; A                  |
| bottle                                                       | RA-46; A                  |
| <b>Resin Impregnation</b>                                    |                           |
| absorbent                                                    | PL                        |
| <b>Wallboards</b>                                            |                           |
|                                                              | A-CG; RA-46; C-50; RCHT   |
| <b>Wall Paper</b>                                            |                           |
|                                                              | A-CG; RA-46; C-50; RCHT   |

## Product

| <i>Product</i>                                | <i>Titanox Applicable</i>         |
|-----------------------------------------------|-----------------------------------|
| <b>Acid resistant ceramic ware</b>            | TG; chemical grade                |
| <b>Artificial Leather</b>                     | RA-45; RA-40; C-50; RCHTX; others |
| <b>Asbestos-cement shingles</b>               | A-WD; RA; RA-50; RCHT             |
| <b>Asphalt base floor covering</b>            | RA-40; RA; "C" pigment            |
| <b>Ceramics</b>                               |                                   |
| enamels, acid resistant                       | TG; chemical grade                |
| enamels, self-opacified                       | TG; chemical grade                |
| blue-white                                    | TG-400                            |
| mill add. opacified                           | A-WD; RA; others                  |
| for aluminum in frit                          | TG; chemical grade                |
| for aluminum mill add. opacified              | RA-10; RA-NC; others              |
| for glass decoration in frit                  | TG                                |
| mill added opacifier                          | RA; RA-50; RA-NC; A               |
| <b>glass</b>                                  |                                   |
| colored                                       | TG; chemical grade                |
| optical                                       | TG; chemical grade                |
| glazes for matte or cryst. effects mill added | A-MO; others                      |
| self-opacified, titania                       | TG                                |
| <b>Coated textiles</b>                        |                                   |
| base coats                                    | RCHTX; C-50                       |
| top coats                                     | RA-51; RA-50; RA-45; others       |
| <b>Concrete Curing Coatings</b>               | RCHT; others                      |

| <i>Product</i>                 | <i>Titanox Applicable</i>                          |
|--------------------------------|----------------------------------------------------|
| Floor coverings                |                                                    |
| felt base, print paints.....   | RCHTX; C-50                                        |
| tiling                         | RA-40; RA;<br>RA-50; RCHT;<br>C-50                 |
| asphalt base .....             | RA; RA-40;<br>RA-50; C-50                          |
| linoleum .....                 | RA; RA-40;<br>RA-50; C-50                          |
| plastic .....                  | RA; RA-40;<br>RA-50; C-50                          |
| rubber .....                   | RA; RA-40;<br>A; C-50;<br>RCHT                     |
| linoleum (roll) .....          | RA; RA-50;<br>A; C-50                              |
| plastic (roll) .....           | RA; RA-40;<br>RA-50; C-50<br>RCHTX                 |
| backing on rugs.....           | A; RA                                              |
| Inks and related products..... | RA-45; RA-51;<br>RA-46; others                     |
| Latex .....                    | RA; RA-50;<br>A-LO; A-CG;<br>A-WD                  |
| Leather                        |                                                    |
| drumming .....                 | RA; RA-50; A                                       |
| finishes .....                 | RA; RA-50; A;<br>RCHT; C-50                        |
| Linoleum .....                 | RA; RA-50;<br>A; C-50                              |
| Oil cloth .....                | RCHT or<br>RCHTX; C-50                             |
| Plastics, all types.....       | RA; RA-40<br>RA-50; RA-NC;<br>A-168; RCHT;<br>C-50 |
| Porcelain enamels              |                                                    |
| dry process .....              | TG; chemical<br>grade                              |
| wet process, titania .....     | TG; chemical<br>grade                              |
| mill addition .....            | A-WD; RA;<br>others                                |

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| <i>Product</i>                  | <i>Titanox Applicable</i>                  |
|---------------------------------|--------------------------------------------|
| for aluminum                    |                                            |
| to impart acid resistance       |                                            |
| in frit .....                   | TG; chemical<br>grade                      |
| mill added opacifier.....       | RA-NC; RA-50;<br>RA-10                     |
| Rayon, delustering              |                                            |
| internal (viscose) .....        | A-MO                                       |
| internal (acetate) .....        | AA                                         |
| internal (nylon) .....          | A-168LO; A-MO                              |
| internal (other non-cellulosic) | A-168; A                                   |
| external .....                  | A-CG; RA-46;<br>others                     |
| Roofing granules .....          | -RA-NC;<br>RA-51; others                   |
| Rubber                          |                                            |
| White .....                     | A-LO; A-MO;<br>A-168                       |
| tints .....                     | RA; RA-40;<br>RA-50; RA-NC;<br>RCHTX; C-50 |
| Shade cloth coatings.....       | RCHT or<br>RCHTX; RC;<br>C-50              |
| Shoe Whiteners .....            | RA-46; RA-50;<br>A-MO; A-WD;<br>others     |
| Textile printing .....          | RA-45; RA-51;<br>A; others                 |
| Welding rod coatings.....       | A-WG; A-WD;<br>A; others                   |
| White Portland Cement.....      | A; others                                  |
| Whiteware glazes                |                                            |
| mill added in matte.....        | A-MO                                       |
| self-opacified titania .....    | TG; chemical<br>grade                      |

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## PART IV

### PHYSICAL AND CHEMICAL TESTS

**T**HROUGH strict control of process variables in the manufacture of Tiranox pigments, uniform products having properties desired by the user are assured. Many physical and chemical tests conducted on the finished pigments at the time of manufacture are actually too exacting in nature to be adopted by the consumer for control of quality of shipments. Some of these tests must not only reveal standard quality but must be so delicate as to indicate even the slightest trend in deviation from standard manufacturing conditions. Such delicacy, of course, is not often applicable to the requirements in use of the pigments. As a general rule, the physical properties of Tiranox pigments, like other white pigments, of greatest interest to the consumer, are:

- Whiteness or Color
- Tinting Strength and Hiding Power
- Oil Absorption
- Coarse Residue or Particles
- Dispersibility

Generally taken as standard methods are those of the A.S.T.M. and Federal Specification TT-P 141b of latest issue, but slight modifications of these are generally employed in testing Tiranox pigments.

#### Whiteness or Color

While the "dry color," that is, reflectance and whiteness of Tiranox pigments in powder form is of interest in the manufacture of the pigment and may be measured quantitatively by careful spectrophotometric and colorimetric methods it is of little value in relation to effective whiteness in a vehicle. This is, of course, readily understood by recalling that the whitest dry substance known—magnesium oxide—is like all white substances having low refractive index practically devoid of whitening power when immersed in drying oils, resins and other substances having similar refractive indices.

Although it is feasible to obtain spectrophotometri-

cally a quantitative result for reflectance or brightness and hue of TIRANOX pigments in a given vehicle, reproducibility is dependent among other factors upon standard samples of pigment and vehicle as controls.

Greatest practical benefit will be derived from a comparison of the color produced by the sample of pigment under test versus a standard sample in a small preparation of the coating in question made and tested under conditions as exactly parallel as possible. For such comparisons to be of any value, however, it is generally recognized that the following precautions must be strictly observed:

1. Other ingredients must not be varied in kind or proportion in comparing different samples of pigment.
2. Mixing and grinding conditions must be strictly comparable to yield equal dispersion.
3. The compositions such as enamels, lacquers, etc., must be prepared at the same time and be of the same age for comparison of different samples of pigment.
4. Films for color measurement, regardless of the instrument used, must be sufficiently thick so that close to maximum reflectance is obtained, otherwise the measurements will reveal opacity rather than color. It goes without saying that these films must be dried, whether air-dried or baked, under conditions yielding comparable results. This holds particularly for laboratory baking ovens which must be checked for variation of baking conditions at different points within the oven.
5. Panels, of course, should be selected as far as possible to be equal in reflectance, color and surface texture before coating.
6. Surface texture of films must not vary due to faulty application such as resulting from wide viscosity variations at spraying.
7. Comparison of pigments should not be made at extremely low or especially extremely high pigment volume concentration and if so made, the results must be interpreted in the light of these conditions.
8. In using reflectometers of the tristimulus colorimeter type, the standard for calibrating the instrument should have spectral characteristics similar to those of the surfaces to be measured.

Spectrophotometric and colorimetric determination of color is of great value to clarify visual observations,

to provide numerical values for record, and most important to contribute to attainment of proper standards and especially tolerances in color.

The following ASTM methods for measurement of color are used in the evaluation of TIRANOX pigments.

#### *ASTM Method*

- |           |                                                                 |
|-----------|-----------------------------------------------------------------|
| D307-44   | Spectral Characteristics and Color of Objects and Materials     |
| D1495-57T | Color Difference using the Color Eye                            |
| D1536-58T | Color Difference using the Colormaster Differential Colorimeter |
| D1482-57T | Color Difference using the General Electric Spectrophotometer   |
| D1365-55T | Color Difference using the Hunter Color Difference Meter        |
| D1260-55T | Color Difference using the Hunter Multi-purpose Reflectometer   |

By each of the above methods, values for reflectance or lightness and for tone which is a measure of deviation from perfect whiteness usually expressed as relative blueness or yellowness, are obtained for a sample in terms of a standard. In evaluating the deviation of a sample of pigment from the standard, factors other than pigment which determine color of the pigmented film must be understood. Any tolerance applied to the values or to a single co-efficient must be based upon the variations inherent in the particular system and not upon any generalization.

#### **Tinting Strength**

#### **Reynolds Constant Volume Method**

The routine method of determination of tinting strength of TIRANOX pigments employed in the laboratories of Titanium Pigment Corporation is similar in principle to the ASTM standard method D 332-57T for tinting strength of white pigments, except that the tinting color is restricted to blue and the content by volume of pigment is always maintained constant.

The tinting strength of the standard samples of TIRANOX have been determined reflectometrically, being proportional to the amount of blue required to yield brightness of 20% in the paste consisting of 46%



total pigment by volume. As a result, all matches are made at about 20% brightness and 46% pigment by volume. While this pigment content by volume (or pigment volume concentration - pvc) is quite high, the concentration of  $TiO_2$  pigment or its effective pvc is relatively low, being about 13.6%.

The amount of blue required to bring the sample of pigment under test to the same brightness, as judged by visual observation of the standard sample of known tinting strength, is proportional to tinting strength of the test sample as will be noted from the table on page 90.

It is extremely important for exact work to employ standards of the same type of pigment as the sample under test. Thus Titanox-RA should be compared with a standard sample of this pigment; Titanox-A-MO versus its standard, etc. Differences in chromaticity as well as texture resulting from different types of pigment may present serious difficulty in matching pastes for brightness.

### Materials and Apparatus

**Tinting Material:** "Tinting Strength Blue" consisting of one part ultramarine blue (No. 4940 United Ultramarine and Chemical Co.) extended with 6 parts barytes (Foam A, Delore Division, National Lead Company). The ultramarine blue and barytes are milled together until a uniform blend is obtained. A suggested milling procedure is: 180 grams ultramarine and 1080 grams Foam A barytes are mixed thoroughly and charged to a one gallon porcelain ball mill, thoroughly dry, containing fifty-five  $1\frac{1}{4}$ - $1\frac{1}{2}$  inch and sixty  $\frac{1}{2}$ - $\frac{3}{4}$  inch porcelain balls and milled for eight hours.

**Linseed Oil:** General purpose linseed oil No. 35 (Minnesota Linseed Oil Company).

**Burette:** Ten ml. capacity graduated 0.05 ml.

**Glass Plate:** Smooth, at least 8 inches by 8 inches for rubbing up pastes.

**Spatulas:** Stainless steel having flexible blade 4 inches by  $\frac{3}{8}$  inches for rubbing. The blade should be ground to an even smooth edge to aid removal of pastes from the plate. Spatula with tapered blade about  $\frac{1}{4}$  inch wide at tip for placing pastes on slides.

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*If tile cardboard or other impervious smooth panels:*  
For setting up pastes for comparison. An optional procedure employs microscope slides.

*Bird Film Applicator* (Bradley Blade): .003" thickness type—Bird Machine Company, East Walpole, Mass.

### Procedure

**Standard Pastes:** The amount of pigment and blue required by the standard sample of the same type of pigment under test are weighed accurately. Thus, if Titanox-A-MO is being tested and the standard sample has tinting strength 1250, this means 0.5 grams of the standard sample and 1.25 grams of blue will be weighed. After transferring these to the glass plate, .515 ml. of oil is added from the burette and worked into the pigment by means of the spatula to a uniform paste. (The Hoover muller may be used to replace hand mixing.)

The sample under test is treated exactly as the standard. After the paste has been made it is compared with the standard paste by drawing down on the cardboard, (pastes side by side) by means of the Bradley Blade, or applying to the microscope slide by means of the spatula using the same pressure on each paste. If the sample is lighter than the standard a new mix is prepared using the same quantity of pigment but additional blue and at the same time additional oil in order to maintain constant pigment volume. If darker than the standard the new mix is made with less blue and less oil, thus:

1200 tinting strength means 1.20 grams of blue to 0.5 grams pigment.

0.5 grams pigment bulks 0.1265 ml.

1.20 grams blue bulks 0.30 ml.

Total volume of pigment and blue = .4265 ml.

At 46% by volume:

0.4265 ml. = 46%.

therefore 0.9272 ml. = 100%.

so that 0.9272 — 0.4265 = 0.500 ml.

oil to be used

The following table lists the quantities of pigment, blue and oil for different tinting strengths at constant pigment volume and is indispensable to rapid work.

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# TITANOX-RC; -RCHT; -RCHT-X 1.0 gram of pigment

| For<br>Tinting<br>Strength | Grams<br>T.S.<br>Blue | ml. oil to<br>be<br>used |
|----------------------------|-----------------------|--------------------------|
| 560                        | 1.12                  | 0.70                     |
| 580                        | 1.16                  | 0.71                     |
| 600                        | 1.20                  | 0.73                     |
| 620                        | 1.24                  | 0.74                     |
| 640                        | 1.28                  | 0.74                     |

## TITANOX-C-50 0.5 gram pigment

| For<br>Tinting<br>Strength | Grams<br>T.S.<br>Blue | ml. oil to<br>be<br>used |
|----------------------------|-----------------------|--------------------------|
| 920                        | 0.92                  | 0.44                     |
| 940                        | 0.94                  | 0.44                     |
| 960                        | 0.96                  | 0.45                     |
| 980                        | 0.98                  | 0.46                     |
| 1000                       | 1.00                  | 0.45                     |

## TITANOX-A and -RA TiO<sub>2</sub> Pigments

### 0.5 gram pigment

| For<br>Tinting<br>Strength | Grams<br>T.S.<br>Blue | ml. oil to<br>be<br>used |
|----------------------------|-----------------------|--------------------------|
| 1150                       | 1.150                 | 0.485                    |
| 1200                       | 1.200                 | 0.50                     |
| 1250                       | 1.250                 | 0.515                    |
| 1300                       | 1.300                 | 0.52                     |
| 1350                       | 1.350                 | 0.54                     |
| 1400                       | 1.400                 | 0.55                     |
| 1450                       | 1.450                 | 0.56                     |
| 1500                       | 1.500                 | 0.58                     |
| 1550                       | 1.550                 | 0.60                     |
| 1600                       | 1.600                 | 0.61                     |
| 1650                       | 1.650                 | 0.62                     |
| 1700                       | 1.700                 | 0.64                     |
| 1750                       | 1.750                 | 0.65                     |
| 1800                       | 1.800                 | 0.67                     |
| 1850                       | 1.850                 | 0.69                     |
| 1900                       | 1.900                 | 0.71                     |
| 1950                       | 1.950                 | 0.73                     |
| 2000                       | 2.000                 | 0.75                     |

## Other Methods of Test for Tinting Strength

Other methods of test generally used differ from the preceding usually in four respects (1) variation in pigment volume as a result of constant amounts of oil (2) use of a different color—usually black (3) use of paste color instead of dry color (4) use of muller instead of spatula. Usually where comparison is being made of the same type of pigment and variation in tinting strength is slight, these differences do not affect the results. Black for tinting strength is sometimes advantageous as it may readily reveal differences in undertone hidden by blue.

As in the case of color, it must be remembered that comparison in the coating which is of interest will reveal more than a rub up in linseed oil.

## Reflectometry in Testing for Tinting Strength

Reflectometer determination of brightness (lightness, or reflectance as determined for example, using the green filter of a trichromatic reflectometer) of tinted compositions, especially enamels, may be used as a measure of tinting strength of titanium pigments. The precautions mentioned on page 86 under determination of color by similar procedures are even more important in the comparison of tinting strength. In determining "undertone" or "tone of tint" as well as strength reflectometrically, it is imperative with tristimulus colorimeters that the standard surface be at the same reflectance level and have similar chromaticity as the sample surface under test.

Obviously at equal titanium pigment concentration and equal amount of added tinting color, the sample of titanium pigment under test, has higher tinting strength if its enamel film has higher brightness than that made with the standard or reference pigment, and vice versa. Naturally by using also the red and blue filters of the tristimulus reflectometer, or from the spectrophotometric curves, if a recording spectrophotometer is employed, undertone or chromaticity of the tint may also be obtained, and comparison made between sample under test and the reference or standard pigment.

In this type of method, the most important consideration is the difference in lightness or brightness between the sample and standard that should be taken as significant. The difference, of course, should be sufficient.

ently greater than that attributable to the errors inherent in the method, in order to permit practical evaluation of a sample in relation to a standard. In general, the precision of this type of method is about 1% at the brightness of most tints.

Although this type of method need involve no more than a comparison of the brightness of the tints of sample and standard, if desired, a numerical value may be assigned or established for the standard. Therefrom a value may be calculated for the sample under test. Simplest of course, is a direct ratio. For example, if a standard pigment has been assigned a value of 1800 and yields brightness of tint of 0.430 (43%) while the sample of pigment under test has brightness of tint of 0.418, the relative tinting strength of the sample is simply:

$$\frac{0.418}{0.430} \times 1800 = 1750, \text{ or } \frac{R_s}{R_t} S$$

where  $R_t$  is reflectance or brightness of standard,  $R_s$  is reflectance or brightness of sample and  $S$  is tinting strength of standard.

In this type of method, inasmuch as the precautions mentioned on page 86 must be observed, the film of tinted coating will be sufficiently thick and opaque for its brightness or reflectance as determined to be the same as  $R_{\infty}$  in the Kubelka-Munk notation of the ASTM method D1738-60T. As a result, rather than the simple

direct ratio  $\frac{R_s}{R_t}$  the relationship is  $\frac{R_s(1-R_t)}{R_t(1-R_s)}$ . Thus,

if  $S$  is the tinting strength value of the standard or reference pigment, then the tinting strength of the sample under test is

$$\frac{R_s(1-R_t)}{R_t(1-R_s)} S.$$

P. B. Milton and A. E. Jacobsen (Reflectometry Method for Measuring Tinting Strength of White Pigments, Official DIGEST 37, 704, July 1962) suggest that the value of the reference or standard sample of titanium pigment be a hiding power value determined by the ASTM method D1738-60T and that it be expressed as square centimeters per gram of pigment.

The use of tinting strength values might be considered superfluous inasmuch as the lightness (reflectance or brightness) of comparable tints is the property of greatest practical importance along with chromaticity.

## Hiding Power

Hiding power is a property of paints or coatings. It is expressed as the spreading rate—the number of square feet of surface that may be hidden by one gallon of paint. The standard surface usually consists of an alternate black and white design to provide a contrast which must be obscured by the coating of paint at complete hiding. White paints containing a single white pigment owe their hiding power, of course, to the pigment. From this results the concept of hiding power of white pigments which may be expressed as square feet of surface per pound of pigment as derived from the square feet per gallon and the number of pounds of pigment in a gallon of paint.

Great difficulty, as would be expected, is experienced by most observers in detecting just when such a black and white contrast is eliminated by wet or dry paint and as a result the visual observation of hiding power over black and white areas does not lend itself to quantitative expression. As a result, many methods which include this condition, have been discontinued including ASTM D406-39 for relative dry hiding power of white pigments in a linseed oil vehicle. However, when visual detection of the obliteration of a contrast is mandatory, a background of lesser contrast than black and white, such as grey and black, can prove helpful. An early method of Titanium Pigment Corporation employs a grey and black background<sup>1</sup> over which the paint is brushed for visual observation of reduction in contrast.

Current methods are reflectometric, that is, visual observation is eliminated in favor of measurements of reflectance of the paint applied over the black and white background. One of these methods utilizes a relationship between spreading rate and contrast ratio and thus involves determination of contrast ratio for a number of spreading rates. Others utilize equations, based on the Kubelka-Munk theory, for the calculation of hiding power. These methods are particularly valuable for comparing standards and test pigments when formulated exactly alike.

<sup>1</sup> A. E. Jacobsen and C. E. Reynolds, I. & E. C., Anal. Ed. Vol. 6, 393 (1935).

## Visual Brush Out Method for Dry Hiding Power of White Paint

### Apparatus

Hiding power charts: Black and gray (25% reflectance) checkerboard background composed of alternate 2" squares of black and gray and having a test area of 1 sq. ft. These charts may be obtained from The Morest Company, 211 Centre Street, New York.

Balance: Sensitivity 0.1 gm.; capacity 200 gm.

Syringe: 20 ml. capacity. Paint Brush: 1½" wide.

### Procedure

A suitable quantity of paint is taken up in the syringe. The brush, thoroughly wetted with the paint, is weighed together with the syringe. A quantity of the paint is applied and brushed as uniformly as possible over the 1 sq. ft. test area. Additional quantities of paint are applied until the contrast background is just short of being obliterated. The brush and the syringe are reweighed. The loss in weight represents, of course, the amount of wet paint applied to the chart.

Additional brushouts are made, on fresh charts, using amounts of paint required for obscuring the contrast as judged from the first brushout. Usually, a maximum of three brushouts are sufficient.

After the paint films have dried completely, the charts are viewed at arm's length in good light and selection is made of the one on which visual hiding of the contrast background exists.

### Calculation:

$$\frac{\text{Hiding power in square feet per gallon} = \text{Weight of paint (in grams) per gallon}}{\text{Grams of paint applied to 1 sq. ft. test area}}$$

### Example:

$$\frac{6350 \text{ grams per gallon}}{10 \text{ grams applied}} = \text{Hiding power of 635 sq. ft. per gallon.}$$

## Contrast Ratio Method for Dry Hiding Power of White Paint

This method is based upon a straight relationship between  $\log_{10}$  of 10 x dry contrast ratio and spreading rate of highly reflecting white paint. A range of 70% to almost 100% contrast ratio is obtained by means of doctor blades, the paint under test being applied at a number of film thicknesses to black and white hiding power charts. Spreading rate is calculated as the weight of wet paint applied, the area covered, divided by the weight per gallon of the paint.

Contrast ratio is determined on the dry film. The spreading rate, and  $\log_{10}$  of 10 x contrast ratio are plotted against spreading rate. For the purpose of comparison, the spreading rate read from the chart is the hiding power of the paint.

### Apparatus

Balance: Beam type, glass enclosed, capacity 200 gm., for weighing charts in horizontal position. (The Morest Company, New Rochelle, New York, has such a balance).

Doctor Blades: A series having clearances of 0.001, 0.0015, 0.002, 0.003, and 0.005 inches. Film Applicators six inches wide have been successfully used (Bird Machine Company, Boston, Mass.).

Hiding Power Charts: Black and white checkerboard piece area large enough for measurement with reflectometer. Form 03, The Morest Company, 211 Centre Street, New York, are suitable. White area having greater reflectance, black area less than 1 inch wide, trimmed to a width of eight inches and fifteen inches retaining the centerpiece. The reverse side for ½ inch and the end of the piece over which the drawdown will pass is coated with lacquer to prevent absorption of paint.

Holder for Charts: Suitable horizontal support for holding charts flat—plate glass supported by clamps with provision for clamping the chart is used.

Paper Cutting Board with attached ruler.  
Reflectometer: Gardner multi-purpose

## Procedure

The chart of proper size (8" x 15") is weighed, then fastened face upward to the horizontal base. A doctor blade having the desired clearance is placed near the top of the chart. A small amount of the thoroughly mixed paint is placed across the front of the applicator which is then drawn across the chart so as to apply a uniform film the full width of the applicator.

The chart is immediately trimmed at each end so that the length of the covered area is nine inches and the black and white centerpiece remains in the center. Thus a wet film covering fifty-four square inches (.375 sq. ft.) is obtained. This section is immediately weighed to .01 gram and set aside to dry. The ends of the chart are thoroughly cleaned and wiped dry, then weighed, and their weight subtracted from the weight of the chart (15" x 8") thus giving the weight of the chart under the paint. The weight of the paint on the 9" x 6" area may thus be determined by difference.

Successive films at different thicknesses are prepared in the same manner. The films are allowed to dry under comparable conditions after which reflectance over the white area and over the black area is measured and contrast ratio is calculated. For each weight of paint applied, spreading rate is calculated.

## Calculations:

$$\text{Spreading Rate} = \frac{\text{Wt./gal. of paint} \times .454 \times .375}{\text{grams paint applied}}$$

$$\text{Contrast Ratio} = \frac{\text{Reflectance over black}}{\text{Reflectance over white}}$$

## Example of Data

| Blade | Grams Paint | Contrast Ratio | Spreading Rate sq. ft./gal. | Logio 10 X Contrast Ratio |
|-------|-------------|----------------|-----------------------------|---------------------------|
| .001" | 1.79        | .890           | 1210                        | .949                      |
| .002" | 3.63        | .957           | 600                         | .981                      |
| .003" | 5.47        | .980           | 400                         | .991                      |

\* Weight per gallon of paint 12.77 lb.

Logio of 10 x contrast ratio is plotted against spreading rate as indicated in Figure 1. For the contrast

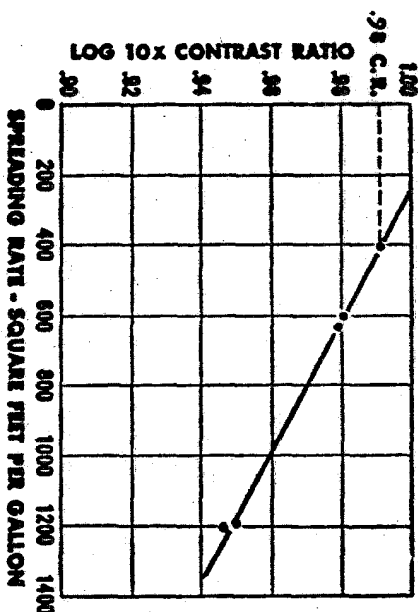
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ratio agreed upon—such as 0.93, 0.95 or 0.98—spreading rate is read from the graph and expresses hiding power.

In place of regular rectangular coordinate paper, semilogarithmic paper may naturally be used to facilitate plotting. Some workers prefer simply to plot contrast ratio (rather than its logarithm) against spreading rate, and from a judiciously drawn curve, to read spreading rate for the contrast ratio of interest.

Of course, this method is also useful when contrast ratio as an index of hiding or opacity, is sought for a specified spreading rate of a white paint.

FIGURE 1



## Newer Methods of Test for Hiding Power

In reflectometric methods for hiding power, improvement is being sought mainly through increased precision and simplification. Efforts at greater precision involve close control of all test conditions and operations. Simplification is sought by elimination of a range of film thicknesses or spreading rates and corresponding contrast ratios in favor of a single film thickness. From simple test data hiding power is calculated by means of equations based upon the well known Kubelka-Munk theory of light scattering. Among methods embodying these features is:

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# ASTM Method D1738-60T<sup>(1)(2)</sup> for Hiding Power of Nonchromatic Paints

In this tentative method, apparatus and operations are essentially the same as in the foregoing contrast ratio method, except that glass plates are required for determining the non-volatile of the paint by sandwiching a sample between two of the weighed plates, weighing, opening the sandwich, allowing the paint to dry, then reweighing.

In the ASTM method, from the weight of dried paint on a determined area of black and white chart, wet film thickness (designated T) is calculated from the non-volatile or percent solids of the paint and its density. Reflectance values of the dried film (corresponding to the wet film thickness T) over the black and white areas are determined and designated respectively R<sub>a</sub> and R<sub>w</sub>. These values, the reflectance of the white background, designated W, and the calculated film thickness T, are utilized in equations that lead to an expression for hiding power (designated V<sub>0.98</sub>) in terms of square feet per gallon for 98% contrast ratio. The scattering coefficient S is involved in the calculations, and the reflectivity or "ultimate reflectance" R<sub>∞</sub> is calculated. This is the limiting value of reflectance for a dry film so thick that increasing the thickness does not change the reflectance. The equations are as follows:

$$V_{0.98} = \frac{1604.17bS}{\coth^{-1} \left( \frac{[(a + 0.0127551)^2 - 1.02040816]^{1/2} + 0.0127551}{b} \right)} = \text{factor } A \times S$$

$$\text{where } a = \frac{1}{2} \left( R_w + \frac{R_a - R_w + W}{R_a R_w} \right)$$

$$b = (a^2 - 1)^{1/2}$$

$$\text{and } S = \frac{1}{bT} \coth^{-1} \frac{(1 - aR_a)}{bR_a} = \frac{\text{factor } B}{T}$$

$$\text{or } ST = \text{factor } B$$

$$R_{\infty} = a - b$$

Calculations can be greatly simplified by the use of tables—"Tabulation of Kubelka-Munk Factors for com-

(1) ASTM Standards 1961, Part 8, page 856.

(2) A. E. Jacobsen, P. B. Milton, and M. H. Switzer, "Determination of the Hiding Power of Nonchromatic Paints," Materials Research and Standards, Vol. 2, No. 12, Dec. 1962, p. 1004.

putting Hiding Power" which are available on loan from ASTM headquarters, 1916 Race Street, Philadelphia 3, Pa. These tables were computed and made available to ASTM by the Research Department of National Lead Company, Titanium Division. P. B. Milton and A. E. Jacobsen of this department, to simplify the computations further, have devised graphs<sup>(3)</sup> and a simple table, which are available from Titanium Pigment Corporation.

In our simplification of the ASTM method, the paint is applied to structural black glass, allowed to dry and reflectance R<sub>a</sub> is read. The dried film of known area is removed from the glass and weighed in order to calculate T, the wet film thickness. The paint is also applied in sufficient thickness of uniform film to a suitable substrate to yield when dry, practical maximum reflectance. This is read and designated R<sub>∞</sub>. These values are used with the aforementioned charts and table to obtain hiding power in terms of square feet per gallon.

## Reflectivity and Scattering Coefficient as Indicators of Hiding Power

It is often assumed that the Kubelka-Munk scattering coefficient S, along with reflectivity R<sub>∞</sub>, indicate quite well the opacity characteristics of a paint. Knowing R<sub>∞</sub>, R<sub>a</sub> and T (in mils), S as determined by a method similar to the foregoing, S may be calculated from the following simple equation<sup>(4)</sup>:

$$ST = \frac{\log_e \left( \frac{R_a R_{\infty} - 1}{R_a / R_{\infty} - 1} \right)}{\left( \frac{1}{R_{\infty}} - R_{\infty} \right)}$$

As an example, given a white paint having wet film thickness T of 2.0 mils, R<sub>a</sub> 0.857, and R<sub>∞</sub> 0.919:

$$ST = \frac{\log_e 3.14}{1.691} = \frac{1.14422}{1.691} = 6.77$$

$$\text{Since } T = 2, S = \frac{6.76}{2} = 3.39$$

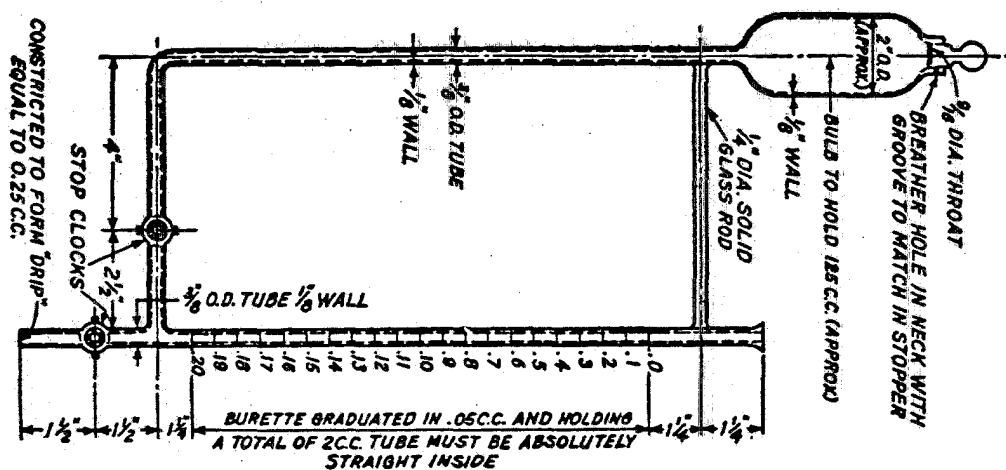
Some values of ST corresponding to values of R<sub>a</sub> and R<sub>∞</sub> over the range from R<sub>a</sub> 0.70 to 0.91 and R<sub>∞</sub> 0.80 to 0.96 in steps of 0.01 are given in Table C-6, page 163. Factors for converting S to hiding power are given in Table C-7, page 164.

<sup>(3)</sup> In the derivation of this equation, reflectance of the black substrate is 0.

<sup>(4)</sup> P. B. Milton and A. E. Jacobsen, "New Graph for Computing Scattering Coefficient and Hiding Power," Official D1CEST Vol. 35, 464, Sept. 1963, p. 871.

FIGURE 11

# MODIFIED BROWN OIL BURETTE



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## Oil Absorption

Oil absorption is determined by spatula rub-out essentially according to ASTM method D 281-31 except that the oil used is definitely specified, a standard sample is run at all times, and a time limit is placed upon mixing the oil and pigment. The method is as follows:

### Apparatus and Materials

*Linseed oil*—General purpose linseed oil No. 35 (Minnesota Linseed Oil Company, Minneapolis, Minn.)

*Burette*—Modified Brown oil burette as shown at left.

*Glass Plate*—Smooth glass plate of convenient size, 12" x 12" or larger.

*Spatula*—Fairly stiff stainless steel blade approximately 10 cm. long by 16 mm. wide (4" x 3/8").

### Procedure

Five grams of the pigment are weighed and transferred to the glass plate. The oil is added from the burette rapidly at first and then slowly drop by drop thoroughly working and rubbing the mixture of pigment and oil after each addition of oil. At first a dry crumbly mass is obtained which does not adhere to the glass but finally an end point is reached after which the addition of one drop more of oil will change the mixture of pigment and oil to a coherent mass which adheres slightly to the glass plate. Considerable pressure should be used in working up the mixture and the operation must be completed within 5 minutes.

The weight of oil is calculated from the volume used and the specific gravity of the oil (usually 0.93). Oil absorption is the grams of oil per 100 grams of pigment, or twenty times the oil required to obtain the end point. This figure is usually expressed as pounds of oil per one hundred pounds of pigment.

A standard sample of the same type of pigment should at all times be tested in the same manner. The results should be corrected for any variation in the standard which is due to variation in temperature and humidity. Standard conditions under which the value of the standard sample should be determined are usually 70° F. and 50% relative humidity.

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## Other Methods of Test for Oil Absorption

Contrasted to the foregoing, the Gardner-Coleman Method—ASTM D 1483-60, prescribes the dropwise addition of oil to the pigment with gentle stirring in a suitable container. Other methods involve addition of pigment to oil and mechanical instead of manual mixing. In all cases, decision has to be made concerning when addition of oil to pigment or vice versa must stop as judged by the plasticity of the mix, which is considered the end point.

Apparently there is no such thing as the absolute oil absorption of any pigment and this, of course, is true of Titanox pigments. The determining factor in oil absorption is the type of oil. Extending this to its full implication, means the type of liquid with which the pigment must be mixed in practice. Relatively, however, oil absorption values as determined by the spatula rub-out method serve to distinguish high and medium oil absorption from low oil absorption titanium dioxide pigments, roughly in their organic vehicle requirements for mixing and grinding at relatively high pigment concentration. Where feasible, the vehicle requirement of the pigment should be determined in laboratory size mechanical mixers employing the vehicle of interest.

When oil absorption is expressed on a volume basis and is also considered a measure of the pore volume or the volume of the voids between particles of pigments, it can be an indicator of critical pigment volume concentration.

## Water and other Liquid Absorption Tests

Analogous to oil absorption, the amount of water taken up by a given amount of pigment to form a paste or slurry has been termed water absorption. This has been of interest in differentiating water dispersible titanium dioxide Titanox-A-WD from other types when distilled water is mixed with the pigment.

The simple water absorption method is as follows: 100 grams of pigment are weighed into a 250 ml. beaker, after which distilled water is added slowly from a burette while working the pigment vigorously with a fairly stiff spatula. When the slurry just flows from the end of the spatula, the end point is reached. There should be a sharp change in the consistency of the mix within 1 ml. addition of water at this point. The results are reported simply as the ml. of water for 100 grams of pigment expressed as percentage, the figure being

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taken as water absorption. Results may also be expressed as percent solids; that is, the percentage of pigment by weight of the total mass of pigment and water.

*Water absorption tests having greatest practical value employ the industrial water and the kind and amount of dispersant and other additives that are used with the pigment.* Mixing is usually mechanical, rather than manual. In such tests, the concentration of pigment in the paste or slurry and the consistency and flow of the slurry, as measured by a suitable viscometer, are often of interest. In some cases, for a given amount of pigment and water, the amount of dispersant to be added to effect a given viscosity is determined and is called the "dispersant demand."

In compositions that utilize sodium silicate solution, this liquid is used in a manner similar to oil in the oil absorption test, except that a mortar and pestle for manual mixing, or an edge-runner or other type mill for mechanical mixing may be used.

Other liquids, especially plasticizers such as those used in lacquers and also in textile coating and plastic sheeting compositions, are employed in a similar manner.

## Method of Test for Coarse Particles

The method used in testing Titanox pigments for coarse particles is essentially that described in ASTM method D 185-45, however, in some cases for greater accuracy, 100 grams of sample is used

The method is as follows:

One hundred grams of pigment are weighed and placed in the container of a Hamilton Beach Mixer with 300 ml. of water and agitated for one minute. The suspension is then poured through an 8" diameter 325 mesh screen (with 40 mesh backing) which has been thoroughly wetted. The sieve is held under a tap delivering a gentle stream of water. Passage of particles through the screen is aided by a 1" paint brush, breaking up the lumps of pigment with as little pressure as possible. Attempts should not be made to force the pigment through the screen. After the very fine material has been washed through the screen and off the brush, the residue remaining on the screen is transferred with the aid of a wash bottle to a small beaker or a deep 5" watch glass. The coarse material is allowed to settle, the water is decanted off as far as pos-

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sible and the remaining residue is dried in an oven for at least 15 minutes at 110°C. After cooling, the residue is then weighed on an analytical balance—the result is reported to 0.01%.

Coarse Residue in Water Dispersible  
Titanium Dioxide TITANOX-A-WD

The pigment is dispersed in water and the suspension is poured through a 325 mesh screen, but a brush is not used to aid passage of the pigment through the screen. The method is as follows:

To 350 ml. of distilled water in a container of a Hamilton Beach mixer are added 20 grams of pigment and the mixture is stirred for exactly 2 minutes. The suspension is poured onto a 325 mesh screen holding the wire cloth sieve of the screen just below the surface of the distilled water in a suitable container. By lowering and raising the sieve in the water, the fine particles are separated from the coarse. The water in the container is circulated frequently. When no more pigment has passed through the screen as determined by observing the lack of turbidity in water drained from the screen, the residue is washed into a beaker; the water is decanted, the residue dried at 110°C, cooled and weighed.

$$\% \text{ Residue on 325 mesh} = \frac{\text{grams residue}}{20} \times 100$$

The result is reported to 0.01%.

While designed primarily for water dispersible pigment, this type of test is applicable to other types of TITANOX pigments. Interesting modifications involve the use of a constant pressure of water, of course, with the avoidance of any manual work by means of a brush or other apparatus. However, such tests can yield misleading results inasmuch as some specialized types of pigment may tend to agglomerate in water despite their fine dispersion in organic liquids in which they may be used.

**Dispersibility, Texture, "Fineness of Grind"**

TITANOX pigments carry very much less than the maximum residue on 325 mesh prescribed by all pigment specifications such as ASTM D 476-48 which prescribes a maximum of 0.2%.

TITANOX pigments are micron sized products which like all pigments must in use be converted from a powder in air to a powder permeated by the paint vehicle or other medium. The concept of dispersion is involved because clusters or groups of ultimate particles of pigment must be loosened and scattered in the medium to a degree of dispersion or dispersity meeting the requirements of the coating or composition. The capability of a pigment of being incorporated into a medium (such as a paint vehicle or plastic) and of being diffused therein to a suitable degree, is the dispersibility of the pigment.

To measure this quality the degree of dispersion must always be the criterion of the test method. This may be determined or indicated and taken as the result of the test when the work of dispersion is maintained constant. On the other hand a predetermined degree of dispersion or indication of such may be established and the work of dispersion determined to achieve this.

In our laboratories both these general types of methods are employed but for laboratory examination of pigments, generally the first type is preferred.

In practice, freedom from specks in a pigmented film is taken as a measure of a high degree of dispersion. The appearance of pigmented films whether of pastes or of liquids by reflected light which shows up specks is the texture of the film but is often considered the texture of the pigment. There is considerable danger in always considering such film texture to be pigment texture when the method of mixing pigment and vehicle involves an impractical amount of work. For example, light mixing of a pigment with a vehicle by means of a spatula to form a paste may yield a film of rough texture because the work was insufficient to break up loose aggregates that might readily have been dispersed by mechanical means comparable to plant mixing equipment.

In all methods of this type, all factors have to be maintained as constant as possible, so that the only variable is the pigment under test.

Where a single pigment is being dispersed in a paint vehicle, "fineness of grind" is synonymous with dispersibility of the pigment.

"Fineness of Grind" is determined by the Hegman\* or a similar gage which is a hardened steel block having a calibrated tapered groove in which the suspension is spread. At some point along the groove, specks are visible. This texture is observed but is expressed numerically according to the numbers along the groove corresponding to depth or thickness of the suspension. The Hegman scale contains gradations from 0 to 8, from coarsest to finest of texture. The Federation of Societies for Paint Technology scale runs from 0 to 10 for the same length and taper of the groove as the Hegman.

| Inches<br>Length<br>(distance from<br>0 end) | Depth, Mils<br>(Thickness of<br>Wet Film) | Hegman<br>Scale | Federation<br>Scale |
|----------------------------------------------|-------------------------------------------|-----------------|---------------------|
| 5                                            | 4.0                                       | 0               | 0                   |
| 4 1/8                                        | 3.5                                       | 1               | 1.25                |
| 3 3/4                                        | 3.0                                       | 2               | 2.50                |
| 3 1/8                                        | 2.5                                       | 3               | 3.75                |
| 2 1/2                                        | 2.0                                       | 4               | 5.00                |
| 1 7/8                                        | 1.5                                       | 5               | 6.25                |
| 1 1/4                                        | 1.0                                       | 6               | 7.50                |
| 3/4                                          | 0.5                                       | 7               | 8.75                |
| 0                                            | 0                                         | 8               | 10                  |

The design of the gage, the scraper used with it and directions for their use are given in Standard Method of Test for Fineness of Dispersion of Pigment-Vehicle Systems ("Fineness of Grind"), ASTM Designation D 1210-54.

Inasmuch as the work of dispersion has to be maintained as constant as possible and must not be so great as to eliminate differences in dispersibility, one of our procedures calls for controlled mixing of pigment with vehicle followed by grinding through a 3-roll laboratory mill with roll clearances set at 0.015". The final suspension is measured on the Hegman gage and expressed in the Hegman scale. Similar procedures are used with dispersing equipment of the high-speed mixer type that operate on suspensions having suitable consistency. In such tests, Hegman fineness for a standard mixing time is determined in relation to reference or standard pigments.

\* First described by E. W. Fawc, Drugs, Oils and Paints 54 (1938).

## Methods for Determination of Particle Size and Particle Size Distribution

Many technologists are interested in the sub-sieve or microscopic size and size distribution of the particles of a pigment in suspension (see ASTM E20-51T).

Following are the main procedures that have been employed for the determination of particle size distribution of pigments:

- (1) Microscopic
- (2) Sedimentation
- (3) Air and liquid classification
- (4) Infra red transmission
- (5) Spectral transmission

For the determination of average particle size, the following methods have been employed:

- (1) Adsorption (gas and liquid)
- (2) Permeability
- (3) Dark field microscope

The American Society for Testing and Materials has issued a tentative recommended practice (ASTM D 1366-55T) for reporting the results of particle size determinations. It suggests numbers that may express the fineness characteristics of pigments having sub-sieve particles. Measurements leading to data from which the suggested calculations are made may be obtained by the microscopic or the sedimentation method.

### Microscopic Methods for Determination of Particle Size Distribution

The white light microscope, then the ultra violet microscope and now the electron microscope are employed. The procedure for these is essentially similar to ASTM method E 20-51T as is also the method of computation of distribution. The ultra violet microscope was brought into the picture because the white light microscope was limited to particle size above 0.3 micron. But with the limitations of the ultra violet microscope set at 0.2 micron, the electron microscope covering a much wider range is now being widely used. The electron microscope reveals most clearly the size and shape of individual particles, but the size distribution is usually tedious to calculate and also exists only in the mounting medium. Apparently, the limitations of the ordinary microscope have not been quite so serious as has been predicted, inasmuch as many of the older results on Titanox pigments are being confirmed by the newer procedures.

## Sedimentation Methods for Determination of Particle Size Distribution

Sedimentation methods are flexible in that wide latitude in the amount of force which can be exerted on a suspension having proper viscosity are applicable to a wide range of particle sizes. Such flexibility is the result of centrifugal sedimentation which eliminates the excessive time required for very small particles to settle and minimizes the effect of Brownian movement.

The sedimentation tube method, pipette method and Tyndall method have been employed at times for materials below 1 micron in size. The reliability of these methods as well as turbidimetric methods for the examination of pigment may be open to question.

Centrifugal sedimentation methods because they are easily carried out and also can utilize the medium of interest—such as water, oil, resin solution, etc.—for a complete particle size distribution are particularly valuable for use with TIRANOX pigments.

In working with these pigments, however, sedimentation of the composite pigment TIRANOX-RCHT may not yield results as highly exact as the sedimentation of "pure" titanium dioxide types. It is assumed that the specific gravity of a composite remains constant. But any appreciable fraction of a component of the composite set free from the other will not have the settling rate calculated on the specific gravity of the composite.

### Methods Used for Determination of Average Particle Size

Those methods based upon adsorption of a gas or liquid, or rate of flow of a gas or liquid through a porous mass of pigment, yield values for surface area of the pigment from which an average diameter of the particles can be calculated.

Liquid adsorption methods early carried out by Harkins and Gans<sup>1</sup>, using oleic acid, yielded results comparable to the average calculated from determination by means of the white light microscope. Gans, Brooks and Boyd<sup>2</sup>, working with the nitrogen adsorption methods have reported values somewhat lower than those obtained by other methods. The permeability method as employed by Pechukas and Gage<sup>3</sup> yielded average size on the order of that reported by Harkins

<sup>1</sup> J. Phys. Chem. 16, 86, 1932.

<sup>2</sup> I. & E. C., Anal. Ed. 14, 5, 396, May 1942.

and Gans in their work with oleic acid. Such methods have found some application as control methods because they often can be carried out rapidly.

Greater emphasis is usually placed upon particle size distribution than average particle size. Obviously in coatings, any undue percentage of very coarse particles or very fine particles may be the source of irregularities in product. There follows a typical method for the determination of particle size distribution by centrifugal sedimentation of TIRANOX-RA-50 in an acrylic vehicle:

### Centrifugal Sedimentation Method<sup>4</sup>

**Theory:** The centrifugal sedimentation method for particle size analysis is based upon the application of Stokes' law for obtaining sedimentation-time curves and upon Oden's method of tangential intercepts for the determination of particle size distribution from these curves. Oden's method corrects for the fines which settle due to their proximity to the bottom of the cup.

The following equation gives Stokes' law, modified for use in sedimentation:

$$D_m = 10^4 \frac{3\eta (R - S)}{10(d_1 - d_2) \omega^2 R t_m}$$

$D_m$  = equivalent spherical diameter of the particle (microns)

$\eta$  = coefficient of viscosity of the suspension medium (poise)

$d_1$  = density of particle (g/cc)

$d_2$  = density of suspension medium (g/cc)

$t_m$  = time for a particle of size  $D_m$  to settle a distance of  $R - S$  (cm)

$R$  = distance from center of rotation to bottom of cup (cm)

$S$  = distance from center of rotation to surface of suspension (cm)

$R$  = average distance from center of rotation to suspension (cm)

$\omega$  = angular velocity in radians per second:

$$2\pi \times \text{revolutions per minute}$$

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<sup>4</sup> I. & E. C., Anal. Ed. 18, 6, 370, 1946.

<sup>5</sup> See Jacobsen, A. E. and Sullivan, W. F., Ind. Eng. Chem. 13 360-64 (1946) also Symposium on Particle Size Measurement, Special Technical Publication No. 234, American Society for Testing Materials, Philadelphia, Pa., 1958.



*Apparatus:* International Centrifuge, Size 1, Type SB, equipped with a Servo-Tek 300T Precision Adjustable Speed Drive and special motor to maintain the rpm within close limits. The centrifuge head holds eight flat-bottom chromium plated cylindrical cups (9.20 x 3.58 cm), each having a cover to prevent evaporation. The distance R from the center of rotation to the bottom of the cylindrical cup is 21.3 cm. and, since the suspension is 1 cm. in height, S is then equal to 20.3 cm. The centrifuge is operated at 350. rpm. From these constants, the viscosity of the suspension medium (0.0148 poise at 25°C.) and its density (0.960), it is possible to determine the rate of settling for equivalent spherical particles.

*Procedure:* The suspension is prepared by adding 20.0 grams of pigment to 12.0 grams of a solution consisting of 40% Acryloid-B72 (Rohm & Haas, Philadelphia, Pa.) and 60% "Cellosolve" acetate by weight. After hand mixing, the mixture is put through a laboratory three-roller paint mill at contact setting. A sufficient amount of this suspension is diluted with Cellosolve Acetate to three percent solids after which 11.6 ml. is delivered into each of the eight cylindrical cups with a dispensing burette. The centrifugation of the suspension in the cups is performed in accordance with a time schedule which allows development of a sedimentation-time curve. A suitable time schedule is shown in the accompanying table under centrifuging time. Pigment suspensions are analyzed for percent solids by pipetting a 10 ml. aliquot into weighed crucibles, evaporating the solvent with infrared lamps, burning off the organic by ignition in an electric muffle at 800°C. for 15 minutes and weighing the residue as titanium dioxide. Since the suspension is dilute, the percent sedimented may be calculated from the equation:

$$\begin{aligned} \% \text{ sedimented} &= \frac{\text{weight of sediment}}{\text{weight of total}} \times 100 \\ &= \frac{\text{weight of total} - \text{weight in suspension}}{\text{weight of total}} \times 100 \\ &= \frac{(C_{TiO_2}) \text{ initial} - (C_{TiO_2}) \text{ suspension}}{(C_{TiO_2}) \text{ initial}} \times 100 \end{aligned}$$

where  $(C_{TiO_2})$  = concentration of  $TiO_2$  in grams per liter.

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A sedimentation-time curve is plotted on graph paper (about 20 x 20 inches in size). Page 113 presents such a curve on a reduced scale obtained for a sample of TITANOX-RA-50 having a specific gravity of 4.10. The curve is plotted from the following data:

| Centrifuging Time (min.) | Wt. % Sedimented |
|--------------------------|------------------|
| 0                        | 0                |
| 5                        | 4.7              |
| 10                       | 8.1              |
| 20                       | 23.0             |
| 40                       | 35.0             |
| 60                       | 49.0             |
| 92                       | 61.0             |
| 164                      | 88.0             |
| 232                      | 92.5             |

The time  $t_m$  (min.) it takes for a particle of diameter  $D_m$  ( $\mu$ ) to settle through the distance R-S is calculated from the modified Stokes' law equation by substituting the given apparatus constants and known values of the viscosity and densities.

For the specific conditions described, using a sample of TITANOX-RA-50, the settling times are given by:

$$\begin{aligned} t_m &= \frac{3 \times 10^8 \times \eta \times (R-S)}{10(d_1-d_2) \rho^2 R D_m^2} \\ &= \frac{3 \times 10^8 \times 0.0148 \times (21.3-20.3)}{(4.10-0.96) (3.663 \times 10)^2 (20.8) D_m^2} \end{aligned}$$

$$\text{which reduces to: } t_m = \frac{5.067}{D_m^2}$$

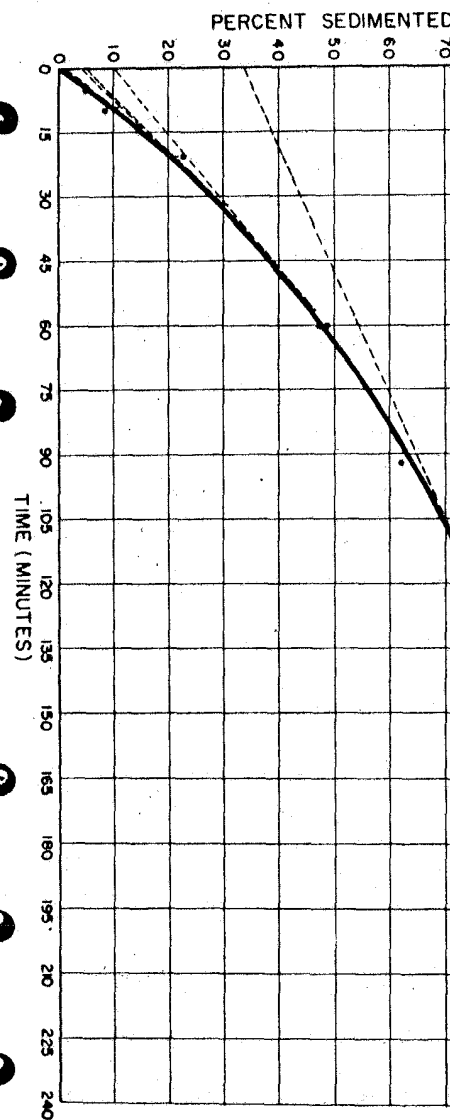
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The times corresponding to a series of particle diameters ranging from 0.15 to 1.0 micron are shown in the accompanying table.

The particle size distribution is obtained by drawing tangents to the sedimentation curve at these times,  $t_m$ , and measuring the Y-intercepts. The intercept value subtracted from 100 gives the weight percent less than  $D_m$ . These cumulative distribution values are listed in the same table.

| $D_m$<br>( $\mu$ ) | Time, $t_m$<br>(min.) | Tangential<br>Intercept<br>(wt. %) | Wt. %<br>Less than<br>$D_m$ |
|--------------------|-----------------------|------------------------------------|-----------------------------|
| 1.0                | 5.1                   | 0.0                                | 100.0                       |
| 0.75               | 9.0                   | 1.0                                | 99.0                        |
| 0.5                | 20.3                  | 4.0                                | 96.0                        |
| 0.4                | 31.7                  | 5.0                                | 95.0                        |
| 0.3                | 56.3                  | 10.0                               | 90.0                        |
| 0.2                | 126.7                 | 34.0                               | 66.0                        |
| 0.15               | 225.2                 | 82.0                               | 18.0                        |



## Alkalinity or Acidity

Titanox pigments are generally close to the neutral point and any deviation from it is too slight to be titratable by the usual methods such as section 5 of ASTM D1208-52T. However, an indication of this variation can adequately be represented by the pH value of a water slurry of the pigment. pH value is determined essentially according to ASTM D1208-52T sections 4(a) and 4(b), except that a larger sample of pigment is taken.

The electrometric method is considered more reliable than the colorimetric and as indicated in ASTM D1208-52T is the preferred procedure. The following potentiometric method is used:

### Apparatus and Materials

Beckman Model H-2 pH Meter (Manual 190-E), and General-purpose Glass Electrodes (No. 4970-80)  
Saturated KCl calomel reference electrode (sleeve type—No. 4970-71)  
Freshly distilled water  
100 ml. beaker  
Stirring rod

### Procedure

The meter is calibrated with a standard buffer solution (e.g. Beckman Buffer Solution pH 7) after which the electrodes are rinsed with freshly distilled water. 10 grams of pigment are placed in the 100 ml. beaker and 50 ml. of freshly distilled water are added.

The slurry is thoroughly agitated and placed under the electrodes. The electrodes are immersed in the slurry and pH value is read directly from the scale. It is important that equilibrium be reached before the final reading. This may require as long as several minutes with occasional stirring.

The colorimetric method has been used with the following indicators:

|                        | pH Range  |
|------------------------|-----------|
| Chlorophenol Red ..... | 5.2 — 6.8 |
| Phenol Red .....       | 6.8 — 8.4 |
| Thymol Blue .....      | 8.0 — 9.6 |

The pigment slurry is prepared by stirring 50 grams of pigment into 500 ml. of freshly distilled water.

Ten ml. of the pigment suspension is added to a standard test tube with one-half ml. of the indicator. Ten ml. of pigment suspension is added to each of two similar test-tubes without the addition of indicator. The suspensions are settled by means of a centrifuge and the color of the supernatant liquor in the tube containing the pigment and indicator is matched against the standards, looking through the supernatant liquor in the tubes without indicator. In case of retarded settling, the suspension should be centrifuged.

## Specific Resistance of TITANOX-A and BA

### Type pigments

The specific resistance of a water extract of titanium dioxide pigment is considered by some technologists to be inversely proportional to water soluble salt content of the pigment. It must be remembered that the extremely low water solubility of Titanox-A type pigments is difficult to measure and as a result this electrometric method is called upon. Procedure is as follows:

### Apparatus and Materials

**Distilled water:** Should have specific resistance of at least 250,000 ohms.

**Conductivity Bridge and Cell:** Model RCIB and cell type CEL-1A manufactured by Industrial Instruments, Inc., Jersey City, New Jersey, has been found satisfactory.

### Procedure

Into a tared 500 ml. Erlenmeyer flask, 25 grams of pigment and 225 grams of distilled water are weighed. The mixture is boiled for ten minutes (covering the top of the flask with a stemless funnel), then cooled and loss in weight restored by addition of freshly boiled distilled water.

The slurry is filtered (usually by vacuum through four #42 Whatman filter papers). The first 10-15 ml. of sample filtrate are usually discarded.



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About 200 ml. of clear filtrate is transferred to a 250 ml. graduate cylinder and cooled to 18°C, in a controlled temperature bath.

Resistance is then determined by means of the bridge and cell. Specific resistance is equal to measured resistance divided by the cell constant.

## Chemical Examination of TITANOX Pigments

The chemical analysis of TITANOX pigments is carried out by methods almost exactly similar to the tentative ASTM method D 1394-56T. In the determination of titanium however a new method for reducing the titanium with aluminum, developed in our laboratories, is a step forward in simplicity, convenience and reliability. (See page 121.)

### Qualitative Method for Detecting Titanium

About 0.5 gram of the sample is placed in a 250 ml. beaker after which 20 ml. of concentrated sulfuric acid and 10 grams of ammonium sulfate\* are added and the mixture is boiled five minutes. An insoluble residue denotes the presence of silica or siliceous matter. The solution is cooled then diluted with 100 ml. of water, heated to boiling, settled, then filtered through a double Whatman No. 42 paper. The residue on the filter is washed with hot, 5% sulfuric acid until free from titanium.

A small portion of the filtrate is tested with 3% hydrogen peroxide; a clear, yellow-orange to brownish-red color indicates the presence of titanium. (Chromium, vanadium and molybdenum give blue, brownish-red and yellow colors respectively with hydrogen peroxide, and in case any of these are thought to be present they may be removed by subjecting the original sample to a fusion with a mixture of sodium carbonate and sodium nitrate (20:3) and leaching the melt with hot water. After dissolving the residue in sulfuric acid, the color test for titanium is made in the usual manner.)

The residue obtained on dilution of the sulfuric acid digestion of the original sample is tested for lead, barium and silica, and also antimony. (If antimony is present in large amount, it will be found in both the residue and the filtrate.)

\* Note: If titanium analyses are being run often, it is convenient to make up a solution of ammonium sulfate in concentrated sulfuric acid. Ammonium sulfate crystals, 100 grams, are added to 170 ml. concentrated sulfuric acid and the mixture just brought to fumes by heating. In this ratio a stock solution may be maintained. Such a prepared solution does not "bump" on boiling when dissolving titanium dioxide. 20 ml. of this solution will dissolve 1 gm.  $\text{TiO}_2$  pigment.

The remainder of the filtrate from the sulfuric acid digestion may be tested for the presence of calcium, zinc, iron, chromium, antimony, etc., by the usual methods of qualitative analysis. For determination of iron, to a portion of the filtrate, 5 grams of tartaric acid is added after which the solution is made slightly ammoniacal, and hydrogen sulfide added in excess, followed by digestion on a steam-bath for a while. No precipitate denotes the absence of iron, nickel, cobalt, lead, copper, zinc, antimony, etc. A black precipitate easily soluble in dilute hydrochloric acid denotes iron. If the precipitate is only partially soluble in dilute hydrochloric acid, the presence of iron may be detected in the hydrochloric acid solution by boiling off the hydrogen sulfide, adding ammonium persulfate, and then making the usual color test for iron with ammonium thiosulfate.

### Qualitative Method for Identifying Titanium Pigments

About 0.5 gram of the sample in a 250-ml. beaker is treated with 20 ml. of concentrated sulfuric acid and 10 grams of ammonium sulfate, boiling until completely dissolved. The solution is cooled, then diluted with 100 ml. of water, and heated to boiling. A clear solution which, on the addition of hydrogen peroxide, gives a clear, yellow-orange to brownish-red color, indicates that the pigment may be pure titanium dioxide.

A white precipitate indicates the presence of barium sulfate which may be confirmed by the flame test for barium.

To test for calcium, 0.5 grams of original sample in a 250 ml. beaker is leached with 100 ml. 1:3 hydrochloric acid. The leaching is done on a hot plate near the boiling temperature of the solution for 1/2 hour. The solution is cooled and filtered, the precipitate is rejected. To the filtrate are added 2 grams ammonium chloride, 0.2 gram ammonium oxalate and the solution is heated to boiling. Ammonium hydroxide ( $\text{NH}_4\text{OH}$  1:1) is added to the hot solution until it is alkaline to litmus, after which 0.3 gram ammonium oxalate is added. The solution is allowed to stand overnight. A white precipitate indicates calcium, which may be confirmed by the flame test for calcium.

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## Quantitative Analysis of Titanium Pigments

### Determination of Titanium using Jones Reductor

$\text{TiO}_2$  in titanium pigments is determined by a volumetric method involving reduction of titanium and titration with a ferric salt.

**Reagent:** Standard ferric ammonium sulfate solution, of which 1 ml., is equivalent to 0.005 gram of titanium dioxide, is standardized by reduction and titration with 0.1 N potassium permanganate, which has been standardized against Bureau of Standards sodium oxalate.

The ferric ammonium sulfate is prepared by dissolving 30 grams of the salt in 300 ml., of distilled water acidified with 10 ml. of sulfuric acid. Potassium permanganate solution is added, drop by drop, as long as the pink color disappears. The solution is finally diluted to one liter. In standardizing, 50 ml. of the solution are made up to about 100 ml. in 5% sulfuric acid, reduced in the Jones reductor and titrated against standard 0.1 N potassium permanganate.

**Indicator:** A saturated solution of ammonium thiocyanate.

**Reductor:** The Jones reductor consists of a dispensing burette about 22 inches long and 2 inches in diameter, equipped with a glass stop-cock and a delivery tube 6 mm. in diameter x 3 1/2 inches long.

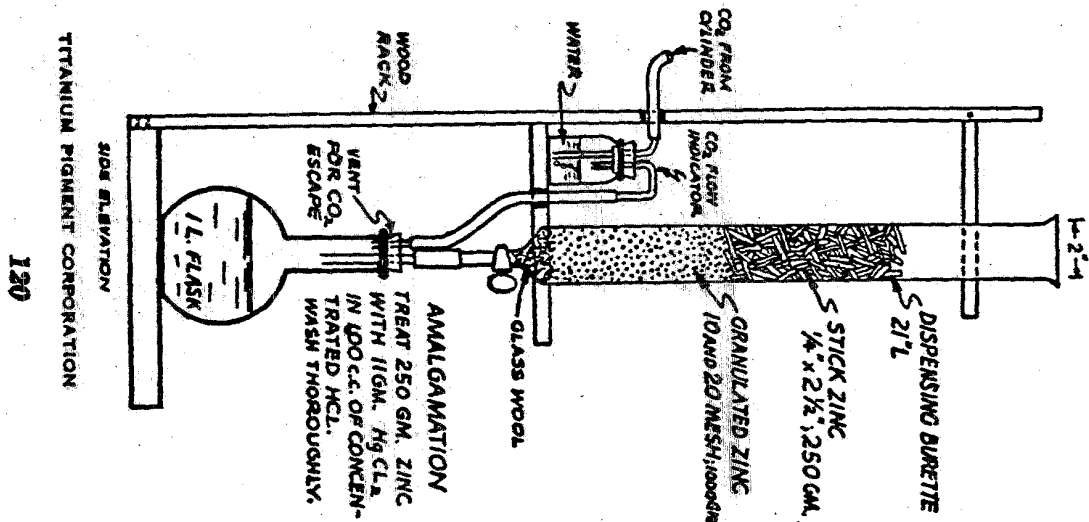
The reductor is charged with a 7 inch column of 20 mesh and 10 mesh amalgamated zinc (500 gms. each), and on top of this a 5 inch column of broken amalgamated zinc (about 500 grams). The delivery tube is connected to a one-liter flask through a three-hole rubber stopper. One hole is used as an inlet and the other as an outlet for carbon dioxide gas.

The zinc is amalgamated by immersing it in a solution of mercuric bichloride in hydrochloric acid. Eleven grams of mercuric chloride are dissolved in 100 ml. of concentrated hydrochloric acid. Two hun-

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## JONES REDUCTOR FOR TITANIUM



dred and fifty grams of zinc are covered with distilled water in a one-liter suction flask and the mercuric chloride solution is poured in, with slow mixing and shaking, for about 2 minutes. The solution is poured off, the zinc washed thoroughly, first with hot tap water and finally with distilled water.

### Procedure using Jones Reductor

The reductor is drained to the top of the fine mesh zinc and 200 ml. of a boiling solution of sulfuric acid (5%) are added. The reductor is slowly drained and then washed at least four times with boiling water. The reductor is drained to the top of the fine mesh zinc, and the hot titanium solution is washed into it and allowed to remain from 15 to 20 minutes. The reductor is kept covered with a watch glass during the period of reduction. During the whole period of reduction a slow stream of carbon dioxide is passed through the receiving flask. The reductor is slowly drained into the receiving flask while carbon dioxide is passed through the latter. When the solution has reached the level of the fine mesh zinc a boiling 5% solution of sulfuric acid is added to the level of the top of the stick zinc. The reductor is then drained to the fine mesh zinc, then washed in the same manner as above, with boiling water, four times. The flask is removed and 7 ml. of the indicator are added and the solution is titrated rapidly with the standard ferric ammonium sulfate solution.

$$\text{ml. ferric ammonium sulfate soln.} \times \text{factor} = \text{grams TiO}_2$$

### Reduction by Aluminum

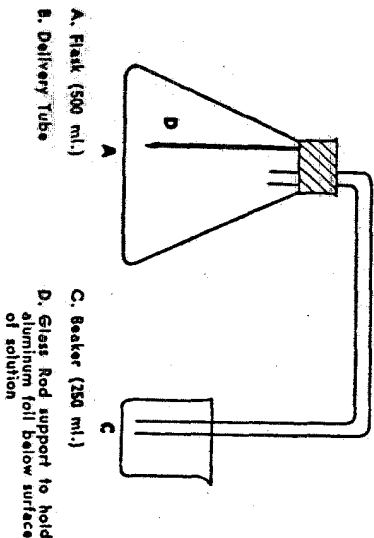
The modified Jones reductor requires considerable attention not only in preparation of the amalgam but in care and maintenance of the long column of amalgamated zinc. This reductor is particularly inconvenient if only occasional use arises for it.

Although there is a simplified method using a liquid amalgam shaken with the titanium solution and blanketed by carbon dioxide in a separatory funnel, the hazard of handling mercury still exists.

A new method for reducing titanium solutions, devel-

oped in our laboratories is described by Rahm in *Analytical Chemistry*, 24, No. 11, 1832-3 (Nov., 1952). This method has proven entirely satisfactory. In this scheme, aluminum foil replaces amalgamated zinc. The total apparatus is extremely simple, consisting only of a flask, stopper delivery tube and beaker as shown in Figure IV. A solution of sodium bicarbonate ingeniously replaces the cylinder of carbon dioxide gas required by other methods.

FIGURE IV  
Simple Apparatus for Reduction of  
Titanium Solutions



In this method the same reagent—ferric ammonium sulfate for titanium and the indicator are used as described on page 119.

The following are required however:

Hydrochloric Acid (HCL) 12N, reagent grade (this must be present in the titanium solution which is to be reduced in order to prevent passivation of the aluminum and stoppage of the reduction)

Aluminum metal foil—any high purity aluminum foil which contains no more than 0.03%  $\text{TiO}_2$  and no interfering ions.

Sodium bicarbonate ( $\text{NaHCO}_3$ ) reagent grade—a saturated solution is prepared at the time of analysis.

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**Reductor**—the simple apparatus shown in Figure IV which consists of —

- A — 500 ml. Erlenmeyer flask
- B — Delivery tube
- C — 250 ml. beaker
- D — Pointed glass rod with collar to hold aluminum foil below surface of aluminum

#### Procedure

The operation of dissolving the sample is carried out in the Erlenmeyer flask shown as A in Figure IV. Details for reducing and titrating are given under Quantitative Determinations of  $\text{TiO}_2$  in pure  $\text{TiO}_2$  pigments Rahm's Method.

#### Quantitative Determination of $\text{TiO}_2$ in pure $\text{TiO}_2$ Pigment

0.2-0.25 gram of pigment is transferred to a 250 ml. beaker; 10 grams of ammonium or sodium sulfate ( $\text{C.P.}$ ), and 20 ml. concentrated sulfuric acid are added; the beaker is covered with a watch glass. The contents are digested to complete solution on a hot plate, allowed to cool and then carefully diluted with water to about 125 ml.<sup>1</sup> If the sample of pigment should prove refractory and offer resistance to solution in the above quantities of ammonium sulfate and sulfuric acid, these are varied until the material dissolves.

The procedure is then the same as under Determination of Titanium using Jones Reductor. (See page 121.)

**Rahm's Method**—0.200 gram is transferred to the Erlenmeyer flask; 8 grams of ammonium sulfate and 20 ml. of concentrated sulfuric acid<sup>2</sup> are added followed by heating (boiling) until the sample is dissolved. The contents are cooled sufficiently to allow careful dilution with 120 ml. water and 20 ml. concentrated hydrochloric acid followed by again boiling. The flask is removed from the burner and two grams of aluminum foil is attached to the end of the glass rod (D, Figure IV).

<sup>1</sup>The titanium solution having volume of 125-150 ml. should contain 10-15%  $\text{H}_2\text{SO}_4$ , and not more than 0.25 gram  $\text{TiO}_2$ . <sup>2</sup>Instead of separately added ammonium sulfate and concentrated sulfuric acid, 20 ml. of the mixture of these described in Note on page 117 may be used conveniently.

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The rubber stopper containing the delivery tube as shown in Figure IV is immediately inserted in the flask while the other end of the delivery tube is placed below the level of the saturated sodium bicarbonate which is in the beaker (C, Figure IV).

When the aluminum appears to have dissolved completely, the solutions should be boiled gently for three to five minutes. (During this step the delivery tube must remain immersed in the sodium bicarbonate solution).

The reduction solution is cooled to less than 60°C. During cooling, the sodium bicarbonate solution is sucked into the Erlenmeyer flask, releasing carbon dioxide to provide the necessary protective atmosphere. After the solution has cooled, the delivery tube is removed, 2 ml. ammonium thiocyanate indicator are added and the solution is titrated rapidly with the standard ferric ammonium sulfate solution.

ml. ferric ammonium sulfate soln. x factor =  
grams  $\text{TiO}_2$ .

### Quantitative Determination of $\text{TiO}_2$ in Titanium-Calcium Pigment

#### Titanium Dioxide ( $\text{TiO}_2$ )

Using *Jones Reductor*—0.5 gram of the pigment if *Titanox-RCHT* or 3 gram if *Titanox-C-50* is weighed into a 250 ml. Pyrex beaker; 10 grams of ammonium sulfate and 25 ml. of concentrated sulfuric acid\* are added; the beaker is covered with a watch glass and carefully heated on the hot plate to complete solution of the sample. After cooling, the solution is carefully diluted to a volume of about 200 ml. with distilled water, heated to boiling, transferred immediately to the reductor and the titanium determined as under *Determination of Titanium using Jones Reductor*.

*Rahn's Method*—0.5 gram of the pigment if *Titanox-RCHT* and 0.3 gram if *Titanox-C-50* is transferred to the Erlenmeyer flask. 20 ml. of concentrated sulfuric acid—ammonium sulfate solution\* (100 grams ammonium sulfate; 170 ml. concentrated sulfuric acid) is added followed by heating (boiling).

\*See Note, page 117.

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until the sample is dissolved. The contents are cooled sufficiently to allow careful dilution with 120 ml. water and 20 ml. concentrated hydrochloric acid followed by again boiling. The flask is removed from the burner and two grams of aluminum foil is attached to the end of the glass rod (D, Figure IV, page 122).

The rubber stopper containing the delivery tube as shown in Figure IV is immediately inserted in the flask while the other end of the delivery tube is placed below the level of the saturated sodium bicarbonate which is in the beaker (C, Figure IV).

When the aluminum appears to have dissolved completely, the solutions should be boiled gently for three to five minutes. (During this step the delivery tube must remain immersed in the sodium bicarbonate solution).

The reduced solution is cooled to less than 60°C. During cooling, the sodium bicarbonate solution is sucked into the Erlenmeyer flask, releasing carbon dioxide to provide the necessary protective atmosphere. After the solution has cooled, the delivery tube is removed, 2 ml. ammonium thiocyanate indicator are added and the solution is titrated rapidly with the standard ferric ammonium sulfate solution.

ml. ferric ammonium sulfate soln. x factor =  
grams  $\text{TiO}_2$ .

#### Calcium Oxide ( $\text{CaO}$ )

0.5 gram of the pigment is weighed into a 250 ml. beaker; 3 grams of ammonium chloride are added followed by sufficient water to moisten the mixture; 25 ml. of concentrated hydrochloric acid are then added and the beaker is covered with a watch glass and boiled 15 minutes on a hot plate. 100 ml. of hot distilled water are added; the solution is boiled for five minutes, filtered through double 11 cm. No. 42 Whatman papers, using a small amount of paper pulp, and washed three times with hot distilled water. The residue is washed back into the original beaker, 3 grams of ammonium chloride and 25 ml. of hydrochloric acid are added, and the whole is boiled on the hot plate for 15 minutes. The solution is diluted with 100 ml. of water, boiled and filtered through the original filter paper, receiving the filtrate in the first

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filtrate. The precipitate is washed six times with hot distilled water. The combined filtrate is made slightly alkaline to litmus with ammonia, boiled five minutes, and filtered through double 11 cm. Whatman No. 42 filter papers. The precipitate, after washing six times with hot water, is rejected. The filtrate is evaporated to a volume of about 400 ml., after which 25 ml. of a saturated solution of ammonium oxalate are slowly added to the hot solution from a pipette. 40 ml. of ammonium hydroxide are then added; the solution is boiled for five minutes and allowed to stand in a warm place over night. The precipitate of calcium oxalate is filtered and washed with hot water to remove all of the ammonium oxalate (usually 10 to 12 washings). The calcium oxalate precipitate is then washed back into the beaker with hot water, 15 ml. of 1:1 sulfuric acid are added, and the whole is diluted to about 300 ml. The solution, heated to about 80°C., is titrated with 0.1 N potassium permanganate to a pink color. The filter paper is carefully unfolded and placed in the solution, and the titration is continued, after stirring thoroughly, until a pink color is reached.

#### Determination of Titanium in a Mixture of Pigments

Usually titanium may be detected by the following procedure:

0.5-1.0 gram of the sample is weighed and transferred to a 250 ml. Pyrex beaker; 10 grams of ammonium or sodium sulfate and 20 ml. of concentrated sulfuric acid are added and thoroughly mixed, and the contents digested until the pigment is dissolved. After cooling, the solution is carefully diluted to about 200 ml. Lead and barium will be precipitated. Hydrogen peroxide added to the solution will impart a yellow-orange color, denoting the presence of titanium. If no antimony is present, the above method of separation may be used for a quantitative determination of  $\text{TiO}_2$ . After dissolving the pigment mixture and diluting, the precipitate is filtered and washed, and the filtrate is reduced and titrated as previously described.

Titanium dioxide in a mixture of white pigments will always be found in the insoluble residue obtained by treatment with hydrochloric acid. The hydrochloric acid treatment will remove lead, zinc and antimony,

if present. The residue may be dissolved in ammonium or sodium sulfate and sulfuric acid and titanium determined by the usual reduction and oxidation titration method.

#### Routine Analysis for Titanium Dioxide in Paper

Detailed methods for the qualitative examination of paper ash are given in ASTM D 686-59 "Qualitative Examination of Mineral Filler and Mineral Coating of Paper" and in TAPPI T 421-m-44 "Qualitative Examination of Mineral Filler and Mineral Coating of Paper," and in TAPPI Data Sheet No. 47 "Analyses of Ash from Paper." The quantitative analysis of paper containing titanium pigments is given in ASTM D 921-58, TAPPI T-439-m-60 and T-627-m-58.

#### Qualitative

The ash from a 2 gram sample of paper is boiled in 20 ml. of concentrated sulfuric acid and 10 grams of ammonium sulfate for at least 3 minutes. Any insoluble residue is filtered off and the filtrate is tested with hydrogen peroxide as described on page 118.

#### Quantitative

Weigh accurately 2 grams of paper and ignite to constant weight in a crucible, being careful to prevent loss of the ash by air currents.

*In our laboratories loss of ash and paper while ashing are prevented by placing a piece of nichrome gauze over the top of the crucible, then heating the crucible containing the paper to be ashed, with a Meker burner.*

**Reduction-Titration Method using Jones Reductor:** Transfer ash to a 250 ml. beaker and add 20 to 30 ml. concentrated sulfuric acid and 10 grams of ammonium sulfate. Cover the beaker with a watch glass and boil vigorously for at least 3 minutes. After cooling, dilute with distilled water to 125 ml.



Filter off any residue and wash with hot 5% sulfuric acid until the washings are free from titanium as indicated by the hydrogen peroxide test, followed by 6 additional washings with hot water. Evaporate the filtrate to 150 to 200 ml. and determine the amount of titanium in the usual way as described on page 119.

**Rahn's Method:** The ash is transferred to the 500cc Erlenmeyer flask and is dissolved and reduced as described under Rahn's Method on page 123.

**Colorimetric Method:** The following method while less accurate than the reduction-titration method may be used with reasonable success, provided care is taken in maintaining fairly dilute solutions and in maintaining the titer of the standard solution.

The method involves the use of a standard solution of titanium dioxide which is prepared as follows: To 0.1 gram of titanium dioxide are added 20 ml of concentrated sulfuric acid to which has been added 10 grams of ammonium sulfate, and the mixture is boiled until solution is complete. After cooling, the solution is diluted to 200 ml. with 5% sulfuric acid. The solution is standardized by reduction of a known volume and subsequent titration (see page 119).

The unknown is prepared in much the same way as for the reduction-titration method as follows: The ash of a 2 gram sample is dissolved by vigorous boiling in 20 ml. of concentrated sulfuric acid and 10 grams of ammonium sulfate. The solution is diluted, filtered, the residue is washed and the volume of the filtrate adjusted to exactly 100 ml.

To 1 ml. of the sample solution, in a 100 ml. Nessler tube, 2 ml. of 3% hydrogen peroxide (U.S.P.), 20 ml. of 5% sulfuric acid are added and diluted with distilled water to 100 ml. To another tube 2 ml. of hydrogen peroxide (U.S.P.), 20 ml. of 5% sulfuric acid are added and diluted to 100 ml. with distilled water. To the second tube the standardized titanium dioxide from a burette is added until the color matches that developed by the sample.

**Colorimetric Method Involving Measurement of Transmission or Color:** The following method, like the preceding, utilizes the colored reaction product of titanium and hydrogen peroxide. It differs in that the color produced by the sample is measured, such as by its transmittance at a selected wavelength. The concentration of titanium dioxide in the sample is found from an established relationship between titanium dioxide concentration and transmittance of the titanium dioxide-hydrogen peroxide solution.

This method is applied to a sample containing 2% or less  $\text{TiO}_2$  and requires a spectrophotometer or other instrument suitable for measuring the transmission of light by solutions.

**Calibration of the Instrument:** The instrument is calibrated as follows:

A solution of known titanium dioxide content is prepared by dissolving 0.1 gram of standard titanium dioxide (National Bureau of Standards standard sample No. 154 of titanium dioxide) in 35 ml. of  $\text{H}_2\text{SO}_4$  (Sp. Gr. 1.84) and 10 gm.  $(\text{NH}_4)_2\text{SO}_4$ . To the resulting solution, 90 ml. water is added followed by filtering through a fine-texture paper\* into a 200 ml. volumetric flask. The contents are cooled, diluted to volume and mixed. This titanium solution thus has a concentration of 0.5 mg.  $\text{TiO}_2$  per ml. It is diluted to a range of concentrations as follows: 5, 10, 15, 20, 25 and 30 ml. portions are transferred to 100 ml. volumetric flasks and to each is added 20 ml.  $\text{H}_2\text{SO}_4$  (1:1), 15 ml. of  $\text{H}_2\text{O}_2$  (3 percent), then diluted to volume and mixed. The transmittance at 420  $\mu$  of each of these solutions, utilizing a  $\frac{1}{2}$  cm. cell is measured. The transmittance is plotted against the concentration of  $\text{TiO}_2$  on semi-log paper, using the linear scale for the concentration of  $\text{TiO}_2$ . A line is drawn through the plotted points.

**Procedure:** A sample of paper ash<sup>(1)</sup> is weighed to the nearest 0.0001 g. into a 250 ml. beaker. 7 to 9 grams of  $(\text{NH}_4)_2\text{SO}_4$  and 20 ml. concentrated  $\text{H}_2\text{SO}_4$  are then added, mixed well and heated on hot plate until fumes of  $\text{H}_2\text{SO}_4$  are evolved. The heating is then continued over a strong flame until solution is complete (usually not over 5 minutes of boiling), or it is apparent that the residue is composed of  $\text{SiO}_2$  or siliceous matter. The solution is cooled and with extreme caution 50 ml. of water is added<sup>(2)</sup>. Any insoluble matter

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is filtered off through a fine-texture paper\* and is washed with 5 ml. water. The filtrate is transferred to a 100 ml. volumetric flask. 15 ml. of  $H_2O_2$  (3%) is added, the whole diluted to volume and mixed. The color develops immediately.

The transmission at 420 millimicrons of a  $\frac{1}{2}$  cm. cell is measured. From the calibration curve, obtained as described above, the  $TiO_2$  content is read as grams of  $TiO_2$ . From this, the percentage of  $TiO_2$  in the sample is calculated from the weight of the sample used.

### Spectrographic and Photometric Methods of Analysis

Titanium Pigment Corporation pioneered the application of the spectrograph to the chemical analysis of titanium products. Many years of painstaking research resulted in standards and procedures leading to the most reliable results in the analysis of ores, compounds and pigments.

The reduction of the presence in pigment of harmful amounts of trace elements such as chromium, manganese and copper and the efficient control of additives are some of the benefits gained from early application of spectrographic methods.

The x-ray spectrograph too was early employed in research and then as the basis for control of the crystal structure of Titanox pigments.

Flame photometry was early adopted for the determination and control of those substances for which it is best suited as a means of detection and determination.

\* Detail requirements for filter paper are given in the Specifications for Filter Paper for Use in Chemical Analysis (ASTM Designation D 1100).

- (1) If the sample contains less than 1%  $TiO_2$ , it is possible to ash 1 gram of paper in a platinum crucible, after which the ash may be transferred quantitatively to the 250 ml. beaker.
- (2) If the ash is to be dissolved completely, it is fused in a platinum crucible with 8 grams of anhydrous sodium carbonate ( $Na_2CO_3$ ) for one hour at 900°C. The crucible and melt are cooled, transferred to a 250 ml. beaker, 40 ml. of water and 70 ml. HCl are added to dissolve the melt. When solution is complete, the crucible and cover are removed, and the solution evaporated to a volume of 75 ml. As described above, hydrogen peroxide is added with dilution, and transmittance is measured.

### PART V—USEFUL TABLES

TABLE No. A-1

#### Some Units and Conversion Factors

|                                             |                                                                   |
|---------------------------------------------|-------------------------------------------------------------------|
| Acceleration of Gravity                     | .980,665 cm./sec./sec.                                            |
| Angstrom Unit                               | $3.937 \times 10^{-8}$ inch;<br>.003937 millionths of an inch     |
| Barrel (bbl.)<br>(U.S. liquid)              | 31.5 gallons                                                      |
| Centimeter (cm.)                            | .039370 inch                                                      |
| Cubic centimeter (cm <sup>3</sup> )<br>(cc) | .0033814 fluid ounces                                             |
| Degree Fahrenheit (°F)                      | 1.8°C. + 32                                                       |
| Gallon (U.S.)                               | .83268 Brit. gal.<br>231 cubic inches<br>3.7853 liters            |
| Gallon (Imperial)<br>(Brit. Can.)           | 1.20094 U.S. gal.                                                 |
| Gram (g.)                                   | .00220462 lb. (avoir.)                                            |
| Inch (in.) U.S.                             | 1000 mils<br>2.540005 cm.                                         |
| Kilogram (Kg.)                              | 2.2046223 lb. (avoir.)                                            |
| Liter (l)                                   | .026417762 U.S. gal.                                              |
| Micron ( $\mu$ )                            | $3.937 \times 10^{-4}$ inch<br>$1 \times 10^{-4}$ cm.<br>.001 mm. |
| Milliliter (ml.)                            | usually 1 cc.                                                     |
| Millimicron ( $m\mu$ )                      | 10 Angstrom Units<br>0.001 micron<br>$1 \times 10^{-4}$ cm.       |
| Ounce, fluid (U.S.)                         | 1/128 gal. (U.S.)<br>(fl. oz.) .295729 ml.                        |
| Poise                                       | 1.00 gm./cm./sec.                                                 |
| Pound (avoir.) (lb.)                        | 453.5924 grams                                                    |
| Pounds per cu. ft.                          | .016018 gm./cc.                                                   |
| Pounds per gallon<br>(U.S.)                 | .0119826 gm./cc.                                                  |
| Pounds per gallon<br>(Brit.)                | .099776 gm./cc.                                                   |
| Ream                                        | 500 Sheets                                                        |
| Velocity of Light                           | $2.9986 \times 10^{10}$ cm. per sec.                              |

TABLE No. A-2

Temperature  
Centigrade to Fahrenheit

| °C. | °F. | °C. | °F.  | °C.  | °F.  | °C.  | °F.  | °C. | °F. |
|-----|-----|-----|------|------|------|------|------|-----|-----|
| -50 | -58 | 250 | 482  | 650  | 1202 | 1050 | 1922 |     |     |
| -40 | -40 | 260 | 500  | 660  | 1220 | 1060 | 1940 |     |     |
| -30 | -22 | 270 | 518  | 670  | 1238 | 1070 | 1958 |     |     |
| -20 | -4  | 280 | 536  | 680  | 1256 | 1080 | 1976 |     |     |
| -10 | 14  | 290 | 554  | 690  | 1274 | 1090 | 1994 |     |     |
| 0   | 32  | 300 | 572  | 700  | 1292 | 1100 | 2012 |     |     |
| 5   | 41  | 310 | 590  | 710  | 1310 | 1110 | 2030 |     |     |
| 10  | 50  | 320 | 608  | 720  | 1328 | 1120 | 2048 |     |     |
| 15  | 59  | 330 | 626  | 730  | 1346 | 1130 | 2066 |     |     |
| 20  | 68  | 340 | 644  | 740  | 1364 | 1140 | 2084 |     |     |
| 25  | 77  | 350 | 662  | 750  | 1382 | 1150 | 2102 |     |     |
| 30  | 86  | 360 | 680  | 760  | 1400 | 1160 | 2120 |     |     |
| 35  | 95  | 370 | 698  | 770  | 1418 | 1170 | 2138 |     |     |
| 40  | 104 | 380 | 716  | 780  | 1436 | 1180 | 2156 |     |     |
| 45  | 113 | 390 | 734  | 790  | 1454 | 1190 | 2174 |     |     |
| 50  | 122 | 400 | 752  | 800  | 1472 | 1200 | 2192 |     |     |
| 55  | 131 | 410 | 770  | 810  | 1490 | 1210 | 2210 |     |     |
| 60  | 140 | 420 | 788  | 820  | 1508 | 1220 | 2228 |     |     |
| 65  | 149 | 430 | 806  | 830  | 1526 | 1230 | 2246 |     |     |
| 70  | 158 | 440 | 824  | 840  | 1544 | 1240 | 2264 |     |     |
| 75  | 167 | 450 | 842  | 850  | 1562 | 1250 | 2282 |     |     |
| 80  | 176 | 460 | 860  | 860  | 1580 | 1260 | 2300 |     |     |
| 85  | 185 | 470 | 878  | 870  | 1598 | 1270 | 2318 |     |     |
| 90  | 194 | 480 | 896  | 880  | 1616 | 1280 | 2336 |     |     |
| 95  | 203 | 490 | 914  | 890  | 1634 | 1290 | 2354 |     |     |
| 100 | 212 | 500 | 932  | 900  | 1652 | 1300 | 2372 |     |     |
| 110 | 230 | 510 | 950  | 910  | 1670 | 1310 | 2392 |     |     |
| 120 | 248 | 520 | 968  | 920  | 1688 | 1320 | 2408 |     |     |
| 130 | 266 | 530 | 986  | 930  | 1706 | 1330 | 2426 |     |     |
| 140 | 284 | 540 | 1004 | 940  | 1724 | 1340 | 2444 |     |     |
| 150 | 302 | 550 | 1022 | 950  | 1742 | 1350 | 2462 |     |     |
| 160 | 320 | 560 | 1040 | 960  | 1760 | 1360 | 2480 |     |     |
| 170 | 338 | 570 | 1058 | 970  | 1778 | 1370 | 2498 |     |     |
| 180 | 356 | 580 | 1076 | 980  | 1796 | 1380 | 2516 |     |     |
| 190 | 374 | 590 | 1094 | 990  | 1814 | 1390 | 2534 |     |     |
| 200 | 392 | 600 | 1112 | 1000 | 1832 | 1400 | 2552 |     |     |
| 210 | 410 | 610 | 1130 | 1010 | 1850 | 1410 | 2570 |     |     |
| 220 | 428 | 620 | 1148 | 1020 | 1868 | 1420 | 2588 |     |     |
| 230 | 446 | 630 | 1166 | 1030 | 1886 | 1430 | 2606 |     |     |
| 240 | 464 | 640 | 1184 | 1040 | 1904 | 1440 | 2624 |     |     |

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TABLE No. A-3

End Point of Some Standard Pyrometric Cones  
(Heating Rate 302°F. per hour)

| Cone No. | End Point | Cone No. | End Point |
|----------|-----------|----------|-----------|
| 022      | 1121      | 1        | 2120      |
| 021      | 1139      | 2        | 2129      |
| 020      | 1202      | 3        | 2138      |
| 019      | 1220      | 4        | 2174      |
| 018      | 1328      | 5        | 2201      |
| 017      | 1418      | 6        | 2246      |
| 016      | 1463      | 7        | 2282      |
| 015      | 1481      | 8        | 2300      |
| 014      | 1526      | 9        | 2345      |
| 013      | 1580      | 10       | 2381      |
| 012      | 1607      | 11       | 2417      |
| 011      | 1661      | 12       | 2435      |
| 010      | 1642      | 13       | 2462      |
| 09       | 1706      | 14       | 2552      |
| 08       | 1742      | 15       | 2615      |
| 07       | 1814      | 16       | 2669      |
| 06       | 1859      | 17       | 2687      |
| 05       | 1904      | 18       | 2714      |
| 04       | 1940      | 19       | 2768      |
| 03       | 2039      | 20       | 2786      |
| 02       | 2057      |          |           |
| 01       | 2093      |          |           |

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TABLE No. A-4

U. S. Standard Gage for Sheet Iron and Steel

| No. of Gage | Thickness—Inches<br>Approx.<br>Fraction of an inch | Approx.<br>Inches | Oz. Av.<br>per Sq. Ft. | Pounds Av.<br>per Sq. Ft. |
|-------------|----------------------------------------------------|-------------------|------------------------|---------------------------|
| 000         | 3/8                                                | 0.375             | 240                    | 15.00                     |
| 00          |                                                    | 0.344             | 220                    | 13.75                     |
| 0           | 5/16                                               | 0.313             | 200                    | 12.50                     |
| 1           |                                                    | 0.281             | 180                    | 11.25                     |
| 2           |                                                    | 0.266             | 170                    | 10.63                     |
| 3           | 1/4                                                | 0.250             | 160                    | 10.00                     |
| 4           |                                                    | 0.234             | 150                    | 9.38                      |
| 5           |                                                    | 0.219             | 140                    | 8.75                      |
| 6           |                                                    | 0.203             | 130                    | 8.13                      |
| 7           | 3/16                                               | 0.188             | 120                    | 7.50                      |
| 8           |                                                    | 0.172             | 110                    | 6.88                      |
| 9           |                                                    | 0.156             | 100                    | 6.25                      |
| 10          |                                                    | 0.141             | 90                     | 5.63                      |
| 11          | 1/8                                                | 0.125             | 80                     | 5.00                      |
| 12          |                                                    | 0.109             | 70                     | 4.38                      |
| 13          |                                                    | 0.094             | 60                     | 3.75                      |
| 14          |                                                    | 0.078             | 50                     | 3.13                      |
| 15          |                                                    | 0.070             | 45                     | 2.81                      |
| 16          | 1/16                                               | 0.063             | 40                     | 2.50                      |
| 17          |                                                    | 0.056             | 36                     | 2.25                      |
| 18          |                                                    | 0.050             | 32                     | 2.00                      |
| 19          |                                                    | 0.044             | 28                     | 1.75                      |
| 20          |                                                    | 0.038             | 24                     | 1.50                      |
| 21          |                                                    | 0.034             | 22                     | 1.38                      |
| 22          | 1/32                                               | 0.031             | 20                     | 1.25                      |
| 23          |                                                    | 0.028             | 18                     | 1.13                      |
| 24          |                                                    | 0.025             | 16                     | 1.00                      |
| 25          |                                                    | 0.022             | 14                     | 0.88                      |
| 26          |                                                    | 0.019             | 12                     | 0.75                      |
| 27          |                                                    | 0.017             | 11                     | 0.69                      |
| 28          | 1/64                                               | 0.016             | 10                     | 0.63                      |
| 29          |                                                    | 0.014             | 9                      | 0.56                      |
| 30          |                                                    | 0.013             | 8                      | 0.50                      |

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TABLE No. A-5

Approximate Data on Sieves of the Standard

Screen Scale

| Sieve No. | Sieve Opening<br>mm. | Sieve Opening<br>in. | Wire<br>Diameter<br>mm. | Wire<br>Diameter<br>in. | Mesh<br>per cm. | Mesh<br>per inch |
|-----------|----------------------|----------------------|-------------------------|-------------------------|-----------------|------------------|
| 2 1/2     | 8.00                 | .315                 | 1.85                    | .073                    | 1               | 2.6              |
| 3         | 6.72                 | .265                 | 1.65                    | .065                    | 1.2             | 3.0              |
| 3 1/2     | 5.66                 | .223                 | 1.45                    | .057                    | 1.4             | 3.6              |
| 4         | 4.76                 | .187                 | 1.27                    | .050                    | 1.7             | 4.2              |
| 5         | 4.00                 | .157                 | 1.12                    | .044                    | 2               | 5.0              |
| 6         | 3.36                 | .132                 | 1.02                    | .040                    | 2.3             | 5.8              |
| 7         | 2.83                 | .111                 | .92                     | .036                    | 2.7             | 6.8              |
| 8         | 2.38                 | .094                 | .84                     | .033                    | 3               | 7.9              |
| 10        | 2.00                 | .079                 | .76                     | .030                    | 3.5             | 9.2              |
| 12        | 1.68                 | .066                 | .69                     | .027                    | 4               | 10.8             |
| 14        | 1.41                 | .0557                | .61                     | .024                    | 5               | 12.5             |
| 16        | 1.19                 | .0468                | .54                     | .021                    | 6               | 14.7             |
| 18        | 1.00                 | .0394                | .48                     | .0187                   | 7               | 17.2             |
| 20        | .84                  | .0331                | .42                     | .0165                   | 8               | 20.2             |
| 25        | .71                  | .0278                | .37                     | .0146                   | 9               | 23.6             |
| 30        | .59                  | .0234                | .33                     | .0129                   | 11              | 27.5             |
| 35        | .50                  | .0197                | .29                     | .0113                   | 13              | 32.3             |
| 40        | .42                  | .0166                | .25                     | .0098                   | 15              | 37.9             |
| 45        | .35                  | .0139                | .22                     | .0085                   | 18              | 44.7             |
| 50        | .30                  | .0117                | .188                    | .0074                   | 20              | 52.4             |
| 60        | .25                  | .0098                | .162                    | .0064                   | 24              | 61.7             |
| 70        | .21                  | .0083                | .140                    | .0055                   | 29              | 72.5             |
| 80        | .177                 | .0070                | .119                    | .0047                   | 34              | 85.5             |
| 100       | .149                 | .0059                | .102                    | .0040                   | 40              | 101              |
| 120       | .125                 | .0049                | .086                    | .0034                   | 47              | 120              |
| 140       | .105                 | .0041                | .074                    | .0029                   | 56              | 143              |
| 170       | .088                 | .0035                | .063                    | .0025                   | 66              | 167              |
| 200       | .074                 | .0029                | .053                    | .0021                   | 79              | 200              |
| 230       | .062                 | .0025                | .046                    | .0018                   | 93              | 233              |
| 270       | .053                 | .0021                | .041                    | .0016                   | 106             | 270              |
| 325       | .044                 | .0017                | .036                    | .0014                   | 125             | 323              |

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TABLE No. A-6

| Correlation of Viscosity |                         |                           |        | Libro<br>Ink Stat.<br>Gardner |
|--------------------------|-------------------------|---------------------------|--------|-------------------------------|
| Gardner<br>Holt<br>Tube  | Second<br># Ford<br>Cup | Second<br>Gardner<br>Holt | Stokes |                               |
| A                        | 20                      |                           | 0.50   |                               |
| B                        | 26                      |                           | 0.65   |                               |
| C                        | 34                      |                           | 0.85   |                               |
| D                        | 40                      |                           | 1.00   |                               |
| E                        | 46                      | 1.46                      | 1.25   |                               |
| F                        | 51                      | 1.83                      | 1.40   |                               |
| G                        | 57                      | 2.05                      | 1.65   |                               |
| G-H                      | 60                      | 2.42                      | 1.80   | 000                           |
| H                        | 65                      | 2.64                      | 2.00   |                               |
| I                        | 65                      | 2.93                      | 2.25   |                               |
| J                        | 75                      | 3.30                      | 2.50   |                               |
| K                        | 85                      | 3.67                      | 2.75   |                               |
| L                        | 96                      | 4.03                      | 3.00   |                               |
| M                        | 108                     | 4.40                      | 3.20   |                               |
| N                        | 117                     | 4.70                      | 3.40   |                               |
| O                        | 123                     | 5.00                      | 3.70   |                               |
| P                        | 127                     | 5.40                      | 4.00   |                               |
| Q                        | 131                     | 5.80                      | 4.35   |                               |
| R                        | 137                     | 6.40                      | 4.70   |                               |
| R+                       | 144                     | 6.90                      | 4.80   |                               |
| S                        | 147                     | 7.03                      | 5.00   | 00                            |
| T                        | 154                     | 7.30                      | 5.50   |                               |
| U                        | 166                     | 8.10                      | 6.27   |                               |
| U-V                      |                         | 9.20                      | 8.00   | 0                             |
| V                        |                         | 11.60                     | 8.84   |                               |
| W                        |                         | 13.00                     | 10.70  |                               |
| X                        |                         | 15.70                     | 12.90  |                               |
| X+                       |                         | 18.90                     | 14.40  | 1                             |
| Y                        |                         | 21.10                     | 17.60  |                               |
| Z                        |                         | 25.80                     | 22.70  |                               |
| Z+                       |                         | 33.30                     | 23.50  | 2                             |
| Z1                       |                         | 35.00                     | 27.00  |                               |
|                          |                         | 39.60                     | 34.00  | 3                             |
| Z2                       |                         | 53.10                     | 36.20  |                               |
| Z3                       |                         | 67.90                     | 46.30  | 4                             |
|                          |                         |                           | 62.1   |                               |
| Z4                       |                         | 93.00                     | 63.40  |                               |
| Z5                       |                         | 144.50                    | 98.50  | 5                             |
| Z6                       |                         | 217.10                    | 120.00 |                               |
|                          |                         |                           | 148.00 |                               |
|                          |                         |                           | 200.00 | 6                             |

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TABLE No. A-7

## Mohs' Scale of Scratch Hardness

| No. |            |
|-----|------------|
| 1   | Talc       |
| 2   | Gypsum     |
| 3   | Calcite    |
| 4   | Fluorite   |
| 5   | Apatite    |
| 6   | Orthoclase |
| 7   | Quartz     |
| 8   | Topaz      |
| 9   | Corundum   |
| 10  | Diamond    |

Some Knoop Hardness Numberst compared with

## Mohs' Scale

| Material                                                     | Knoop<br>Hardness | Mohs'   |
|--------------------------------------------------------------|-------------------|---------|
| Flint glass .....                                            | 200-40            | 4.5-5.5 |
| Apatite .....                                                | 365-430           | 5       |
| Crown glass .....                                            | 420-470           | 5.5-5.8 |
| Moonstone (feldspar) .....                                   | 490-560           | 6       |
| Strontium Titanate<br>(SrTiO <sub>3</sub> single crystal) .. | 595               | 6-6.5   |
| Rutile (TiO <sub>2</sub> single crystal)                     | 670               | 6.5-7.0 |
| Amethyst .....                                               | 710-790           | 7       |
| Topaz .....                                                  | 1250-1650         | 8       |
| Sapphire (corundum) .....                                    | 1600-2200         | 9       |
| Silicon carbide .....                                        | 2130-2140         | 9.1     |
| Boron Carbide .....                                          | 2250-2800         | 9.2     |
| Diamond .....                                                | 6000-6500         | 10      |

$$\text{Knoop Hardness Number} = \frac{L}{Cp} = \frac{\text{Kg./mm}^2}{\text{mm}}$$

where L = Load in kilograms

I = Length in mm. of long diagonal  
of indentation patternCp = Constant of instrument (Knoop  
Indenter)

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TABLE No. A-8

## Color

## Correlation of Liquid Color Standards

| Grams<br>K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub><br>per 100 cc.<br>H <sub>2</sub> SO <sub>4</sub> | Gardner<br>Stand-<br>ards<br>1933 | Hellige<br>Com-<br>parator | Rottn<br>Stand-<br>ards |
|---------------------------------------------------------------------------------------------------------|-----------------------------------|----------------------------|-------------------------|
| 0.0039                                                                                                  | 1                                 | -1                         | X                       |
| 0.0048                                                                                                  | 2                                 | -1                         | WV                      |
| 0.0071                                                                                                  | 3                                 | -1                         | W-WG                    |
| 0.0112                                                                                                  | 4                                 | -1                         | WG                      |
| 0.0205                                                                                                  | 5                                 | 1L                         | N                       |
| 0.0322                                                                                                  | 6                                 | 1-2L                       | M-K                     |
| 0.0384                                                                                                  | 7                                 | 2                          | M                       |
| 0.0449                                                                                                  | 7-8                               | 2-3L                       | I                       |
| 0.0515                                                                                                  | 8                                 | 3L                         | H                       |
| 0.0780                                                                                                  | 9                                 | 3                          | G                       |
| 0.1210                                                                                                  | 1-10                              | 3-4                        | F                       |
| 0.1640                                                                                                  | 10                                | 4                          | E                       |
| 0.2070                                                                                                  | 10-11                             | 4-5L                       | D                       |
| 0.2500                                                                                                  | 11                                | 5L                         |                         |
| 0.3800                                                                                                  | 12                                | 5                          |                         |
| 0.5720                                                                                                  | 13                                | 6                          |                         |
| 0.7630                                                                                                  | 14                                | 7L                         |                         |
| 1.0410                                                                                                  | 15                                | 7                          |                         |
| 1.2800                                                                                                  | 16                                | 8L                         |                         |
| 2.2200                                                                                                  | 17                                | 8                          |                         |
| 3.0000                                                                                                  | 18                                | 9L                         |                         |

TABLE No. A-9

## Paper

## Basis Weight Conversion Factors

| Basis                       | To Convert From Weight from<br>25 x 40 — 500 Basis to Basis<br>Shown in Opposite Column,<br>Multiply by: |
|-----------------------------|----------------------------------------------------------------------------------------------------------|
| 25 x 40 — 500.....          | 1.000                                                                                                    |
| 25 x 38 — 500.....          | 0.950                                                                                                    |
| 24 x 36 — 500.....          | 0.864                                                                                                    |
| 24 x 36 — 480.....          | 0.829                                                                                                    |
| 22 x 34 — 500.....          | 0.748                                                                                                    |
| 20 x 30 — 500.....          | 0.600                                                                                                    |
| 20 x 30 — 480.....          | 0.576                                                                                                    |
| 17 x 22 — 500.....          | 0.374                                                                                                    |
| Pounds per 1000 Sq. Ft..... | 0.288                                                                                                    |
| Grams per Sq. Meter.....    | 1.406                                                                                                    |



TABLE No. B-1

Specific Gravity, Pound per Gallon (U. S.) and Gallons (U. S.) per Pound at 77°F.

Where 8.32 is weight in pounds of one U. S. gallon of water at 77°F.

Pounds per Gallon = Specific Gravity x 8.32

Gallons per Pound =  $\frac{1}{\text{Pounds per Gallon}}$

Specific Gravity =  $\frac{\text{Pounds per Gallon}}{8.32}$

Specific Gravity =  $\frac{\text{Gallons per Pound} \times 8.32}{1}$

To express the values in the following table on the basis of Imperial gallons (British and Canadian)

Multiply Pounds per Gallon (U. S.) by 1.2009

Multiply Gallons (U. S.) per Pound by .8327

| Specific Gravity (U.S.) | Pounds per Gallon (U.S.) | Gallons (U.S.) per Pound | Specific Gravity (U.S.) | Pounds per Gallon (U.S.) | Gallons (U.S.) per Pound |
|-------------------------|--------------------------|--------------------------|-------------------------|--------------------------|--------------------------|
| .70                     | 5.824                    | .1717                    | .89                     | 7.405                    | .1350                    |
| .71                     | 5.907                    | .1693                    | .90                     | 7.488                    | .1335                    |
| .72                     | 5.990                    | .1669                    | .91                     | 7.571                    | .1321                    |
| .73                     | 6.074                    | .1646                    | .92                     | 7.654                    | .1306                    |
| .74                     | 6.157                    | .1624                    | .93                     | 7.738                    | .1292                    |
| .75                     | 6.240                    | .1603                    | .94                     | 7.821                    | .1279                    |
| .76                     | 6.323                    | .1581                    | .95                     | 7.904                    | .1265                    |
| .77                     | 6.406                    | .1561                    | .96                     | 7.987                    | .1252                    |
| .78                     | 6.489                    | .1541                    | .97                     | 8.070                    | .1239                    |
| .79                     | 6.573                    | .1521                    | .98                     | 8.154                    | .1226                    |
| .80                     | 6.656                    | .1502                    | .99                     | 8.237                    | .1214                    |
| .81                     | 6.739                    | .1484                    | 1.00                    | 8.32                     | .1202                    |
| .82                     | 6.822                    | .1466                    | 1.02                    | 8.49                     | .1178                    |
| .83                     | 6.906                    | .1448                    | 1.04                    | 8.65                     | .1156                    |
| .84                     | 6.989                    | .1431                    | 1.06                    | 8.82                     | .1134                    |
| .85                     | 7.072                    | .1414                    | 1.08                    | 8.99                     | .1112                    |
| .86                     | 7.155                    | .1398                    | 1.10                    | 9.15                     | .1093                    |
| .87                     | 7.238                    | .1382                    | 1.12                    | 9.32                     | .1073                    |
| .88                     | 7.322                    | .1366                    | 1.14                    | 9.48                     | .1055                    |

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TABLE No. B-1 (Continued)

| Specific Gravity (U.S.) | Pounds per Gallon (U.S.) | Gallons (U.S.) per Pound | Specific Gravity (U.S.) | Pounds per Gallon (U.S.) | Gallons (U.S.) per Pound |
|-------------------------|--------------------------|--------------------------|-------------------------|--------------------------|--------------------------|
| 1.16                    | 9.65                     | .1036                    | 1.18                    | 9.82                     | .1018                    |
| 1.18                    | 9.98                     | .1002                    | 1.20                    | 10.15                    | .0985                    |
| 1.20                    | 10.32                    | .0969                    | 1.22                    | 10.48                    | .0954                    |
| 1.22                    | 10.65                    | .0937                    | 1.24                    | 10.82                    | .0924                    |
| 1.24                    | 10.98                    | .0910                    | 1.26                    | 11.15                    | .0896                    |
| 1.26                    | 11.32                    | .0883                    | 1.28                    | 11.48                    | .0871                    |
| 1.30                    | 11.65                    | .0858                    | 1.32                    | 11.98                    | .0834                    |
| 1.32                    | 12.02                    | .0834                    | 1.34                    | 12.31                    | .0812                    |
| 1.34                    | 12.35                    | .0801                    | 1.36                    | 12.65                    | .0790                    |
| 1.36                    | 12.68                    | .0780                    | 1.38                    | 12.98                    | .0770                    |
| 1.40                    | 13.01                    | .0751                    | 1.42                    | 13.31                    | .0742                    |
| 1.42                    | 13.34                    | .0724                    | 1.44                    | 13.64                    | .0724                    |
| 1.44                    | 13.67                    | .0715                    | 1.46                    | 13.98                    | .0707                    |
| 1.46                    | 14.01                    | .0698                    | 1.48                    | 14.31                    | .0690                    |
| 1.48                    | 14.34                    | .0682                    | 1.50                    | 14.64                    | .0675                    |
| 1.50                    | 14.67                    | .0667                    | 1.52                    | 14.98                    | .0660                    |
| 1.52                    | 15.01                    | .0653                    | 1.54                    | 15.31                    | .0646                    |
| 1.54                    | 15.34                    | .0639                    | 1.56                    | 15.64                    | .0639                    |
| 1.56                    | 15.67                    | .0632                    | 1.58                    | 15.97                    | .0626                    |
| 1.60                    | 16.00                    | .0619                    | 1.62                    | 16.31                    | .0613                    |
| 1.62                    | 16.34                    | .0607                    | 1.64                    | 16.64                    | .0607                    |
| 1.64                    | 16.67                    | .0600                    | 1.66                    | 16.97                    | .0595                    |
| 1.66                    | 17.01                    | .0588                    | 1.68                    | 17.31                    | .0583                    |
| 1.68                    | 17.34                    | .0577                    | 1.70                    | 17.64                    | .0572                    |
| 1.70                    | 17.67                    | .0566                    | 1.72                    | 17.97                    | .0561                    |
| 1.72                    | 18.01                    | .0555                    | 1.74                    | 18.30                    | .0551                    |
| 1.74                    | 18.34                    | .0544                    | 1.76                    | 18.64                    | .0541                    |
| 1.76                    | 18.67                    | .0536                    | 1.78                    | 18.97                    | .0536                    |
| 1.78                    | 19.01                    | .0527                    | 1.80                    | 19.31                    | .0531                    |
| 1.80                    | 19.34                    | .0522                    | 1.82                    | 19.64                    | .0522                    |
| 1.82                    | 19.67                    | .0511                    | 1.84                    | 19.97                    | .0511                    |
| 1.84                    | 20.01                    | .0500                    | 1.86                    | 20.31                    | .0500                    |
| 1.86                    | 20.34                    | .0490                    | 1.88                    | 20.64                    | .0490                    |
| 1.88                    | 20.67                    | .0480                    | 1.90                    | 20.97                    | .0480                    |
| 1.90                    | 21.01                    | .0471                    | 1.92                    | 21.31                    | .0471                    |
| 1.92                    | 21.34                    | .0462                    | 1.94                    | 21.64                    | .0462                    |
| 1.94                    | 21.67                    | .0453                    | 1.96                    | 21.97                    | .0453                    |
| 1.96                    | 22.01                    | .0445                    | 1.98                    | 22.31                    | .0445                    |
| 1.98                    | 22.34                    | .0437                    | 2.00                    | 22.64                    | .0437                    |
| 2.00                    | 22.67                    | .0429                    | 2.02                    | 22.97                    | .0429                    |
| 2.02                    | 23.01                    | .0421                    | 2.04                    | 23.31                    | .0421                    |
| 2.04                    | 23.34                    | .0414                    | 2.06                    | 23.64                    | .0414                    |
| 2.06                    | 23.67                    | .0407                    | 2.08                    | 23.97                    | .0407                    |
| 2.08                    | 24.01                    | .0400                    | 2.10                    | 24.31                    | .0400                    |
| 2.10                    | 24.34                    | .0394                    | 2.12                    | 24.64                    | .0394                    |
| 2.12                    | 24.67                    | .0387                    | 2.14                    | 24.97                    | .0387                    |
| 2.14                    | 25.01                    | .0381                    | 2.16                    | 25.31                    | .0381                    |
| 2.16                    | 25.34                    | .0375                    | 2.18                    | 25.64                    | .0375                    |
| 2.18                    | 25.67                    | .0369                    | 2.20                    | 25.97                    | .0369                    |
| 2.20                    | 26.01                    | .0364                    | 2.22                    | 26.31                    | .0364                    |
| 2.22                    | 26.34                    | .0359                    | 2.24                    | 26.64                    | .0359                    |
| 2.24                    | 26.67                    | .0353                    | 2.26                    | 26.97                    | .0353                    |
| 2.26                    | 27.01                    | .0348                    | 2.28                    | 27.31                    | .0348                    |
| 2.28                    | 27.34                    | .0343                    | 2.30                    | 27.64                    | .0343                    |
| 2.30                    | 27.67                    | .0338                    | 2.32                    | 27.97                    | .0338                    |
| 2.32                    | 28.01                    | .0334                    | 2.34                    | 28.31                    | .0334                    |
| 2.34                    | 28.34                    | .0330                    | 2.36                    | 28.64                    | .0330                    |
| 2.36                    | 28.67                    | .0326                    | 2.38                    | 28.97                    | .0326                    |
| 2.38                    | 29.01                    | .0322                    | 2.40                    | 29.31                    | .0322                    |
| 2.40                    | 29.34                    | .0318                    | 2.42                    | 29.64                    | .0318                    |
| 2.42                    | 29.67                    | .0314                    | 2.44                    | 29.97                    | .0314                    |
| 2.44                    | 30.01                    | .0310                    | 2.46                    | 30.31                    | .0310                    |
| 2.46                    | 30.34                    | .0306                    | 2.48                    | 30.64                    | .0306                    |
| 2.48                    | 30.67                    | .0302                    | 2.50                    | 30.97                    | .0302                    |
| 2.50                    | 31.01                    | .0298                    | 2.52                    | 31.31                    | .0298                    |
| 2.52                    | 31.34                    | .0294                    | 2.54                    | 31.64                    | .0294                    |
| 2.54                    | 31.67                    | .0290                    | 2.56                    | 31.97                    | .0290                    |
| 2.56                    | 32.01                    | .0286                    | 2.58                    | 32.31                    | .0286                    |
| 2.58                    | 32.34                    | .0282                    | 2.60                    | 32.64                    | .0282                    |
| 2.60                    | 32.67                    | .0278                    | 2.62                    | 32.97                    | .0278                    |
| 2.62                    | 33.01                    | .0274                    | 2.64                    | 33.31                    | .0274                    |
| 2.64                    | 33.34                    | .0270                    | 2.66                    | 33.64                    | .0270                    |
| 2.66                    | 33.67                    | .0266                    | 2.68                    | 33.97                    | .0266                    |
| 2.68                    | 34.01                    | .0262                    | 2.70                    | 34.31                    | .0262                    |
| 2.70                    | 34.34                    | .0258                    | 2.72                    | 34.64                    | .0258                    |
| 2.72                    | 34.67                    | .0254                    | 2.74                    | 34.97                    | .0254                    |
| 2.74                    | 35.01                    | .0250                    | 2.76                    | 35.31                    | .0250                    |
| 2.76                    | 35.34                    | .0246                    | 2.78                    | 35.64                    | .0246                    |
| 2.78                    | 35.67                    | .0242                    | 2.80                    | 35.97                    | .0242                    |
| 2.80                    | 36.01                    | .0238                    | 2.82                    | 36.31                    | .0238                    |
| 2.82                    | 36.34                    | .0234                    | 2.84                    | 36.64                    | .0234                    |
| 2.84                    | 36.67                    | .0230                    | 2.86                    | 36.97                    | .0230                    |
| 2.86                    | 37.01                    | .0226                    | 2.88                    | 37.31                    | .0226                    |
| 2.88                    | 37.34                    | .0222                    | 2.90                    | 37.64                    | .0222                    |
| 2.90                    | 37.67                    | .0218                    | 2.92                    | 37.97                    | .0218                    |
| 2.92                    | 38.01                    | .0214                    | 2.94                    | 38.31                    | .0214                    |
| 2.94                    | 38.34                    | .0210                    | 2.96                    | 38.64                    | .0210                    |
| 2.96                    | 38.67                    | .0206                    | 2.98                    | 38.97                    | .0206                    |
| 2.98                    | 39.01                    | .0202                    | 3.00                    | 39.31                    | .0202                    |
| 3.00                    | 39.34                    | .0198                    | 3.02                    | 39.64                    | .0198                    |
| 3.02                    | 39.67                    | .0194                    | 3.04                    | 39.97                    | .0194                    |
| 3.04                    | 40.01                    | .0190                    | 3.06                    | 40.31                    | .0190                    |
| 3.06                    | 40.34                    | .0186                    | 3.08                    | 40.64                    | .0186                    |
| 3.08                    | 40.67                    | .0182                    | 3.10                    | 40.97                    | .0182                    |
| 3.10                    | 41.01                    | .0178                    | 3.12                    | 41.31                    | .0178                    |
| 3.12                    | 41.34                    | .0174                    | 3.14                    | 41.64                    | .0174                    |
| 3.14                    | 41.67                    | .0170                    | 3.16                    | 41.97                    | .0170                    |
| 3.16                    | 42.01                    | .0166                    | 3.18                    | 42.31                    | .0166                    |
| 3.18                    | 42.34                    | .0162                    | 3.20                    | 42.64                    | .0162                    |
| 3.20                    | 42.67                    | .0158                    | 3.22                    | 42.97                    | .0158                    |
| 3.22                    | 43.01                    | .0154                    | 3.24                    | 43.31                    | .0154                    |
| 3.24                    | 43.34                    | .0150                    | 3.26                    | 43.64                    | .0150                    |
| 3.26                    | 43.67                    | .0146                    | 3.28                    | 43.97                    | .0146                    |
| 3.28                    | 44.01                    | .0142                    | 3.30                    | 44.31                    | .0142                    |
| 3.30                    | 44.34                    | .0138                    | 3.32                    | 44.64                    | .0138                    |
| 3.32                    | 44.67                    | .0134                    | 3.34                    | 44.97                    | .0134                    |
| 3.34                    | 45.01                    | .0130                    | 3.36                    | 45.31                    | .0130                    |
| 3.36                    | 45.34                    | .0126                    | 3.38                    | 45.64                    | .0126                    |
| 3.38                    | 45.67                    | .0122                    | 3.40                    | 45.97                    | .0122                    |
| 3.40                    | 46.01                    | .0118                    | 3.42                    | 46.31                    | .0118                    |
| 3.42                    | 46.34                    | .0114                    | 3.44                    | 46.64                    | .0114                    |
| 3.44                    | 46.67                    | .0110                    | 3.46                    | 46.97                    | .0110                    |
| 3.46                    | 47.01                    | .0106                    | 3.48                    | 47.31                    | .0106                    |
| 3.48                    | 47.34                    | .0102                    | 3.50                    | 47.64                    | .0102                    |
| 3.50                    | 47.67                    | .0098                    | 3.52                    | 47.97                    | .0098                    |
| 3.52                    | 48.01                    | .0094                    | 3.54                    | 48.31                    | .0094                    |
| 3.54                    | 48.34                    | .0090                    | 3.56                    | 48.64                    | .0090                    |
| 3.56                    | 48.67                    | .0086                    | 3.58                    | 48.97                    | .0086                    |
| 3.58                    | 49.01                    | .0082                    | 3.60                    | 49.31                    | .0082                    |
| 3.60                    | 49.34                    | .0078                    |                         |                          |                          |

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**TABLE NO. B-2**

|                  | Pounds<br>Per<br>Gallon<br>(U.S.) | Specific<br>Gravity | Gallons<br>Per<br>Pound | Pounds<br>Per<br>Gallon<br>(U.S.) | Specific<br>Gravity | Gallons<br>Per<br>Pound |
|------------------|-----------------------------------|---------------------|-------------------------|-----------------------------------|---------------------|-------------------------|
| Specific Gravity |                                   |                     |                         |                                   |                     |                         |
| 3.65             | 30.37                             | .0329               | 6.4                     | 53.25                             | .0187               |                         |
| 3.70             | 30.78                             | .0324               | 6.5                     | 54.08                             | .0185               |                         |
| 3.75             | 31.20                             | .0320               | 6.6                     | 54.91                             | .0182               |                         |
| 3.80             | 31.62                             | .0316               | 6.7                     | 55.74                             | .0179               |                         |
| 3.85             | 32.03                             | .0312               | 6.8                     | 56.58                             | .0176               |                         |
| 3.90             | 32.45                             | .0308               | 6.9                     | 57.41                             | .0174               |                         |
| 3.95             | 32.86                             | .0304               | 7.0                     | 58.24                             | .0171               |                         |
| 4.0              | 33.28                             | .0300               | 7.1                     | 59.07                             | .0169               |                         |
| 4.1              | 34.11                             | .0293               | 7.2                     | 59.90                             | .0167               |                         |
| 4.2              | 34.94                             | .0286               | 7.3                     | 60.74                             | .0164               |                         |
| 4.3              | 35.78                             | .0279               | 7.4                     | 61.57                             | .0162               |                         |
| 4.4              | 36.61                             | .0273               | 7.5                     | 62.40                             | .0160               |                         |
| 4.5              | 37.44                             | .0267               | 7.6                     | 63.23                             | .0158               |                         |
| 4.6              | 38.27                             | .0261               | 7.7                     | 64.06                             | .0156               |                         |
| 4.7              | 39.10                             | .0255               | 7.8                     | 64.90                             | .0154               |                         |
| 4.8              | 39.94                             | .0250               | 7.9                     | 65.73                             | .0152               |                         |
| 4.9              | 40.77                             | .0245               | 8.0                     | 66.56                             | .0150               |                         |
| 5.0              | 41.60                             | .0240               | 8.1                     | 67.39                             | .0148               |                         |
| 5.1              | 42.43                             | .0235               | 8.2                     | 68.22                             | .0146               |                         |
| 5.2              | 43.26                             | .0231               | 8.3                     | 69.06                             | .0145               |                         |
| 5.3              | 44.10                             | .0226               | 8.4                     | 69.89                             | .0143               |                         |
| 5.4              | 44.93                             | .0222               | 8.5                     | 70.72                             | .0141               |                         |
| 5.5              | 45.76                             | .0218               | 8.6                     | 71.55                             | .0140               |                         |
| 5.6              | 46.59                             | .0214               | 8.7                     | 72.38                             | .0138               |                         |
| 5.7              | 47.42                             | .0211               | 8.8                     | 73.22                             | .0137               |                         |
| 5.8              | 48.26                             | .0207               | 8.9                     | 74.05                             | .0135               |                         |
| 5.9              | 49.09                             | .0203               | 9.0                     | 74.88                             | .0133               |                         |
| 6.0              | 49.92                             | .0200               | 9.1                     | 75.71                             | .0132               |                         |
| 6.1              | 50.75                             | .0197               | 9.2                     | 76.54                             | .0130               |                         |
| 6.2              | 51.58                             | .0194               | 9.3                     | 77.38                             | .0129               |                         |
| 6.3              | 52.42                             | .0190               | 9.4                     | 78.21                             | .0128               |                         |
|                  |                                   |                     | 9.5                     | 79.04                             | .0126               |                         |

Average Bulking Values  
of  
White Pigments and Extenders

|                                                | Pounds<br>per Gallon | Solid<br>Gallons<br>per Pound |
|------------------------------------------------|----------------------|-------------------------------|
| Titanox-RA (rutile TiO <sub>2</sub> )          | 34.99                | .0286                         |
| Titanox-A (anatase TiO <sub>2</sub> )          | 32.49                | .0308                         |
| Titanox-C-50 (50% TiO <sub>2</sub> )           | 28.94                | .0345                         |
| Titanox-RCHT and RC<br>(30% TiO <sub>2</sub> ) | 27.07                | .0369                         |
| Antimony Oxide                                 | 47.7                 | .0210                         |
| Basic Carbonate White Lead                     |                      |                               |
| Dutch Boy H.T.S.                               | 56.0                 | .0179                         |
| #111                                           | 57.0                 | .0175                         |
| Basic Lead Sulfate                             | 52.0                 | .0192                         |
| Basic Silicate White Lead                      | 48.3                 | .0207                         |
| White Lead, silica core                        |                      |                               |
| Dutch Boy 45X                                  | 33.3                 | .0300                         |
| Leaded Zinc Oxide, 5%                          | 46.9                 | .0213                         |
| Leaded Zinc Oxide, 10%                         | 47.5                 | .0211                         |
| Leaded Zinc Oxide, 35%                         | 49.0                 | .0204                         |
| Leaded Zinc Oxide, 50%                         | 49.5                 | .0202                         |
| Lithopone, regular                             | 35.8                 | .0279                         |
| Lithopone, "titanated"                         | 35.1                 | .0285                         |
| Zinc Oxide                                     | 47.0                 | .0213                         |
| Zinc Sulfide                                   | 33.2                 | .0301                         |
| Zirconium Oxide                                | 47.3                 | .0211                         |
| Aluminum hydrate                               | 20.4                 | .0490                         |
| Aluminum silicate                              | 21.6                 | .0462                         |
| Barium carbonate                               | 36.0                 | .0277                         |
| Blanc fixe (barium sulfate)                    | 36.32                | .0275                         |
| Barytes (barium sulfate)                       | 37.07                | .0270                         |
| Calcium carbonate (whiting)                    | 22.49                | .0445                         |
| Calcium silicate                               | 24.1                 | .0415                         |
| Calcium sulfate (gypsum)                       | 19.66                | .0509                         |
| Calcium sulfate (anhydrite)                    | 24.66                | .0405                         |
| Clay (kaolin)                                  | 21.66                | .0462                         |
| Diatomaceous silica                            | 19.24                | .0520                         |
| Magnesium carbonate                            | 15.08                | .0663                         |
| Magnesium silicate (Talc)                      | 23.74                | .0421                         |
| Mica                                           | 23.5                 | .0426                         |
| Silica                                         | 22.07                | .0453                         |

Table No. B-2A

Approximate Specific Gravity and Weight per Gallon  
of Titanium Dioxide Water Slurries

Anatase Titanium Dioxide — Sp. Gr. 3.9  
Pounds per Gallon 32.49  
(gallon per Pound 0.0308)

Rutile Titanium Dioxide — Sp. Gr. 4.2  
Pounds per Gallon 34.99  
(gallon per Pound 0.0286)

| Percent<br>Pb<br>If Right | Anatase | Rutile                          |                      |                             |                                 |                      |
|---------------------------|---------|---------------------------------|----------------------|-----------------------------|---------------------------------|----------------------|
|                           |         | Pigment<br>Lbs/Gal<br>of Slurry | Sp. Gr.<br>of Slurry | Slurry<br>Weight<br>Lbs/Gal | Pigment<br>Lbs/Gal<br>of Slurry | Sp. Gr.<br>of Slurry |
| 0                         | 0       | 1.000                           | 8.33                 | 0                           | 1.000                           | 8.33                 |
| 1                         | 0.084   | 1.008                           | 8.40                 | 0.084                       | 1.008                           | 8.40                 |
| 2                         | 0.17    | 1.016                           | 8.46                 | 0.17                        | 1.016                           | 8.46                 |
| 3                         | 0.26    | 1.023                           | 8.52                 | 0.26                        | 1.023                           | 8.52                 |
| 4                         | 0.34    | 1.031                           | 8.59                 | 0.34                        | 1.031                           | 8.59                 |
| 5                         | 0.43    | 1.039                           | 8.66                 | 0.43                        | 1.039                           | 8.66                 |
| 6                         | 0.52    | 1.047                           | 8.72                 | 0.52                        | 1.048                           | 8.73                 |
| 7                         | 0.62    | 1.054                           | 8.78                 | 0.62                        | 1.055                           | 8.79                 |
| 8                         | 0.71    | 1.063                           | 8.86                 | 0.71                        | 1.065                           | 8.87                 |
| 9                         | 0.80    | 1.072                           | 8.93                 | 0.80                        | 1.074                           | 8.95                 |
| 10                        | 0.90    | 1.080                           | 9.00                 | 0.90                        | 1.083                           | 9.02                 |
| 11                        | 1.00    | 1.090                           | 9.08                 | 1.00                        | 1.092                           | 9.10                 |
| 12                        | 1.10    | 1.098                           | 9.15                 | 1.10                        | 1.101                           | 9.17                 |
| 13                        | 1.20    | 1.107                           | 9.22                 | 1.20                        | 1.110                           | 9.25                 |
| 14                        | 1.30    | 1.112                           | 9.27                 | 1.31                        | 1.120                           | 9.33                 |
| 15                        | 1.41    | 1.125                           | 9.29                 | 1.42                        | 1.129                           | 9.41                 |
| 16                        | 1.51    | 1.135                           | 9.46                 | 1.52                        | 1.139                           | 9.49                 |
| 17                        | 1.62    | 1.145                           | 9.54                 | 1.63                        | 1.149                           | 9.57                 |
| 18                        | 1.72    | 1.155                           | 9.62                 | 1.73                        | 1.159                           | 9.66                 |
| 19                        | 1.84    | 1.164                           | 9.70                 | 1.85                        | 1.169                           | 9.74                 |
| 20                        | 1.96    | 1.175                           | 9.79                 | 1.97                        | 1.180                           | 9.83                 |
| 21                        | 2.07    | 1.185                           | 9.87                 | 2.08                        | 1.190                           | 9.92                 |
| 22                        | 2.19    | 1.196                           | 9.97                 | 2.20                        | 1.200                           | 10.00                |
| 23                        | 2.31    | 1.206                           | 10.05                | 2.32                        | 1.212                           | 10.10                |
| 24                        | 2.43    | 1.217                           | 10.14                | 2.44                        | 1.223                           | 10.19                |
| 25                        | 2.56    | 1.229                           | 10.24                | 2.57                        | 1.235                           | 10.29                |
| 26                        | 2.68    | 1.239                           | 10.32                | 2.70                        | 1.247                           | 10.39                |
| 27                        | 2.81    | 1.251                           | 10.42                | 2.83                        | 1.259                           | 10.49                |
| 28                        | 2.95    | 1.263                           | 10.52                | 2.97                        | 1.271                           | 10.60                |
| 29                        | 3.08    | 1.274                           | 10.62                | 3.10                        | 1.284                           | 10.70                |
| 30                        | 3.22    | 1.288                           | 10.73                | 3.24                        | 1.296                           | 10.80                |
| 31                        | 3.36    | 1.299                           | 10.82                | 3.38                        | 1.309                           | 10.91                |
| 32                        | 3.50    | 1.312                           | 10.93                | 3.53                        | 1.322                           | 11.02                |

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Table No. B-2A (Continued)

Titanium Dioxide Water Slurries

| Total Solids      | Titanium Dioxide Water Slurries |                   |                            |                   |                            |                   |
|-------------------|---------------------------------|-------------------|----------------------------|-------------------|----------------------------|-------------------|
| Pigment By Weight | Anatase                         |                   | Rutile                     |                   |                            |                   |
|                   | Pigment Lbs./Gal of Slurry      | Sp. Gr. of Slurry | Pigment Lbs./Gal of Slurry | Sp. Gr. of Slurry | Pigment Lbs./Gal of Slurry | Sp. Gr. of Slurry |
| 33                | 3.64                            | 1.326             | 11.05                      | 3.67              | 1.336                      | 11.13             |
| 34                | 3.79                            | 1.338             | 11.15                      | 3.82              | 1.349                      | 11.24             |
| 35                | 3.95                            | 1.352             | 11.27                      | 3.98              | 1.363                      | 11.36             |
| 36                | 4.10                            | 1.365             | 11.37                      | 4.13              | 1.378                      | 11.48             |
| 37                | 4.25                            | 1.379             | 11.49                      | 4.29              | 1.392                      | 11.60             |
| 38                | 4.41                            | 1.393             | 11.61                      | 4.46              | 1.407                      | 11.72             |
| 39                | 4.58                            | 1.408             | 11.73                      | 4.62              | 1.423                      | 11.86             |
| 40                | 4.74                            | 1.423             | 11.86                      | 4.79              | 1.438                      | 11.98             |
| 41                | 4.91                            | 1.438             | 11.98                      | 4.97              | 1.454                      | 12.12             |
| 42                | 5.09                            | 1.454             | 12.12                      | 5.15              | 1.471                      | 12.26             |
| 43                | 5.27                            | 1.470             | 12.25                      | 5.33              | 1.487                      | 12.39             |
| 44                | 5.45                            | 1.486             | 12.38                      | 5.51              | 1.504                      | 12.53             |
| 45                | 5.63                            | 1.502             | 12.52                      | 5.71              | 1.522                      | 12.68             |
| 46                | 5.83                            | 1.519             | 12.66                      | 5.90              | 1.539                      | 12.82             |
| 47                | 6.00                            | 1.531             | 12.76                      | 6.10              | 1.558                      | 12.98             |
| 48                | 6.22                            | 1.555             | 12.96                      | 6.31              | 1.576                      | 13.13             |
| 49                | 6.42                            | 1.573             | 13.11                      | 6.51              | 1.595                      | 13.29             |
| 50                | 6.63                            | 1.591             | 13.26                      | 6.74              | 1.616                      | 13.47             |
| 51                | 6.84                            | 1.611             | 13.42                      | 6.95              | 1.635                      | 13.62             |
| 52                | 7.06                            | 1.630             | 13.58                      | 7.18              | 1.658                      | 13.80             |
| 53                | 7.29                            | 1.650             | 13.75                      | 7.40              | 1.679                      | 13.99             |
| 54                | 7.51                            | 1.670             | 13.92                      | 7.64              | 1.699                      | 14.16             |
| 55                | 7.75                            | 1.692             | 14.10                      | 7.89              | 1.722                      | 14.35             |
| 56                | 7.99                            | 1.713             | 14.27                      | 8.14              | 1.744                      | 14.53             |
| 57                | 8.24                            | 1.735             | 14.46                      | 8.39              | 1.767                      | 14.72             |
| 58                | 8.46                            | 1.750             | 14.59                      | 8.62              | 1.783                      | 14.86             |
| 59                | 8.76                            | 1.781             | 14.84                      | 8.93              | 1.816                      | 15.13             |
| 60                | 9.02                            | 1.805             | 15.04                      | 9.21              | 1.842                      | 15.35             |
| 61                | 9.30                            | 1.830             | 15.25                      | 9.49              | 1.868                      | 15.57             |
| 62                | 9.58                            | 1.855             | 15.46                      | 9.79              | 1.895                      | 15.80             |
| 63                | 9.88                            | 1.881             | 15.67                      | 10.09             | 1.923                      | 16.02             |
| 64                | 10.17                           | 1.907             | 15.90                      | 10.41             | 1.951                      | 16.26             |
| 65                | 10.48                           | 1.936             | 16.13                      | 10.73             | 1.981                      | 16.50             |
| 66                | 10.80                           | 1.963             | 16.36                      | 11.06             | 2.011                      | 16.76             |
| 67                | 11.12                           | 1.992             | 16.60                      | 11.40             | 2.042                      | 17.02             |
| 68                | 11.46                           | 2.002             | 16.85                      | 11.75             | 2.074                      | 17.29             |
| 69                | 11.81                           | 2.053             | 17.11                      | 12.12             | 2.108                      | 17.56             |
| 70                | 12.16                           | 2.085             | 17.37                      | 12.50             | 2.142                      | 17.85             |
| 71                | 12.53                           | 2.118             | 17.65                      | 12.89             | 2.178                      | 18.15             |
| 72                | 12.91                           | 2.152             | 17.93                      | 13.29             | 2.214                      | 18.45             |
| 73                | 13.30                           | 2.186             | 18.22                      | 13.70             | 2.252                      | 18.77             |
| 74                | 13.70                           | 2.223             | 18.52                      | 14.19             | 2.300                      | 19.17             |
| 75                | 13.97                           | 2.234             | 18.62                      | 14.42             | 2.305                      | 19.24             |

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TABLE No. B-3

## Average Bulking Values of Some Color Pigments

|                                                        | Pounds<br>per Solid<br>Gallon | Solid<br>Gallons<br>per Pound |
|--------------------------------------------------------|-------------------------------|-------------------------------|
| Alizarine Lake .....                                   | 13.7                          | .0728                         |
| Benzidine Yellow .....                                 | 11.5                          | .0871                         |
| Black iron oxide .....                                 | 39.3                          | .0254                         |
| Bone Black (thropblack) .....                          | 20.6                          | .0487                         |
| Cadmium red .....                                      | 43.0                          | .0233                         |
| Cadmium red lithopone .....                            | 37.0                          | .0271                         |
| Cadmium yellow .....                                   | 37.4                          | .0267                         |
| Cadmium yellow lithopone .....                         | 36.1                          | .0277                         |
| Carbon black .....                                     | 14.9                          | .0671                         |
| Chrome green, dark .....                               | 27.5                          | .0364                         |
| Chrome green, medium .....                             | 33.1                          | .0302                         |
| Chrome green, light .....                              | 39.1                          | .0256                         |
| Chromium oxide .....                                   | 42.8                          | .0233                         |
| Chromium oxide, hydrated .....                         | 28.4                          | .0353                         |
| Chrome orange, dark .....                              | 57.4                          | .0174                         |
| Chrome orange, light .....                             | 56.6                          | .0177                         |
| Chrome orange, molybdate .....                         | 48.3                          | .0207                         |
| Chrome yellow, lemon .....                             | 47.8                          | .0209                         |
| Chrome yellow, medium .....                            | 49.1                          | .0204                         |
| Chrome yellow, primrose .....                          | 46.6                          | .0215                         |
| Cobalt blue .....                                      | 31.9                          | .0313                         |
| Copper bronze powder .....                             | 66.6                          | .0150                         |
| Cuprous oxide .....                                    | 48.2                          | .0207                         |
| Dinitraniline orange toner .....                       | 13.0                          | .0770                         |
| Gold bronze powder .....                               | 66.6                          | .0150                         |
| Graphite .....                                         | 17.5                          | .0571                         |
| Guignet's green .....                                  | 27.0                          | .0370                         |
| Hansa yellow .....                                     | 12.3                          | .0811                         |
| Indanthrene blue .....                                 | 14.6                          | .0687                         |
| Indian red (98% Fe <sub>2</sub> O <sub>3</sub> ) ..... | 42.57                         | .0235                         |
| Iron blue (Prussian) .....                             | 15.2                          | .0657                         |
| Iron oxide black .....                                 | 39.3                          | .0254                         |
| Iron oxide, red or brown .....                         | 42.5                          | .0235                         |
| 97% Fe <sub>2</sub> O <sub>3</sub> .....               | 34.6                          | .0292                         |
| 70% Fe <sub>2</sub> O <sub>3</sub> .....               | 30.4                          | .0329                         |
| 40% Fe <sub>2</sub> O <sub>3</sub> .....               | 28.3                          | .0353                         |
| Iron yellow, natural .....                             | 32.9                          | .0304                         |
| Iron yellow, synthetic .....                           | 14.6                          | .0687                         |
| Lake red C .....                                       | 14.8                          | .0674                         |
| Lampblack .....                                        | 14.8                          | .0674                         |

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TABLE No. B-3 (Continued)

|                                                          | Pounds<br>per Solid<br>Gallon | Solid<br>Gallons<br>per Pound |
|----------------------------------------------------------|-------------------------------|-------------------------------|
| Litharge .....                                           | 78.7                          | .0127                         |
| Lithol red .....                                         | 13.1                          | .0765                         |
| Maroon lake .....                                        | 23.3                          | .0429                         |
| Maroon toner .....                                       | 13.3                          | .0751                         |
| Mercuric oxide .....                                     | 92.8                          | .0107                         |
| Metallic brown .....                                     | 32.9                          | .0304                         |
| Methyl violet .....                                      | 18.8                          | .0532                         |
| Mineral black .....                                      | 20.8                          | .0480                         |
| Molybdate orange .....                                   | 48.3                          | .0207                         |
| Ochre .....                                              | 24.0                          | .0417                         |
| Orange mineral .....                                     | 73.5                          | .0136                         |
| Orthonitriline orange toner .....                        | 12.3                          | .0812                         |
| Para red .....                                           | 12.3                          | .0811                         |
| Para red (15% on CaCO <sub>3</sub> ) .....               | 20.2                          | .0494                         |
| Para red, chlorinated .....                              | 13.0                          | .0770                         |
| Paris green .....                                        | 27.0                          | .0371                         |
| Peacock blue .....                                       | 20.5                          | .0489                         |
| Phthalocyanine blue .....                                | 12.6                          | .0791                         |
| Phthalocyanine green .....                               | 16.3                          | .0613                         |
| Pigment scarlet, color index 216 .....                   | 15.8                          | .0633                         |
| Prussian blue .....                                      | 15.2                          | .0656                         |
| Red Lead .....                                           | 73.5                          | .0136                         |
| Rhodamine .....                                          | 19.1                          | .0523                         |
| Scarlet lake, color index 79 .....                       | 22.4                          | .0447                         |
| Sienna, burnt .....                                      | 30.6                          | .0326                         |
| Sienna, raw .....                                        | 27.4                          | .0365                         |
| Tolluidine red .....                                     | 11.8                          | .0847                         |
| Tuscan red .....                                         | 29.3                          | .0341                         |
| Ultramarine blue .....                                   | 19.5                          | .0513                         |
| Umber, burnt .....                                       | 30.2                          | .0331                         |
| Umber, raw .....                                         | 28.3                          | .0254                         |
| Venetian red (50% Fe <sub>2</sub> O <sub>3</sub> ) ..... | 31.2                          | .0321                         |
| Venetian red (40% Fe <sub>2</sub> O <sub>3</sub> ) ..... | 28.9                          | .0345                         |
| Venetian red (30% Fe <sub>2</sub> O <sub>3</sub> ) ..... | 26.2                          | .0382                         |
| Venetian red (20% Fe <sub>2</sub> O <sub>3</sub> ) ..... | 24.2                          | .0414                         |
| Victoria blue .....                                      | 15.7                          | .0636                         |
| Zinc chromate (zinc yellow) .....                        | 28.8                          | .0347                         |
| Zinc chromate (basic) .....                              | 31.5                          | .0317                         |

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TABLE No. B-4

## Average Bulking Values of some Metallic Pigments

|                                 | Pounds<br>per<br>Gallon | Gallons<br>per<br>Pound |
|---------------------------------|-------------------------|-------------------------|
| Aluminum bronze,<br>standard    | 21.2                    | .0471                   |
| Aluminum paste,<br>65% solids   | 20.8                    | .0481                   |
| Copper bronze powder            | 12.2                    | .0818                   |
| Lead, metallic<br>(90:10 paste) | 66.6                    | .0150                   |
| Nickel flake                    | 36.0                    | .0278                   |
| Silver flake                    | 72.4                    | .0138                   |
| Stainless steel paste           | 87.4                    | .0114                   |
| Zinc dust                       | 65.8                    | .0152                   |
|                                 | 58.2                    | .0172                   |

TABLE No. B-5

## Bulking Values of some Oils used in Coatings

|                   | Pounds<br>per<br>Gallon | Gallons<br>per<br>Pound |
|-------------------|-------------------------|-------------------------|
| Castor            | 7.99                    | .1252                   |
| China wood (Tung) | 7.84                    | .1276                   |
| Dehydrated castor |                         |                         |
| G-H Viscosity     | 7.75                    | .1290                   |
| Z-3 viscosity     | 8.00                    | .1250                   |
| Fish              | 7.75                    | .1290                   |
| blown             | 8.28                    | .1208                   |
| bodied            | 8.15                    | .1226                   |
| Linseed           |                         |                         |
| raw and refined   | 7.75                    | .1290                   |
| boiled            | 7.80                    | .1282                   |
| bodied, G-H       | 7.85                    | .1275                   |
| bodied, Q         | 7.90                    | .1266                   |
| bodied, Z-2       | 8.00                    | .1250                   |
| bodied, Z-5       | 8.05                    | .1242                   |
| blown, Z-4        | 8.20                    | .1220                   |
| Oiticica, raw     | 8.05                    | .1243                   |
| Perilla           | 7.75                    | .1290                   |
| Safflower         | 7.67                    | .1304                   |
| Soybean           | 7.69                    | .1301                   |
| bodied, E         | 7.82                    | .1278                   |
| bodied, Z to Z-6  | 8.07                    | .1239                   |
| Tall              | 8.15                    | .1226                   |
| Tung              | 7.84                    | .1276                   |

TABLE No. B-6

Average Bulking Values of some Resins and

## Similar Substances

|                                  | Pounds<br>per<br>Gallon | Gallons<br>per<br>Pound |
|----------------------------------|-------------------------|-------------------------|
| Acetoides .....                  | 9.98                    | .1002                   |
| Alkyds, solid .....              | 9.73                    | .1028                   |
| 12% phthalic anhydride .....     | 8.40                    | .1190                   |
| 24% phthalic anhydride .....     | 8.74                    | .1144                   |
| 30% phthalic anhydride .....     | 9.07                    | .1103                   |
| Asphalts, petroleum .....        | 8.2 to                  | .1060 to                |
| Beeswax .....                    | 9.4                     | .1215                   |
| Candelilla wax .....             | 7.99                    | .1252                   |
| Carnauba wax .....               | 8.07                    | .1239                   |
| Caseln .....                     | 8.24                    | .1214                   |
| Cellulose acetate .....          | 11.2                    | .0893                   |
| Cellulose acetate-butyrate ..... | 11.8                    | .0846                   |
| Cellulose nitrate .....          | 11.0                    | .0911                   |
| Ceresin .....                    | 14.1                    | .0707                   |
| Congo .....                      | 7.74                    | .1292                   |
| ester .....                      | 8.82                    | .1134                   |
| Coumarone-indene .....           | 9.0                     | .1112                   |
| Damar .....                      | 8.7 to                  | .1045 to                |
| East India .....                 | 9.6                     | .1144                   |
| Elasterite .....                 | 8.74                    | .1144                   |
| "Epoxy" resins .....             | 8.65                    | .1156                   |
| Ester gum .....                  | 8.57                    | .1167                   |
| Ethyl cellulose .....            | 9.5 to                  | .1051 to                |
| Gilsonite .....                  | 10.2                    | .0980                   |
| Kauri .....                      | 9.00                    | .1111                   |
| Lac .....                        | 9.7                     | .1036                   |
| Maleics .....                    | 8.74                    | .1144                   |
| Manila .....                     | 8.65                    | .1156                   |
| Melamine .....                   | 9.98                    | .1002                   |
| Paraffin .....                   | 9.5                     | .1056                   |
| chlorinated, 70% chlorine .....  | 8.9                     | .1124                   |
| Phenol-aldehyde resins .....     | 10.16                   | .0984                   |
| Rosin .....                      | 7.4                     | .1350                   |
| Rosin, limed, 4 to 6% Ca .....   | 13.64                   | .0733                   |
|                                  | 10.3 to                 | .0969 to                |
|                                  | 8.6                     | .1163                   |
|                                  | 9.0                     | .1111                   |
|                                  | 9.16                    | .1091                   |

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TABLE No. B-6 (Continued)

|                               | Pounds<br>per<br>Gallon | Gallons<br>per<br>Pound |
|-------------------------------|-------------------------|-------------------------|
| Silicone .....                | 10.0                    | .1000                   |
| Styrene-butadiene resin ..... | 8.74                    | .1144                   |
| Urea-formaldehyde .....       | 10.4                    | .0961                   |
| Vinyl resins .....            |                         |                         |
| chloride-acetate .....        | 11.3                    | .0885                   |
| acetate .....                 | 9.8                     | .1018                   |
| butyral .....                 | 9.3                     | .1073                   |

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Table No. B-7  
Average Bulking Values  
Some Driers and Soaps

|                                | Gallons<br>per<br>Pound | Pounds<br>per<br>Gallon |
|--------------------------------|-------------------------|-------------------------|
| Aluminum stearate .....        | .1190                   | 8.40                    |
| Bentone 340* .....             | .0666                   | 15.0                    |
| Calcium naphthenate, 5% .....  | .1205                   | 8.30                    |
| Cobalt naphthenate, 6% .....   | .1250                   | 8.00                    |
| Manganese naphthenate, 6% .... | .1235                   | 8.10                    |
| Lead naphthenate, 16% .....    | .1190                   | 8.40                    |
| Lead naphthenate, 24% .....    | .1042                   | 9.60                    |
| Zinc naphthenate, 8% .....     | .1235                   | 8.10                    |
| Zinc rosinate, 6% .....        | .1045                   | 9.57                    |
| Zinc stearate .....            | .1099                   | 9.10                    |

\* Suspending and jelling agent, dimethyldioctadecyl ammonium bentonate

TABLE No. B-8

## Average Bulking Values of Some Solvents

|                                         | Pounds<br>per<br>Gallon | Gallons<br>per<br>Pound |
|-----------------------------------------|-------------------------|-------------------------|
| Acetone .....                           | 6.61                    | .1514                   |
| n-Amyl acetate .....                    | 7.25                    | .1380                   |
| n-Amyl alcohol .....                    | 6.76                    | .1478                   |
| Benzene, industrially pure .....        | 7.33                    | .1364                   |
| n-Butanol .....                         | 6.76                    | .1478                   |
| n-Butyl acetate .....                   | 7.30                    | .1370                   |
| sec-Butyl acetate .....                 | 7.18                    | .1393                   |
| Butyl lactate .....                     | 8.11                    | .1233                   |
| Carbon tetrachloride .....              | 13.33                   | .0750                   |
| Cyclohexanone .....                     | 7.87                    | .1270                   |
| Diacetone alcohol .....                 | 7.84                    | .1276                   |
| Diethyl carbonate .....                 | 8.12                    | .1232                   |
| Diethylene glycol monoethyl ether ..... | 8.25                    | .1213                   |
| Dioxane .....                           | 8.57                    | .1167                   |
| Dipentene .....                         | 7.16                    | .1396                   |
| Ethanol, 95% .....                      | 6.80                    | .1471                   |
| Ethanol, S.D. 1 .....                   | 6.79                    | .1473                   |
| Ethyl acetate .....                     | 7.50                    | .1334                   |
| Ethylene dichloride .....               | 10.50                   | .0952                   |
| Ethylene glycol monobutyl ether .....   | 7.51                    | .1331                   |
| Ethylene glycol monoethyl ether .....   | 7.76                    | .1289                   |
| acetate .....                           | 8.11                    | .1233                   |
| Ethylene glycol monomethyl ether .....  | 8.05                    | .1243                   |
| Ethylene glycol monomethyl ether .....  |                         |                         |
| acetate .....                           | 8.41                    | .1189                   |
| Ethyl lactate .....                     | 8.58                    | .1166                   |
| Hexahydrophenol .....                   | 7.93                    | .1261                   |
| Isophorone .....                        | 7.65                    | .1306                   |
| Isopropanol .....                       | 6.58                    | .1520                   |
| Isopropyl acetate, 85-88% .....         | 7.1                     | .1409                   |
| Isopropyl acetate, 95-98% .....         | 7.2                     | .1390                   |
| Kerosene .....                          | 6.62                    | .1510                   |
| Methanol .....                          | 6.61                    | .1514                   |
| Methyl acetate .....                    | 7.56                    | .1322                   |
| Methylene chloride .....                | 11.08                   | .0903                   |
| Methyl acetone .....                    | 6.85                    | .1460                   |
| Methyl ethyl ketone .....               | 6.71                    | .1491                   |
| Methyl isobutyl ketone .....            | 6.68                    | .1499                   |

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TABLE No. B-8 (Continued)

|                                  | Pounds<br>per<br>Gallon | Gallons<br>per<br>Pound |
|----------------------------------|-------------------------|-------------------------|
| Mineral spirits—                 |                         |                         |
| approx. distn. range, 300-400°F. | 6.56                    | .1525                   |
| approx. distn. range, 350-480°F. | 6.77                    | .1477                   |
| Naphtha, aromatic petroleum—     |                         |                         |
| approx. distn. range, 190-300°F. | 6.66                    | .1501                   |
| approx. distn. range, 275-375°F. | 7.04                    | .1421                   |
| approx. distn. range, 330-430°F. | 7.25                    | .1380                   |
| Naphtha, lacquer diluent .....   | 6.15                    | .1626                   |
| Naphtha, solvent—                |                         |                         |
| approx. distn. range, 260-312°F. | 7.16                    | .1396                   |
| approx. distn. range, 300-390°F. |                         |                         |
| Hi-flash .....                   | 7.25                    | .1380                   |
| heavy, wire enamel solvent..     | 7.75                    | .1291                   |
| Naphtha, V. M. & P.—             |                         |                         |
| approx. distn. range, 212-320°F. | 6.24                    | .1603                   |
| Nitroethane .....                | 8.75                    | .1143                   |
| Nitromethane .....               | 9.50                    | .1053                   |
| l-Nitropropane .....             | 8.33                    | .1200                   |
| Petroleum spirits—               |                         |                         |
| approx. distn. range, 300-400°F. | 6.56                    | .1525                   |
| approx. distn. range, 350-480°F. | 6.77                    | .1477                   |
| Pine oil .....                   | 7.80                    | .1283                   |
| Toluene, industrially pure ..... | 7.24                    | .1381                   |
| Trichloroethylene .....          | 12.25                   | .0816                   |
| Turpentine .....                 | 7.23                    | .1383                   |
| Xylene, 5° .....                 | 7.21                    | .1388                   |

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TABLE No. B-9

Average Bulking Values of some Plasticizers

|                                       | Gallons<br>per<br>Pound | Pounds<br>per<br>Gallon |
|---------------------------------------|-------------------------|-------------------------|
| Benzyl benzoate .....                 | .1062                   | 9.41                    |
| Blown castor oil, Z .....             | .1200                   | 8.33                    |
| Butyl acetyl ricinoleate .....        | .1166                   | 8.58                    |
| Butyl phthalyl butyl glycolate...     | .1277                   | 7.83                    |
| Butyl sebacate .....                  | .1091                   | 9.16                    |
| Camphor .....                         | .1396                   | 7.16                    |
| Dianyl phthalate .....                | .1200                   | 8.33                    |
| Dibenzyl sebacate .....               | .1166                   | 8.58                    |
| Dibutyl phthalate .....               | .1144                   | 8.74                    |
| Dibutyl sebacate .....                | .1143                   | 8.75                    |
| Dibutyl tartrate .....                | .1277                   | 7.83                    |
| Dibutoxy ethyl phthalate .....        | .1112                   | 9.00                    |
| Diethyl phthalate .....               | .1291                   | 7.75                    |
| Dihexyl adipate .....                 | .1072                   | 9.33                    |
| Di-2-ethylhexyl adipate .....         | .1292                   | 7.74                    |
| Di-2-ethylhexyl phthalate .....       | .1292                   | 7.74                    |
| Dihydromethyl abietate .....          | .1214                   | 8.24                    |
| Dimethyl phthalate .....              | .1166                   | 8.58                    |
| Dimethyl sebacate .....               | .1009                   | 9.91                    |
| Diocetyl phthalate .....              | .1214                   | 8.24                    |
| Diocetyl sebacate .....               | .1220                   | 8.20                    |
| Diphenyl phthalate .....              | .1321                   | 7.57                    |
| Dipropylene glycol benzoate .....     | .0939                   | 10.65                   |
| Ethyl phthalyl ethyl glycolate .....  | .1064                   | 9.4                     |
| Methyl abietate .....                 | .1177                   | 8.50                    |
| Methyl phthalyl ethyl glycolate ..... | .1016                   | 9.84                    |
| Toluene ethyl sulfonamide .....       | .1177                   | 8.50                    |
| Tributyl citrate .....                | .0980                   | 10.20                   |
| Tributyl phosphate .....              | .1009                   | 9.91                    |
| Tricresyl phosphate .....             | .1143                   | 8.75                    |
| Tricresyl phosphate .....             | .1225                   | 8.16                    |
| Triphenyl phosphate .....             | .1017                   | 9.83                    |
| Triphenyl phosphate .....             | .1053                   | 9.50                    |
| Triphenyl phosphate .....             | .1009                   | 9.91                    |

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TABLE No. C-1

Resin Content and Weight per Gallon of Non-volatile Portion of Varnishes Varying in Oil Length (Assuming Resin at 10 lb./gal. and Oils at 7.85 lb./gal.)

| Oil Length | Solids  |                   |
|------------|---------|-------------------|
|            | % Resin | Weight per Gallon |
| 5          | 71.8    | 9.32              |
| 10         | 56.0    | 8.93              |
| 15         | 45.9    | 8.70              |
| 20         | 38.9    | 8.57              |
| 25         | 33.7    | 8.47              |
| 30         | 29.8    | 8.39              |
| 35         | 26.7    | 8.33              |
| 40         | 24.1    | 8.28              |
| 50         | 20.3    | 8.21              |
| 60         | 17.5    | 8.16              |
| 70         | 15.4    | 8.12              |
| 75         | 14.6    | 8.10              |
| 80         | 13.8    | 8.09              |
| 90         | 12.4    | 8.07              |
| 100        | 11.3    | 8.05              |
| 125        | 9.24    | 8.01              |
| 150        | 7.82    | 7.98              |
| 175        | 6.78    | 7.97              |
| 200        | 5.98    | 7.95              |
| 250        | 4.85    | 7.93              |
| 300        | 4.07    | 7.92              |
| 350        | 3.51    | 7.91              |
| 400        | 3.09    | 7.90              |
| 500        | 2.48    | 7.89              |
| All Oil    | 0.00    | 7.90              |

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TABLE No. C-2

Pounds of Non-volatile Vehicle required for 10  
Gallons of Pigment to Obtain Desired % P.V.C.  
with Varnish of Varying Oil Length.  
*Pounds Non-volatile Varnish for % P.V.C.*

| Oil<br>Length | 20    | 25    | 30    | 35    | 40    |
|---------------|-------|-------|-------|-------|-------|
| 5             | ....  | ....  | ....  | ....  | ....  |
| 10            | 357.0 | 268.0 | 208.0 | 166.7 | 134.0 |
| 15            | 348.0 | 261.0 | 203.0 | 161.5 | 130.5 |
| 20            | 343.0 | 257.0 | 200.0 | 159.0 | 128.5 |
| 25            | 339.0 | 254.0 | 197.5 | 157.0 | 127.0 |
| 30            | 335.5 | 251.5 | 196.0 | 155.8 | 125.8 |
| 35            | 333.3 | 250.0 | 194.3 | 154.7 | 125.0 |
| 40            | 331.0 | 248.4 | 193.0 | 153.8 | 124.2 |
| 50            | 328.4 | 246.0 | 191.5 | 152.5 | 123.2 |
| 60            | 326.3 | 245.0 | 190.0 | 151.5 | 122.3 |
| 70            | 325.0 | 243.5 | 189.3 | 150.7 | 121.8 |
| 75            | 324.0 | 243.0 | 189.0 | 150.5 | 121.6 |
| 80            | 323.5 | 242.5 | 188.7 | 150.3 | 121.4 |
| 90            | 322.5 | 242.0 | 188.2 | 149.7 | 121.0 |
| 100           | 322.0 | 241.5 | 188.0 | 149.5 | 120.8 |
| 125           | 320.4 | 240.6 | 187.0 | 148.7 | 120.2 |
| 150           | 319.2 | 239.4 | 186.3 | 148.3 | 119.8 |
| 175           | 318.8 | 239.1 | 186.0 | 148.0 | 119.5 |
| 200           | 318.0 | 238.5 | 185.5 | 147.7 | 119.3 |
| 250           | 317.2 | 237.9 | 185.2 | 147.3 | 119.0 |
| 300           | 316.8 | 237.6 | 185.0 | 147.0 | 118.7 |
| 350           | 316.4 | 237.3 | 184.7 | 146.9 | 118.6 |
| 400           | 316.0 | 237.0 | 184.5 | 146.8 | 118.5 |
| 500           | 315.6 | 236.7 | 184.0 | 146.5 | 118.3 |
| All Oil       | 316.0 | 237.0 | 184.5 | 146.8 | 118.5 |

TABLE No. C-2 (Continued)

Pounds of Non-volatile Vehicle required for 10  
Gallons of Pigment to Obtain Desired % P.V.C.  
with Varnish of Varying Oil Length.  
*Pounds Non-volatile Varnish for % P.V.C.*

| Oil<br>Length | 45     | 50   | 55   | 60   |
|---------------|--------|------|------|------|
| 5             | ....   | .... | .... | .... |
| 10            | 109.00 | 89.3 | 73.0 | 59.5 |
| 15            | 106.3  | 87.0 | 71.1 | 58.0 |
| 20            | 104.8  | 85.7 | 70.1 | 57.1 |
| 25            | 103.5  | 84.7 | 69.2 | 56.5 |
| 30            | 102.5  | 83.9 | 68.6 | 55.9 |
| 35            | 102.0  | 83.3 | 68.2 | 55.6 |
| 40            | 101.3  | 82.8 | 67.8 | 55.3 |
| 50            | 100.4  | 82.1 | 67.1 | 54.8 |
| 60            | 99.7   | 81.6 | 66.8 | 54.4 |
| 70            | 99.2   | 81.2 | 66.4 | 54.2 |
| 75            | 99.0   | 81.0 | 66.2 | 54.0 |
| 80            | 98.8   | 80.9 | 66.2 | 54.0 |
| 90            | 98.5   | 80.7 | 66.0 | 53.8 |
| 100           | 98.4   | 80.5 | 65.8 | 53.7 |
| 125           | 97.8   | 80.1 | 65.5 | 53.4 |
| 150           | 97.5   | 79.8 | 65.3 | 53.2 |
| 175           | 97.3   | 79.7 | 65.2 | 53.1 |
| 200           | 97.1   | 79.5 | 65.0 | 53.0 |
| 250           | 96.9   | 79.3 | 64.9 | 52.9 |
| 300           | 96.7   | 79.2 | 64.7 | 52.8 |
| 350           | 96.6   | 79.1 | 64.7 | 52.8 |
| 400           | 96.5   | 79.0 | 64.6 | 52.7 |
| 500           | 96.4   | 78.9 | 64.5 | 52.6 |
| All Oil       | 96.5   | 79.0 | 64.6 | 52.7 |

TABLE No. C-3

Film Thickness in Mils (.001 in.)  
and Spreading Rate

| Film Thickness Mils | Spreading Rate Square feet per gallon | Film Thickness Mils | Spreading Rate Square feet per gallon |
|---------------------|---------------------------------------|---------------------|---------------------------------------|
| 0.2                 | 8020                                  | 4.6                 | 349                                   |
| 0.4                 | 4010                                  | 4.8                 | 334                                   |
| 0.6                 | 2670                                  | 5.0                 | 321                                   |
| 0.8                 | 2010                                  | 5.2                 | 308                                   |
| 1.0                 | 1604                                  | 5.4                 | 297                                   |
| 1.1                 | 1458                                  | 5.6                 | 286                                   |
| 1.2                 | 1337                                  | 5.8                 | 277                                   |
| 1.3                 | 1234                                  | 6.0                 | 267                                   |
| 1.4                 | 1146                                  | 6.2                 | 259                                   |
| 1.5                 | 1069                                  | 6.4                 | 251                                   |
| 1.6                 | 1000                                  | 6.6                 | 243                                   |
| 1.7                 | 945                                   | 6.8                 | 236                                   |
| 1.8                 | 891                                   | 7.0                 | 229                                   |
| 2.0                 | 802                                   | 7.2                 | 223                                   |
| 2.2                 | 729                                   | 7.4                 | 217                                   |
| 2.3                 | 700                                   | 7.6                 | 211                                   |
| 2.4                 | 668                                   | 7.8                 | 206                                   |
| 2.6                 | 617                                   | 8.0                 | 201                                   |
| 2.8                 | 573                                   | 8.2                 | 196                                   |
| 3.0                 | 535                                   | 8.4                 | 191                                   |
| 3.2                 | 501                                   | 8.8                 | 182                                   |
| 3.4                 | 472                                   | 9.0                 | 178                                   |
| 3.6                 | 446                                   | 9.2                 | 174                                   |
| 3.8                 | 442                                   | 9.4                 | 171                                   |
| 4.0                 | 401                                   | 9.6                 | 167                                   |
| 4.2                 | 382                                   | 9.8                 | 164                                   |
| 4.4                 | 365                                   | 10.0                | 160                                   |

TABLE No. C-4

Paint Hiding Power and Spreading Rate  
(as calculated from grams paint applied to one square foot  
and weight per gallon of paint in pounds)  
Spreading Rate (square feet per gallon)

| Grams Weight Paint Applied of paint | 10  | 11  | 12  | 13  | 14  | 15  | 16  |
|-------------------------------------|-----|-----|-----|-----|-----|-----|-----|
| 15                                  | 302 | 333 | 363 | 393 | 423 | 454 | 484 |
| 16                                  | 284 | 312 | 340 | 369 | 397 | 425 | 454 |
| 17                                  | 267 | 293 | 320 | 347 | 374 | 400 | 427 |
| 18                                  | 252 | 277 | 302 | 328 | 353 | 378 | 403 |
| 19                                  | 239 | 263 | 286 | 310 | 334 | 358 | 382 |
| 20                                  | 227 | 249 | 272 | 295 | 318 | 340 | 363 |
| 21                                  | 216 | 238 | 259 | 281 | 302 | 324 | 346 |
| 22                                  | 206 | 227 | 247 | 268 | 289 | 309 | 330 |
| 23                                  | 197 | 217 | 237 | 256 | 276 | 296 | 316 |
| 24                                  | 189 | 208 | 227 | 246 | 265 | 284 | 302 |
| 25                                  | 181 | 200 | 218 | 236 | 254 | 272 | 290 |
| 26                                  | 174 | 192 | 209 | 227 | 244 | 262 | 279 |
| 27                                  | 168 | 185 | 202 | 218 | 235 | 252 | 269 |
| 28                                  | 162 | 178 | 194 | 211 | 227 | 243 | 259 |
| 29                                  | 156 | 172 | 188 | 203 | 219 | 235 | 250 |
| 30                                  | 151 | 166 | 181 | 197 | 212 | 227 | 242 |
| 31                                  | 146 | 161 | 176 | 190 | 205 | 219 | 234 |
| 32                                  | 142 | 156 | 170 | 184 | 198 | 213 | 227 |
| 33                                  | 137 | 151 | 165 | 179 | 192 | 206 | 220 |
| 34                                  | 133 | 147 | 160 | 173 | 187 | 200 | 213 |
| 35                                  | 130 | 143 | 156 | 168 | 181 | 194 | 207 |

TABLE No. C-5

Milliliters (ml.) per square foot to square feet per  
Gallon (spreading rate)

Note: Some specifications for hiding power are expressed as the milliliters (ml.) of paint required to hide one square foot of area of a hiding power chart or to achieve a specified contrast ratio. The following table presents the relationship of milliliters per square foot to square feet covered by one gallon of paint (spreading rate).

| ml. per<br>sq. ft. | sq. ft.<br>per gal. | ml. per<br>sq. ft. | sq. ft.<br>per gal. | ml. per<br>sq. ft. | sq. ft.<br>per gal. |
|--------------------|---------------------|--------------------|---------------------|--------------------|---------------------|
| 3.0                | 1262                | 6.0                | 631                 | 9.0                | 421                 |
| 3.1                | 1221                | 6.1                | 620                 | 9.1                | 416                 |
| 3.2                | 1183                | 6.2                | 610                 | 9.2                | 411                 |
| 3.3                | 1147                | 6.3                | 601                 | 9.3                | 407                 |
| 3.4                | 1113                | 6.4                | 591                 | 9.4                | 403                 |
| 3.5                | 1081                | 6.5                | 582                 | 9.5                | 398                 |
| 3.6                | 1051                | 6.6                | 573                 | 9.6                | 394                 |
| 3.7                | 1023                | 6.7                | 565                 | 9.7                | 390                 |
| 3.8                | 996                 | 6.8                | 557                 | 9.8                | 386                 |
| 3.9                | 971                 | 6.9                | 549                 | 9.9                | 382                 |
| 4.0                | 946                 | 7.0                | 541                 | 10.0               | 379                 |
| 4.1                | 923                 | 7.1                | 533                 | 10.5               | 360                 |
| 4.2                | 901                 | 7.2                | 526                 | 11.0               | 344                 |
| 4.3                | 880                 | 7.3                | 518                 | 11.5               | 329                 |
| 4.4                | 860                 | 7.4                | 511                 | 12.0               | 315                 |
| 4.5                | 841                 | 7.5                | 505                 | 12.5               | 303                 |
| 4.6                | 823                 | 7.6                | 498                 | 13.0               | 291                 |
| 4.7                | 805                 | 7.7                | 492                 | 13.5               | 280                 |
| 4.8                | 789                 | 7.8                | 485                 | 14.0               | 270                 |
| 4.9                | 772                 | 7.9                | 479                 | 14.5               | 261                 |
| 5.0                | 757                 | 8.0                | 473                 | 15.0               | 252                 |
| 5.1                | 742                 | 8.1                | 467                 | 15.5               | 244                 |
| 5.2                | 728                 | 8.2                | 462                 | 16.0               | 237                 |
| 5.3                | 714                 | 8.3                | 456                 | 16.5               | 229                 |
| 5.4                | 701                 | 8.4                | 451                 | 17.0               | 223                 |
| 5.5                | 688                 | 8.5                | 445                 | 17.5               | 216                 |
| 5.6                | 676                 | 8.6                | 440                 | 18.0               | 210                 |
| 5.7                | 664                 | 8.7                | 435                 | 18.5               | 205                 |
| 5.8                | 653                 | 8.8                | 430                 | 19.0               | 199                 |
| 5.9                | 642                 | 8.9                | 425                 | 19.5               | 194                 |
|                    |                     |                    |                     | 20.0               | 189                 |

W. FIL



are feet per

Expressed as  
1 to hide one  
square foot of  
surface with  
one square foot  
of paint (spread)

liters per  
sq. ft.  
per gal.

|      |     |
|------|-----|
| 9.0  | 421 |
| 9.1  | 416 |
| 9.2  | 411 |
| 9.3  | 407 |
| 9.4  | 403 |
| 9.5  | 398 |
| 9.6  | 394 |
| 9.7  | 390 |
| 9.8  | 386 |
| 9.9  | 382 |
| 10.0 | 379 |
| 10.1 | 376 |
| 10.2 | 373 |
| 10.3 | 370 |
| 10.4 | 367 |
| 10.5 | 364 |
| 10.6 | 361 |
| 10.7 | 358 |
| 10.8 | 355 |
| 10.9 | 352 |
| 11.0 | 349 |
| 11.1 | 346 |
| 11.2 | 343 |
| 11.3 | 340 |
| 11.4 | 337 |
| 11.5 | 334 |
| 11.6 | 331 |
| 11.7 | 328 |
| 11.8 | 325 |
| 11.9 | 322 |
| 12.0 | 319 |
| 12.1 | 316 |
| 12.2 | 313 |
| 12.3 | 310 |
| 12.4 | 307 |
| 12.5 | 304 |
| 12.6 | 301 |
| 12.7 | 298 |
| 12.8 | 295 |
| 12.9 | 292 |
| 13.0 | 289 |
| 13.1 | 286 |
| 13.2 | 283 |
| 13.3 | 280 |
| 13.4 | 277 |
| 13.5 | 274 |
| 13.6 | 271 |
| 13.7 | 268 |
| 13.8 | 265 |
| 13.9 | 262 |
| 14.0 | 259 |
| 14.1 | 256 |
| 14.2 | 253 |
| 14.3 | 250 |
| 14.4 | 247 |
| 14.5 | 244 |
| 14.6 | 241 |
| 14.7 | 238 |
| 14.8 | 235 |
| 14.9 | 232 |
| 15.0 | 229 |
| 15.1 | 226 |
| 15.2 | 223 |
| 15.3 | 220 |
| 15.4 | 217 |
| 15.5 | 214 |
| 15.6 | 211 |
| 15.7 | 208 |
| 15.8 | 205 |
| 15.9 | 202 |
| 16.0 | 199 |
| 16.1 | 196 |
| 16.2 | 193 |
| 16.3 | 190 |
| 16.4 | 187 |
| 16.5 | 184 |
| 16.6 | 181 |
| 16.7 | 178 |
| 16.8 | 175 |
| 16.9 | 172 |
| 17.0 | 169 |

TABLE No. C-6  
VALUES OF ST FOR VALUES OF R<sub>∞</sub> and R<sub>a</sub>  
over the range of R<sub>∞</sub> 0.80 to 0.96 and R<sub>a</sub> 0.70 to 0.91

See Page 09 for explanation

| R <sub>∞</sub><br>Reflectance<br>or<br>Brightness | R <sub>a</sub> | Reflectance or Brightness of the White Paint over Black Substrate | R <sub>∞</sub> | R <sub>a</sub> | Reflectance or Brightness of the White Paint over Black Substrate |
|---------------------------------------------------|----------------|-------------------------------------------------------------------|----------------|----------------|-------------------------------------------------------------------|
| 0.80                                              | 0.70           | 2.80                                                              | 0.80           | 0.70           | 2.80                                                              |
| 0.81                                              | 0.71           | 2.74                                                              | 0.81           | 0.71           | 2.74                                                              |
| 0.82                                              | 0.72           | 2.67                                                              | 0.82           | 0.72           | 2.67                                                              |
| 0.83                                              | 0.73           | 2.63                                                              | 0.83           | 0.73           | 2.63                                                              |
| 0.84                                              | 0.74           | 2.59                                                              | 0.84           | 0.74           | 2.59                                                              |
| 0.85                                              | 0.75           | 2.55                                                              | 0.85           | 0.75           | 2.55                                                              |
| 0.86                                              | 0.76           | 2.51                                                              | 0.86           | 0.76           | 2.51                                                              |
| 0.87                                              | 0.77           | 2.48                                                              | 0.87           | 0.77           | 2.48                                                              |
| 0.88                                              | 0.78           | 2.46                                                              | 0.88           | 0.78           | 2.46                                                              |
| 0.89                                              | 0.79           | 2.43                                                              | 0.89           | 0.79           | 2.43                                                              |
| 0.90                                              | 0.80           | 2.41                                                              | 0.90           | 0.80           | 2.41                                                              |
| 0.91                                              | 0.81           | 2.39                                                              | 0.91           | 0.81           | 2.39                                                              |
| 0.92                                              | 0.82           | 2.37                                                              | 0.92           | 0.82           | 2.37                                                              |
| 0.93                                              | 0.83           | 2.35                                                              | 0.93           | 0.83           | 2.35                                                              |
| 0.94                                              | 0.84           | 2.33                                                              | 0.94           | 0.84           | 2.33                                                              |
| 0.95                                              | 0.85           | 2.31                                                              | 0.95           | 0.85           | 2.31                                                              |
| 0.96                                              | 0.86           | 2.29                                                              | 0.96           | 0.86           | 2.29                                                              |
| 0.97                                              | 0.87           | 2.27                                                              | 0.97           | 0.87           | 2.27                                                              |
| 0.98                                              | 0.88           | 2.25                                                              | 0.98           | 0.88           | 2.25                                                              |
| 0.99                                              | 0.89           | 2.23                                                              | 0.99           | 0.89           | 2.23                                                              |
| 1.00                                              | 0.90           | 2.21                                                              | 1.00           | 0.90           | 2.21                                                              |
| 1.01                                              | 0.91           | 2.19                                                              | 1.01           | 0.91           | 2.19                                                              |
| 1.02                                              | 0.92           | 2.17                                                              | 1.02           | 0.92           | 2.17                                                              |
| 1.03                                              | 0.93           | 2.15                                                              | 1.03           | 0.93           | 2.15                                                              |
| 1.04                                              | 0.94           | 2.13                                                              | 1.04           | 0.94           | 2.13                                                              |
| 1.05                                              | 0.95           | 2.11                                                              | 1.05           | 0.95           | 2.11                                                              |
| 1.06                                              | 0.96           | 2.09                                                              | 1.06           | 0.96           | 2.09                                                              |
| 1.07                                              | 0.97           | 2.07                                                              | 1.07           | 0.97           | 2.07                                                              |
| 1.08                                              | 0.98           | 2.05                                                              | 1.08           | 0.98           | 2.05                                                              |
| 1.09                                              | 0.99           | 2.03                                                              | 1.09           | 0.99           | 2.03                                                              |
| 1.10                                              | 1.00           | 2.01                                                              | 1.10           | 1.00           | 2.01                                                              |
| 1.11                                              | 1.01           | 1.99                                                              | 1.11           | 1.01           | 1.99                                                              |
| 1.12                                              | 1.02           | 1.97                                                              | 1.12           | 1.02           | 1.97                                                              |
| 1.13                                              | 1.03           | 1.95                                                              | 1.13           | 1.03           | 1.95                                                              |
| 1.14                                              | 1.04           | 1.93                                                              | 1.14           | 1.04           | 1.93                                                              |
| 1.15                                              | 1.05           | 1.91                                                              | 1.15           | 1.05           | 1.91                                                              |
| 1.16                                              | 1.06           | 1.89                                                              | 1.16           | 1.06           | 1.89                                                              |
| 1.17                                              | 1.07           | 1.87                                                              | 1.17           | 1.07           | 1.87                                                              |
| 1.18                                              | 1.08           | 1.85                                                              | 1.18           | 1.08           | 1.85                                                              |
| 1.19                                              | 1.09           | 1.83                                                              | 1.19           | 1.09           | 1.83                                                              |
| 1.20                                              | 1.10           | 1.81                                                              | 1.20           | 1.10           | 1.81                                                              |
| 1.21                                              | 1.11           | 1.79                                                              | 1.21           | 1.11           | 1.79                                                              |
| 1.22                                              | 1.12           | 1.77                                                              | 1.22           | 1.12           | 1.77                                                              |
| 1.23                                              | 1.13           | 1.75                                                              | 1.23           | 1.13           | 1.75                                                              |
| 1.24                                              | 1.14           | 1.73                                                              | 1.24           | 1.14           | 1.73                                                              |
| 1.25                                              | 1.15           | 1.71                                                              | 1.25           | 1.15           | 1.71                                                              |
| 1.26                                              | 1.16           | 1.69                                                              | 1.26           | 1.16           | 1.69                                                              |
| 1.27                                              | 1.17           | 1.67                                                              | 1.27           | 1.17           | 1.67                                                              |
| 1.28                                              | 1.18           | 1.65                                                              | 1.28           | 1.18           | 1.65                                                              |
| 1.29                                              | 1.19           | 1.63                                                              | 1.29           | 1.19           | 1.63                                                              |
| 1.30                                              | 1.20           | 1.61                                                              | 1.30           | 1.20           | 1.61                                                              |
| 1.31                                              | 1.21           | 1.59                                                              | 1.31           | 1.21           | 1.59                                                              |
| 1.32                                              | 1.22           | 1.57                                                              | 1.32           | 1.22           | 1.57                                                              |
| 1.33                                              | 1.23           | 1.55                                                              | 1.33           | 1.23           | 1.55                                                              |
| 1.34                                              | 1.24           | 1.53                                                              | 1.34           | 1.24           | 1.53                                                              |
| 1.35                                              | 1.25           | 1.51                                                              | 1.35           | 1.25           | 1.51                                                              |
| 1.36                                              | 1.26           | 1.49                                                              | 1.36           | 1.26           | 1.49                                                              |
| 1.37                                              | 1.27           | 1.47                                                              | 1.37           | 1.27           | 1.47                                                              |
| 1.38                                              | 1.28           | 1.45                                                              | 1.38           | 1.28           | 1.45                                                              |
| 1.39                                              | 1.29           | 1.43                                                              | 1.39           | 1.29           | 1.43                                                              |
| 1.40                                              | 1.30           | 1.41                                                              | 1.40           | 1.30           | 1.41                                                              |
| 1.41                                              | 1.31           | 1.39                                                              | 1.41           | 1.31           | 1.39                                                              |
| 1.42                                              | 1.32           | 1.37                                                              | 1.42           | 1.32           | 1.37                                                              |
| 1.43                                              | 1.33           | 1.35                                                              | 1.43           | 1.33           | 1.35                                                              |
| 1.44                                              | 1.34           | 1.33                                                              | 1.44           | 1.34           | 1.33                                                              |
| 1.45                                              | 1.35           | 1.31                                                              | 1.45           | 1.35           | 1.31                                                              |
| 1.46                                              | 1.36           | 1.29                                                              | 1.46           | 1.36           | 1.29                                                              |
| 1.47                                              | 1.37           | 1.27                                                              | 1.47           | 1.37           | 1.27                                                              |
| 1.48                                              | 1.38           | 1.25                                                              | 1.48           | 1.38           | 1.25                                                              |
| 1.49                                              | 1.39           | 1.23                                                              | 1.49           | 1.39           | 1.23                                                              |
| 1.50                                              | 1.40           | 1.21                                                              | 1.50           | 1.40           | 1.21                                                              |
| 1.51                                              | 1.41           | 1.19                                                              | 1.51           | 1.41           | 1.19                                                              |
| 1.52                                              | 1.42           | 1.17                                                              | 1.52           | 1.42           | 1.17                                                              |
| 1.53                                              | 1.43           | 1.15                                                              | 1.53           | 1.43           | 1.15                                                              |
| 1.54                                              | 1.44           | 1.13                                                              | 1.54           | 1.44           | 1.13                                                              |
| 1.55                                              | 1.45           | 1.11                                                              | 1.55           | 1.45           | 1.11                                                              |
| 1.56                                              | 1.46           | 1.09                                                              | 1.56           | 1.46           | 1.09                                                              |
| 1.57                                              | 1.47           | 1.07                                                              | 1.57           | 1.47           | 1.07                                                              |
| 1.58                                              | 1.48           | 1.05                                                              | 1.58           | 1.48           | 1.05                                                              |
| 1.59                                              | 1.49           | 1.03                                                              | 1.59           | 1.49           | 1.03                                                              |
| 1.60                                              | 1.50           | 1.01                                                              | 1.60           | 1.50           | 1.01                                                              |
| 1.61                                              | 1.51           | 0.99                                                              | 1.61           | 1.51           | 0.99                                                              |
| 1.62                                              | 1.52           | 0.97                                                              | 1.62           | 1.52           | 0.97                                                              |
| 1.63                                              | 1.53           | 0.95                                                              | 1.63           | 1.53           | 0.95                                                              |
| 1.64                                              | 1.54           | 0.93                                                              | 1.64           | 1.54           | 0.93                                                              |
| 1.65                                              | 1.55           | 0.91                                                              | 1.65           | 1.55           | 0.91                                                              |
| 1.66                                              | 1.56           | 0.89                                                              | 1.66           | 1.56           | 0.89                                                              |
| 1.67                                              | 1.57           | 0.87                                                              | 1.67           | 1.57           | 0.87                                                              |
| 1.68                                              | 1.58           | 0.85                                                              | 1.68           | 1.58           | 0.85                                                              |
| 1.69                                              | 1.59           | 0.83                                                              | 1.69           | 1.59           | 0.83                                                              |
| 1.70                                              | 1.60           | 0.81                                                              | 1.70           | 1.60           | 0.81                                                              |
| 1.71                                              | 1.61           | 0.79                                                              | 1.71           | 1.61           | 0.79                                                              |
| 1.72                                              | 1.62           | 0.77                                                              | 1.72           | 1.62           | 0.77                                                              |
| 1.73                                              | 1.63           | 0.75                                                              | 1.73           | 1.63           | 0.75                                                              |
| 1.74                                              | 1.64           | 0.73                                                              | 1.74           | 1.64           | 0.73                                                              |
| 1.75                                              | 1.65           | 0.71                                                              | 1.75           | 1.65           | 0.71                                                              |
| 1.76                                              | 1.66           | 0.69                                                              | 1.76           | 1.66           | 0.69                                                              |
| 1.77                                              | 1.67           | 0.67                                                              | 1.77           | 1.67           | 0.67                                                              |
| 1.78                                              | 1.68           | 0.65                                                              | 1.78           | 1.68           | 0.65                                                              |
| 1.79                                              | 1.69           | 0.63                                                              | 1.79           | 1.69           | 0.63                                                              |
| 1.80                                              | 1.70           | 0.61                                                              | 1.80           | 1.70           | 0.61                                                              |
| 1.81                                              | 1.71           | 0.59                                                              | 1.81           | 1.71           | 0.59                                                              |
| 1.82                                              | 1.72           | 0.57                                                              | 1.82           | 1.72           | 0.57                                                              |
| 1.83                                              | 1.73           | 0.55                                                              | 1.83           | 1.73           | 0.55                                                              |
| 1.84                                              | 1.74           | 0.53                                                              | 1.84           | 1.74           | 0.53                                                              |
| 1.85                                              | 1.75           | 0.51                                                              | 1.85           | 1.75           | 0.51                                                              |
| 1.86                                              | 1.76           | 0.49                                                              | 1.86           | 1.76           | 0.49                                                              |
| 1.87                                              | 1.77           | 0.47                                                              | 1.87           | 1.77           | 0.47                                                              |
| 1.88                                              | 1.78           | 0.45                                                              | 1.88           | 1.78           | 0.45                                                              |
| 1.89                                              | 1.79           | 0.43                                                              | 1.89           | 1.79           | 0.43                                                              |
| 1.90                                              | 1.80           | 0.41                                                              | 1.90           | 1.80           | 0.41                                                              |
| 1.91                                              | 1.81           | 0.39                                                              | 1.91           | 1.81           | 0.39                                                              |
| 1.92                                              | 1.82           | 0.37                                                              | 1.92           | 1.82           | 0.37                                                              |
| 1.93                                              | 1.83           | 0.35                                                              | 1.93           | 1.83           | 0.35                                                              |
| 1.94                                              | 1.84           | 0.33                                                              | 1.94           | 1.84           | 0.33                                                              |
| 1.95                                              | 1.85           | 0.31                                                              | 1.95           | 1.85           | 0.31                                                              |
| 1.96                                              | 1.86           | 0.29                                                              | 1.96           | 1.86           | 0.29                                                              |
| 1.97                                              | 1.87           | 0.27                                                              | 1.97           | 1.87           | 0.27                                                              |
| 1.98                                              | 1.88           | 0.25                                                              | 1.98           | 1.88           | 0.25                                                              |
| 1.99                                              | 1.89           | 0.23                                                              | 1.99           | 1.89           | 0.23                                                              |
| 2.00                                              | 1.90           | 0.21                                                              | 2.00           | 1.90           | 0.21                                                              |

\* Terminal reflectivity  
Reflectance of paint film of such thickness, that further increase in thickness  
does not change its reflectance.

TABLE No. C-7

Reflectivity ( $R_p$ ) of White Paint

and Factor for conversion of  $S$  (scattering coefficient) to hiding power in terms of square feet per gallon

Note: Values of  $ST$  are given in Table No. C-6, from which  $S$  may be calculated. Following is an example of the use of these tables:

If the method as described on page 99, for a white paint,  $R_a$  (reflectance over black) was 0.85, and reflectivity  $R_z = 0.89$ . The wet film thickness  $T$  (that gave the dried film on which  $R_a$  was measured) was 3.00 mils.

From Table No. C-6 (preceding page), the  $ST$  value corresponding to  $R_a$  0.85 and  $R_z$  0.89 is found to be 7.24.

$$S = \frac{ST}{T} = \frac{7.24}{3} = 2.41$$

Now, from the table below, we find for  $R_z = 0.89$ , the factor 181.8 by which  $S$  must be multiplied to give hiding power in square feet per gallon for 98% contrast ratio (over black and white), so  $181.8 \times 2.41 = 438$  square feet per gallon. For 93% contrast ratio, the factor is 343.5 and hiding power is  $343.5 \times 2.41$  or 828 square feet per gallon.

| $R_z$<br>Reflectivity<br>on ultimate<br>reflectance | To Convert $S$ to<br>Hiding Power in<br>square feet per gallon<br>for 98% contrast ratio<br>multiply $S$ by | To Convert $S$ to<br>Hiding Power in<br>square feet per gallon<br>for 93% contrast ratio<br>multiply $S$ by |
|-----------------------------------------------------|-------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| 0.800                                               | 246.8                                                                                                       | 411.3                                                                                                       |
| 0.810                                               | 239.0                                                                                                       | 402.2                                                                                                       |
| 0.820                                               | 231.3                                                                                                       | 393.5                                                                                                       |
| 0.830                                               | 223.8                                                                                                       | 385.3                                                                                                       |
| 0.840                                               | 216.5                                                                                                       | 378.0                                                                                                       |
| 0.850                                               | 209.2                                                                                                       | 370.5                                                                                                       |
| 0.860                                               | 202.1                                                                                                       | 363.3                                                                                                       |
| 0.870                                               | 195.2                                                                                                       | 356.6                                                                                                       |
| 0.880                                               | 188.4                                                                                                       | 350.1                                                                                                       |
| 0.890                                               | 181.8                                                                                                       | 343.5                                                                                                       |
| 0.900                                               | 175.5                                                                                                       | 337.7                                                                                                       |
| 0.910                                               | 169.3                                                                                                       | 332.6                                                                                                       |
| 0.920                                               | 163.5                                                                                                       | 327.8                                                                                                       |
| 0.930                                               | 158.0                                                                                                       | 323.4                                                                                                       |
| 0.940                                               | 153.0                                                                                                       | 319.3                                                                                                       |
| 0.950                                               | 148.4                                                                                                       | 315.8                                                                                                       |
| 0.960                                               | 144.4                                                                                                       | 313.4                                                                                                       |

TABLE No. D-1

Average refractive index of White  
Pigments and Extenders

|                                    |           |
|------------------------------------|-----------|
| Titanox-RA (rutile $TiO_2$ )       | 2.7       |
| Titanox-A (anatase $TiO_2$ )       | 2.55      |
| Zirconium oxide                    | 2.40      |
| Zinc sulfide                       | 2.37      |
| Antimony oxide                     | 2.09-2.29 |
| Basic carbonate white lead         | 1.94-2.09 |
| Basic sulphate white lead          | 1.93      |
| Titanox-RCHT (30% rutile $TiO_2$ ) |           |
| 70% $CaSO_4$                       | 1.98      |
| Zinc oxide                         | 1.99-2.02 |
| Lithopone                          | 1.84      |
| Barytes (barium sulphate)          | 1.64      |
| Barium carbonate                   | 1.60      |
| Calcium sulphate (anhydrite)       | 1.59      |
| Calcium carbonate                  | 1.57      |
| Calcium sulphite                   | 1.57      |
| Talc                               | 1.57      |
| Clay                               | 1.55      |
| Silica (quartz)                    | 1.55      |
| Calcium sulphate (gypsum)          | 1.52      |
| Diatomaceous silica                | 1.45      |

TABLE No. D-2

## Refractive Index of Some Oils (25°C.)

|                     |        |
|---------------------|--------|
| Castor Oil          | 1.4771 |
| China wood Oil      | 1.5170 |
| Cocunut Oil         | 1.4530 |
| Corn Oil            | 1.4800 |
| Cottonseed Oil      | 1.4720 |
| Hemp seed Oil       | 1.4822 |
| Linseed Oil, raw    | 1.4800 |
| Linseed Oil, boiled | 1.4895 |
| Linseed Oil, bodied | 1.4966 |
| Menhaden Oil        | 1.4850 |
| Perilla Oil         | 1.4874 |
| Poppyseed Oil       | 1.4740 |
| Rapeseed Oil        | 1.4654 |
| Soya bean Oil       | 1.4813 |
| Sardine Oil         | 1.4800 |

TABLE No. D-3

## Refractive Index of Some Resins

|                                                      |               |
|------------------------------------------------------|---------------|
| Pale East India Macassar                             |               |
| Bold-Hiroe                                           | 1.543         |
| Nubs-Hiroe                                           | 1.542         |
| Chips-Hiroe                                          | 1.540         |
| Pale East India, Singapore                           |               |
| Bold                                                 | 1.541         |
| Nubs                                                 | 1.540         |
| Chips                                                | 1.540         |
| Batu East India                                      |               |
| Scraped                                              | 1.538         |
| Black East India                                     |               |
| Bold scraped                                         | 1.541         |
| Batavia Damar                                        |               |
| A/E Standard                                         | 1.535         |
| Singapore Damar                                      |               |
| No. 1                                                | 1.538         |
| Kauri                                                |               |
| Pale No. 3                                           | 1.546         |
| Pale chips                                           | 1.546         |
| Brown No. 3                                          | 1.544         |
| Congo                                                |               |
| No. 1 Water white and transparent.                   | 1.540         |
| No. 15 Ord. Ivory Sorts                              | 1.541         |
| Some alkylid resins                                  | 1.512-1.548   |
|                                                      | 20°C.         |
| Methyl Abietate (Abalyn)                             | 1.5280-1.5300 |
| Methyl Dihydroabietate (Hercolyn)                    | 1.517-1.5200  |
| Diethylene Glycol Diabietate (Flexalyn)              | 1.5361-1.5363 |
| Diethylene Glycol Ester of Staybelite Resin          | 1.5225-1.5230 |
| Ethylene Glycol Diabietate                           | 1.5319-1.5324 |
| Pentaerythritol Tetraabietate (Pentalyns A, G, M, X) | 1.544-1.545   |

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TABLE No. D-4

## Refractive Index of Some Solvents and Thinners (20°C.)

|                          |       |
|--------------------------|-------|
| Acetone                  | 1.359 |
| Amyl Acetate (85-88%)    | 1.403 |
| Amyl Alcohol, normal     | 1.399 |
| Benzol, 90%              | 1.495 |
| Butyl Acetate            | 1.399 |
| Butyl Alcohol            | 1.399 |
| Butyl Cellosolve         | 1.477 |
| Butyl Lactate            | 1.422 |
| Butyl Propionate         | 1.399 |
| Carbon Tetrachloride     | 1.460 |
| Cellosolve               | 1.410 |
| Cellosolve Acetate       | 1.403 |
| Cyclohexanol             | 1.456 |
| Dipentene                | 1.474 |
| Ethyl Acetate (85-88%)   | 1.374 |
| Ethyl Alcohol (95%)      | 1.361 |
| Ethyl Ether              | 1.351 |
| Ethyl Lactate            | 1.411 |
| Isobutyl Alcohol         | 1.399 |
| Isopropyl Acetate        | 1.377 |
| Isopropyl Alcohol        | 1.377 |
| Kerosene                 | 1.450 |
| Laquer Petroleum Diluent | 1.406 |
| Methyl Alcohol           | 1.329 |
| Methyl Cellosolve        | 1.402 |
| Mineral Spirits          | 1.440 |
| V. M. & P. Naphtha       | 1.411 |
| H. F. Naphtha            | 1.496 |
| Toluol                   | 1.495 |
| Turpentine               | 1.472 |
| Xylole                   | 1.497 |

TABLE No. D-5

## Average Refractive Index of some Miscellaneous Materials

|                |           |
|----------------|-----------|
| Cellulose      | 1.53      |
| Casain         | 1.53      |
| Starch         | 1.53      |
| Natural rubber | 1.522     |
| Chloroprene    | 1.45-1.55 |
| Paraffin Wax   | 1.47      |

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## PART VI

### TITANOX PIGMENTS IN PAINTS

The application of Titanox pigments to paints is universal, that is, every type of paint that requires white pigment can be pigmented with one or more types of Titanox pigments.

In discussing the use of these pigments in paints, some general principles are presented. While being of general interest because they have played a part in bringing the advantages of titanium pigments to so many coatings, these principles should be of particular interest to the inexperienced formulator.

The discussion here is according to type of paint mainly in two divisions—the broad fields of trade sales products and of industrial product finishes. These are classified into more specific types such for example as interior architectural, exterior architectural, baking enamels.

#### TRADE SALES PRODUCTS

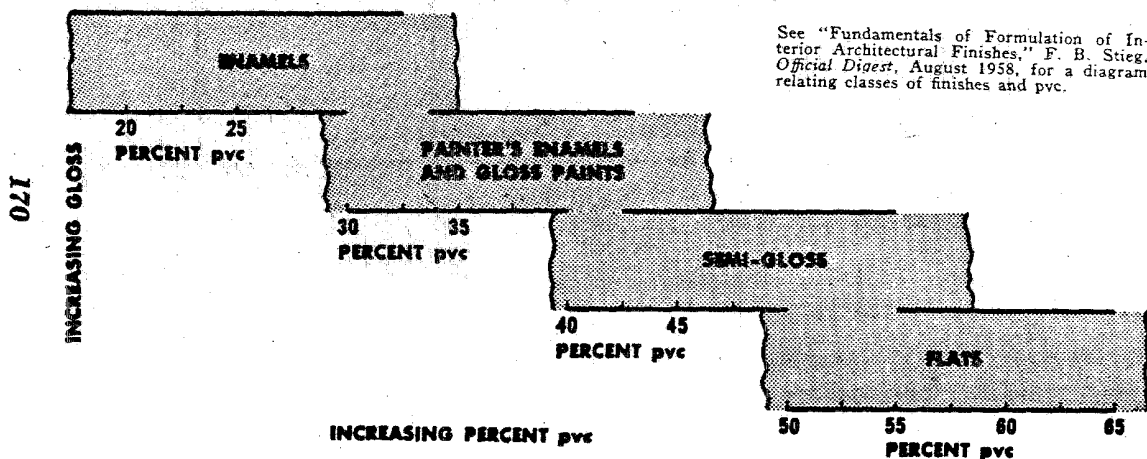
##### Interior Architectural Finishes

###### General

THE simplest and most widely acceptable classification of interior architectural finishes is according to gloss of the dried film into the three groups, flat, semi-gloss, and gloss. Frequently the first mentioned is divided into flat wall paints, wall primers and sealers, combination primer-finish coat and overallsomine paints while the last mentioned group is divided into the three divisions—gloss paints, painters' enamels and enamels.

*Gloss dependent upon pigment volume concentration.* Although a number of factors determine gloss, one was early most easily recognizable, namely the content of total pigment by volume of the film. Early recognition of this factor was afforded by the simplicity of decreasing gloss by increasing the amount of pigment in a paint without changing the amount of non-volatile vehicle. That this was a relation between pigment volume and volume of non-volatile vehicle

# INTERIOR ARCHITECTURAL FINISHES ACCORDING TO PIGMENT VOLUME CONCENTRATION (pvc)



was readily apparent by noting the lesser weight of a pigment or extender of low specific gravity which was required to reduce gloss, in comparison with the greater weight of a pigment of higher specific gravity used for the same purpose. Throughout this discussion, the content of pigment by volume of the film is termed "pigment volume concentration" and is expressed as a percentage by volume. Thus for example, one volume of pigment and four volumes of non-volatile vehicle will be expressed as "20% pigment volume concentration" and will be abbreviated "20% pvc." Frequently this factor is expressed as the ratio of pigment volume to non-volatile vehicle volume, or of non-volatile vehicle volume to pigment volume. Thus, in the example just cited, these ratios would be, in order, 0.25 and 4.

Almost without exception for a given pigment and a given vehicle, gloss will vary in a regular way with pigment volume concentration, increasing as the pigment volume concentration is decreased.

*Pigment volume concentration primary determinant of traditional classification.* Because other factors also determine gloss, an exact general relationship between pigment volume and gloss of interior architectural finishes cannot be given. Nevertheless, in the light of established practice there are overlapping ranges of pigment volume concentration associated with the classes of interior architectural finishes as depicted in the accompanying figure. These ranges have influenced formulation perhaps more than any other single factor. For example, in the transition from gloss to flat paint by an increase in pigment volume, high consistency resulted so that additional thinner was required for brushability. In the flat paint the large proportion of thinner brought on a demand for vehicles having a structure to seal porous surfaces, as well as a need in many cases for suspending and bodying agents. Particularly with the introduction of the Trianox pigments which are non-reactive chemically with the vehicle, proper structure of vehicle could be readily utilized without fear of formation of objectionable reaction products.

Furthermore, because of change in hiding power (in terms of spreading rate) of the pigment with change in pigment volume concentration, different types of

Titanox came to be demanded for different types of interior architectural finishes. Thus at the high pigment volume in flat paints, the amount of extender or non-hiding pigment may be increased beyond that required for flattening effect, whereas at the low pigment volume in enamels much less extender may be used. As a result, unextended titanium dioxide such as Titanox-RA has come to be demanded for high gloss enamels having exceptionally high hiding power, whereas the extended titanium pigment Titanox-RCHT (30% rutile  $\text{TiO}_2$ , 70% calcium sulfate) has established itself in flat paints which require a relatively high percentage of extender. Between these two types is Titanox-C-50 (50% rutile  $\text{TiO}_2$ , 50%  $\text{CaSO}_4$ ) for intermediate pigment volumes such as for semi-gloss finishes and flats in which total pigment volume or total non-volatile must be lowered due to peculiarities of the vehicle system.

It is well recognized that in order to utilize titanium dioxide at high total pigment volume concentration it should be extended so that its hiding power per pound will be increased. As the pigment volume concentration is decreased, less extender may be tolerated and straight titanium dioxide may have to be used in order to maintain exceptionally high hiding power. Although stated in relation to interior architectural finishes, this principle also governs any white or light colored coating to which titanium pigments are applicable.

No single property of interior finishes is exclusive of others. Despite the traditional acceptance of a relationship between pigment volume concentration and gloss even so far as to classify interior finishes, a general quantitative rule cannot be developed. It may be said, however, that the probability of producing high gloss at high pigment volume concentration or dead flatness at low pigment volume concentration is usually low, although there are exceptions such as the employment of extenders such as diatomaceous silica at rather low total pigment volume to reduce gloss.

*Volatile thinner varies with change in pigment volume concentration.* It has been mentioned that in going from gloss to flat paint the proportion of volatile thinner in the vehicle is increased, or conversely the proportion of non-volatile in the vehicle is de-

creased. As a result, certain ranges of non-volatile content of the vehicle have become traditionally associated with the types of interior finishes, of the following order:

|                | Non-volatile<br>% by weight<br>of vehicle | Volatile thinner<br>% by weight<br>of vehicle |
|----------------|-------------------------------------------|-----------------------------------------------|
| Flat .....     | 25-40                                     | 60-75                                         |
| Semi-gloss ... | 30-50                                     | 50-70                                         |
| Gloss .....    | 45-75                                     | 25-55                                         |

These ranges overlap just as do the ranges of pigment volume concentration. Nevertheless with the vehicles ordinarily used, they serve to classify interior architectural finishes. It should be borne in mind that although the proportion of volatile thinner in the vehicle may vary according to these ranges between flat, semi-gloss and gloss paints, its proportion of the total paint may be quite similar or occasionally identical. Thus, from the following table, non-volatile content by weight of the vehicle falls in the above range yet each paint contains 45% total volatile thinner by volume. This means that the unadjusted cost of thinner is the same in each paint.

#### TO 100 GALLONS OF PAINT

| Type of<br>Interior Paint | Pigment            |          |
|---------------------------|--------------------|----------|
|                           | Pounds             | Gal. per |
| Flat                      | Titanox-RCHT 688 } | 33       |
|                           | Whiting 172 }      |          |
| Semi-gloss                | Titanox-RCHT 518 } | 24.75    |
|                           | Whiting 129 }      |          |
| Enamel (gloss)            | Titanox-RA 385     | 11       |
|                           |                    | 20       |

| Vehicle |                         |                         |                               |
|---------|-------------------------|-------------------------|-------------------------------|
|         | % non-vol.<br>by weight | % non-vol.<br>by volume | Gal. of total<br>Vol. thinner |
| Gal.    |                         |                         |                               |
| 67      | 37.5                    | 32.8                    | 45                            |
| 75.25   | 46.7                    | 40.2                    | 45                            |
| 89      | 56.1                    | 49.4                    | 45                            |



On the other hand if the volume of non-volatile vehicle in the paint is maintained constant, the traditional range of non-volatile vehicle content will not apply between flat, semi-gloss and gloss. Instead of the usual relationship the exact opposite will be found, that is, volatile thinner will be increased in gloss paints and decreased in flat paints. Thus, from the following table, no thinner is permissible at 60% pvc where 40% of the paint by volume must be volatile thinner (No. 1). Yet at 20% pvc, (No. 3), thinner is permissible conforming to the traditional pigment-vehicle pattern of an enamel. The relationships shown in the following table are not traditional because they would be associated with some undesirable property in one or more of the types of interior paint. Thus, the enamel (No. 6) represented by 22% non-volatile vehicle by volume of the paint would, usually, have excessively thin consistency, whereas the flat (No. 1) at 40% non-volatile by volume of the paint would be a paste.

To 100 GALLONS OF PAINT

| No.          | Type of Interior Paint | Pigment |      | Gal. | % |
|--------------|------------------------|---------|------|------|---|
|              |                        | Pounds  | Gal. |      |   |
| 1 Flat       | TITANOX-RCHT           | 1253    | 60   | 60   |   |
|              | Whiting                | 313     |      |      |   |
| 2 Semi-gloss | TITANOX-RCHT           | 766     | 32.7 | 45   |   |
|              | Diat. Silica           | 85      |      |      |   |
| 3 Enamel     | TITANOX-RA             | 350     | 10   | 20   |   |
| 4 Flat       | TITANOX-RCHT           | 688     | 33   | 60   |   |
|              | Whiting                | 172     |      |      |   |
| 5 Semi-gloss | TITANOX-RCHT           | 376     | 18   | 45   |   |
|              | Whiting                | 94      |      |      |   |
| 6 Enamel     | TITANOX-RA             | 192     | 5.5  | 20   |   |

| Vehicle |                  |                        |  |      | % |
|---------|------------------|------------------------|--|------|---|
| Gal.    | Non-vol. Vehicle | Total Gal Vol. Thinner |  |      |   |
| 40      | 40               | 0                      |  | 100  |   |
| 67.3    | 40               | 27.3                   |  | 66   |   |
| 90.0    | 40               | 50.0                   |  | 51   |   |
| 67      | 22               | 45.0                   |  | 37.5 |   |
| 82      | 22               | 60.0                   |  | 32.4 |   |
| 94.5    | 22               | 72.5                   |  | 28.4 |   |
| 174     |                  |                        |  |      |   |

Pigment and Vehicle as Determinants of Properties of Interior Architectural Finishes

With pigment volume concentration affording a differentiation between flat, semi-gloss and gloss, obviously manipulation of the pigment portion or of the vehicle portion will provide the particular properties desired in the paint. Certain properties of the paint are influenced predominantly by the pigment, others by the vehicle. Those properties mainly dependent upon the pigment are:

- Hiding Power
- Reflectance
- Gloss, sheen or flatness

Those mainly dependent upon the vehicle are:

- Consistency
- Working qualities, such as brushability
- Leveling and flow (running and sagging)
- Drying
- Color or chromaticity of whites
- Color retention (after-yellowing)
- Flexibility
- Adhesion and penetration into porous surfaces

It must be remembered, of course, that pigment and vehicle together account for the properties of the wet paint and the dried film so that no one property depends exclusively upon pigment or vehicle. For example, consistency, while determined by the vehicle at a constant pigmentation, may be greatly altered by changing a pigment component, such as the type of extender, as recognized by experienced formulators.

Flat Wall Paints

Qualities

Before discussing the use of TITANOX pigments in flat wall paints, it is well to recall that these paints must be easily applicable to large surfaces and must dry reasonably fast to provide lasting decoration characterized by:

- 1. Pleasing matte or flat (low gloss) finish
- 2. High reflection of light

3. Whiteness or brilliancy of tints
4. Uniformity of color and sheen
5. Non-yellowing
6. Cleanability
7. Good repeatability

#### Components governing Qualities

The components of flat wall paints which must be balanced to obtain the qualities desired in the paint, comprise all or several of the following:

1. Prime or hiding Pigment (and colors)
2. Extender or non-hiding pigment
3. Suspending agent
4. Vehicle or binder (non-volatile)
5. Drier
6. Thinner
7. Bodying or thickening agent
8. Anti-skimming agents and deodorants

The proper selection of pigment and non-volatile vehicle and their proper combination account for the film properties of the paint. Considering ease of application broadly, this is also related to consistency or body and also flow of the paint, its brushability or "rollability" and condition in the package on storage. While these qualities are dependent upon the proper combination of components, they are largely influenced by suspending agents and bodying or thickening agents.

#### Relationship of Components of Flat Wall Paints

##### Prime Pigment

Titanox-RCHT has attained a pre-eminent position as the prime pigment for white and light colored flat wall paints because it makes easy the achievement of all of the qualities desired in these paints. The low specific gravity of this pigment contributes to the desired high pigment volume through its exceptionally fine and stable extender (calcium sulfate anhydrite). High light reflection or brightness, high hiding power, brilliancy of tints and contribution to non-yellowing

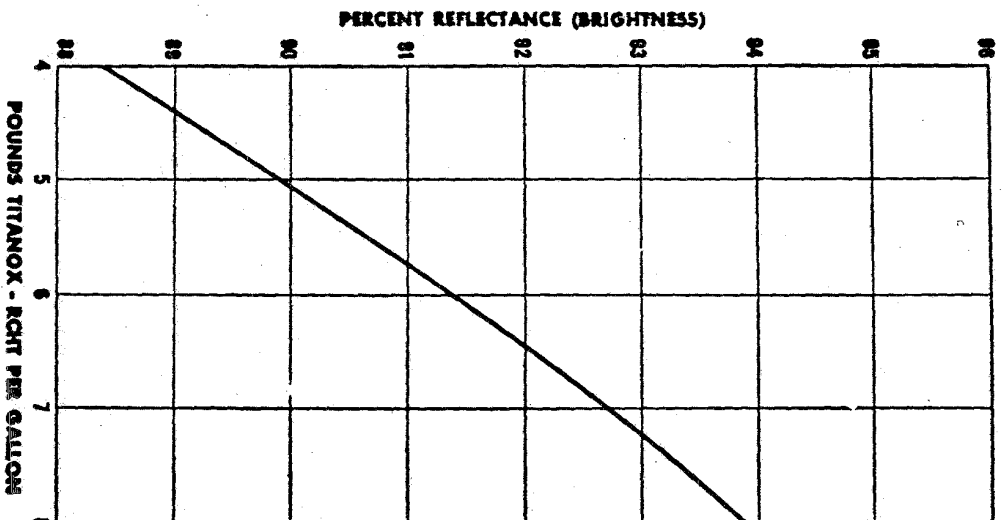
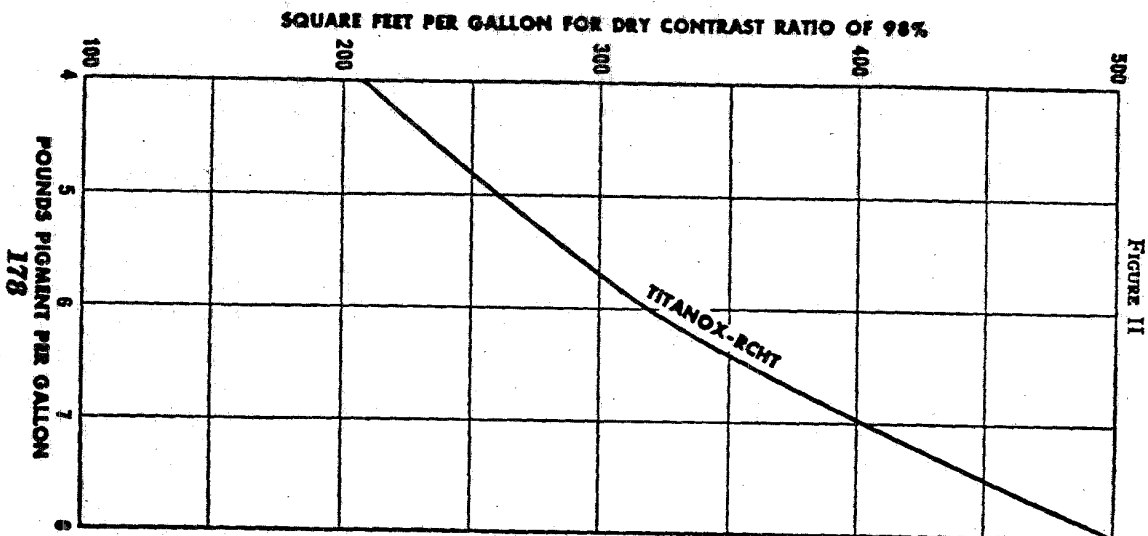


FIGURE I



result from its inherent properties of high refractive index at optimum particle size and chemical stability. Its lack of chemical reactivity permits the use of a wide range of vehicles to secure any type of flat finish desired.

Examples of brightening power and hiding power of TITANOX-RCHT are illustrated in Figures I and II which while not intended for exact application to any given case are useful guides. Brightness and hiding, as shown near 6 pounds per gallon of pigment (the amount generally found at the high pigment volume of flat wall paints), are illustrative of the unusual effectiveness of this pigment. Exceptionally high brightness afforded by TITANOX-RCHT enables the use of small amounts of dark colors such as black to increase hiding power. An example of the increase in hiding power of a flat paint as brightness is decreased through addition of color is shown in Figure III.

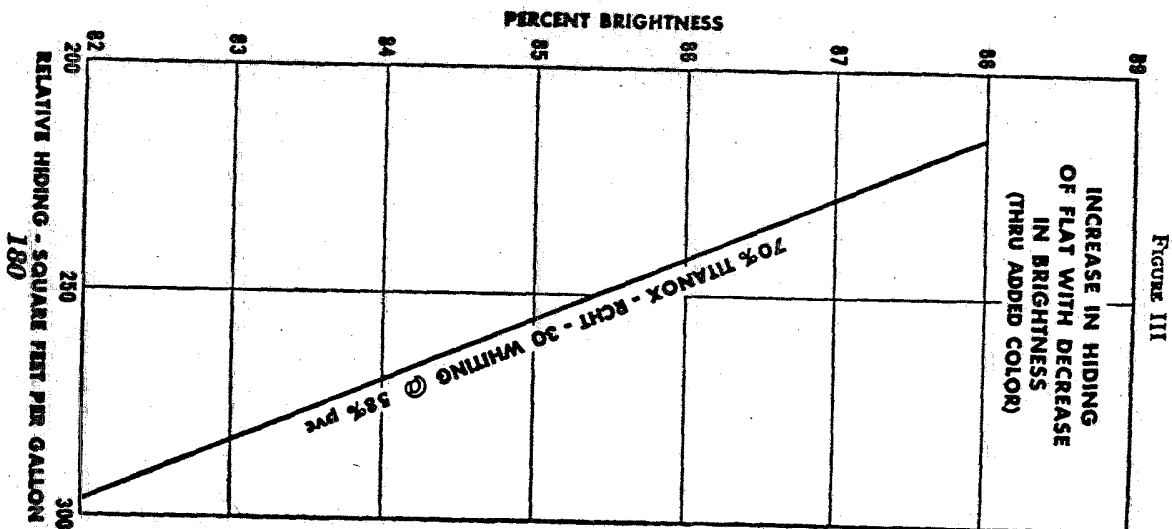
#### Composite TITANOX pigments preferred to "pure" titanium dioxide plus extender

Generally, TITANOX-RA or other "pure" rutile titanium dioxide blended with extender is not a suitable replacement for TITANOX-RCHT, because of lower hiding at the same cost and usually the need for at least two types of extender to secure other properties attainable with TITANOX-RCHT. In the following table an interesting comparison of brightness and hiding power of flat wall paints pigmented with TITANOX-RCHT in one case and a blend of TITANOX-RA and extender in the other at equal costs reveals the superiority of the former.

#### PARALLEL FLAT WALL PAINTS AT EQUAL COST

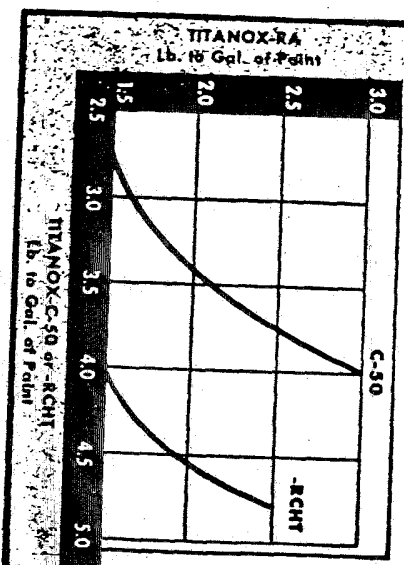
|                      | TITANOX-RCHT | Blend of<br>TITANOX-RA<br>plus Extender |
|----------------------|--------------|-----------------------------------------|
| Brightness % .....   | 89.2         | 85.0                                    |
| Hiding sq.ft./gal... | 330          | 207                                     |

Whether the amount of "pure" titanium dioxide considered necessary in flat wall paints be low or high, the composite TITANOX (rutile-calcium) pigments are preferable to the "pure" pigments. Indeed the com-



posite pigments function at a lower level of pounds of  $\text{TiO}_2$  per gallon of paint. A striking example of this is the relationship of the number of pounds of the composite pigments equivalent to the "pure" pigment to yield similar hiding power in a particular series of flat wall paints as shown in Figure IV. In this series, note that per gallon of paint, 4.35 pounds of Titanox-RCHT (30%  $\text{TiO}_2$ ), 3.15 pounds of Titanox-C-50 (50%  $\text{TiO}_2$ ) and 1.75 pounds of Titanox-RA (rutile "pure"  $\text{TiO}_2$ ) were equivalent. The role of Titanox-C-50 to replace higher concentration of "pure" pigment is also suggested by this series. Note that 4 pounds of Titanox-C-50 (50%  $\text{TiO}_2$ ) was equivalent to 3 pounds of the "pure" pigment. Of course in this series, all factors were comparable—constant pvc (65%), the same alkyd vehicle, the same total non-volatile content of paint (40%) while in addition to the pounds of Titanox, extenders selected for best results were added to bring total pvc to 65%.

**Figure IV**  
Example of Equivalence\*  
of composite Titanox (rutile-calcium)  
pigments and "pure" pigment  
plus extender



\*For illustrative purpose only—not to be applied to any paint system selected at random.

Expanding this series of paints to a broader range of total pigment volume concentration yielded the no less striking relationships shown in Figures V and VI. These illustrate the long established fact that the true composite Tiranox pigments produce more hiding power and other pigment benefits in relation to their  $\text{TiO}_2$  content than does the "pure" pigment.

Figure V

Example of equivalence\* of Tiranox-RCHT (30%  $\text{TiO}_2$ ) and "pure" titanium dioxide plus extenders

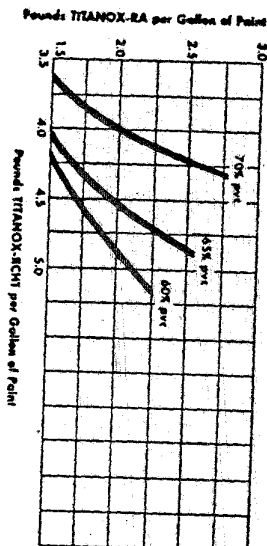
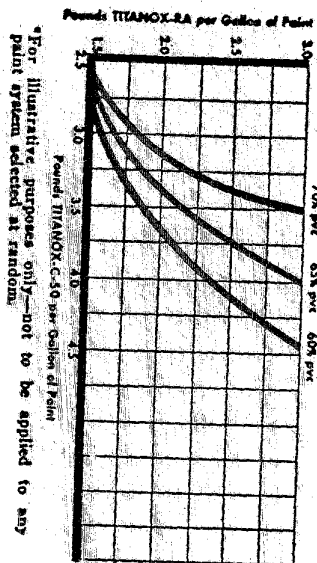


Figure VI

Example of equivalence\* of Tiranox-C-50 (30%  $\text{TiO}_2$ ) and "pure" titanium dioxide plus extenders



\*For illustrative purposes only—not to be applied to any paint system selected at random.

## Extenders

In flat wall paints, extenders or non-hiding pigments are usually indispensable to the attainment of proper sheen or degree of flatness. While suitable flatness may be obtained with Tiranox-RCHT or Tiranox-C-50 as sole pigment the amount used for dead flatness may go beyond the traditional range of pigmentation previously mentioned, and other properties may be impaired. Extender usually accounts for 20% to 40% of the total pigment by weight, the remainder being Tiranox-RCHT, the whole usually in the range of 55% to 62% PVC.

Extenders which possess high oil absorption and irregularity of particle shape are most effective in reducing gloss and achieving flatness. Roughly in order these are:

- Diatomaceous silica
- Fibrous talc (magnesium silicate)
- Colloidal silica
- High oil absorption calcium carbonate
- China clay

Natural and precipitated calcium carbonates though not as high in flattening effect usually constitute the majority of the extender content since they are readily dispersible and do not seriously affect consistency and color.

## Balance between Extender, Prime Pigment and total PVC

The selection of the right extender combination at the right pvc is essential to the attainment of flatness accompanied by all other desirable paint and film properties such as consistency, stain removal, uniformity of tint over surfaces of varying porosity and of course maximum hiding power per dollar of pigment.

Within the range of practical proportions of prime pigment and extender for any given combination there is usually a maximum pvc which should not be exceeded if all film properties are to be satisfactory. Of course there is a minimum too, below which flatness and its uniformity may be lost, but usually the danger

in flat wall paint formulation is in exceeding the maximum.

As a general rule, the maximum pvc which should not be exceeded varies indirectly with the oil absorption or vehicle absorption of the extender or combination of extenders. Within the usual range of pigmentation of flat wall paints, high pvc may characterize paints containing appreciable proportions of low oil absorption extenders such as ground limestone whittings, whereas lower pvc may characterize paints containing appreciable proportions of high oil absorption extenders such as certain clays and diatomaceous silica.

Undue lowering of pvc, where high oil absorption and highly flattening extender is needed, is prevented by combining a low oil absorption extender with the high.

In general, too, pvc becomes critical when the vehicle is deficient in penetration resistance and also when the proportion of extender is greatly increased to reduce tinting strength of the white pigmentation to provide dark colors.

*Because the titanium dioxide content of TIRANOX rutile-calcium pigments is integrated with the extender, the whole functions largely as a pigimentary unit.* Similar dilution of "pure" titanium dioxide by adding extender is generally not feasible and the usual result is a conglomeration of loose titanium dioxide particles and extender particles. At the pvc level of flat wall paints where appreciable dilution of "pure" titanium dioxide is necessary, the fine particles of this pigment can be crowded together and thereby lose hiding efficiency. This effect is especially noticeable when attempts are made to increase hiding power by increasing the proportion of "pure" titanium dioxide, especially when total pvc and total non-volatile must be maintained constant. On the other hand the titanium dioxide of TIRANOX-RCHT and TIRANOX-C50 is carried into further dilution largely upon its own extender. As a result maximum hiding efficiency of the titanium dioxide is maintained in these TIRANOX composite pigments upon dilution with added extender.

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### Suspending Agents

*Aluminum Stearate*—Like many polar compounds of similar type, aluminum stearate is relatively insoluble in paint liquids and presents a colloidal dispersion which prevents "caking" of pigment in the container. Aluminum stearate, however, will affect the consistency of the paint and is used for this purpose particularly in producing shortness in stipple flats. Usually the types of aluminum stearate lowest in "free stearic acid" content are most effective.

Aluminum stearate is most effective when incorporated as solid during grinding of the paint. Caution should be observed in grinding dispersed gels of aluminum stearate through paint mills as the structure upon which suspension (maintenance of proper degree of flocculation of pigment) depends, may be lost. Aluminum stearate also aids the bodying action of aqueous bodying agents. In addition to aluminum stearate, stearated aluminum silicates, metallic soaps and specially treated extenders also have long been used as suspending agents.

*Modified Bentonite—Bentone 34*—Products resulting from cation exchange reactions between organic bases and bentonite are unique and therefore best identified by the designation Bentone.\* Dimethyldioctadecyl ammonium bentonite called Bentone 34 is highly effective as a suspending agent. This complex swells and is dispersed as a gel in organic systems. In flat wall paint vehicles the continuous gel structure afforded by Bentone 34 prevents hard settling of pigment agglomerates. A solid, Bentone 34 is ground into the paint along with prime pigment and extenders. Mixing into the finished paint especially under light mixing conditions is usually not recommended because Bentone 34 must be well dispersed for maximum benefit. In addition to value as a suspending agent, Bentone 34 is also a bodying agent.

### Vehicle

Because of the high pigmentation of flat wall paints the non-volatile portion of the vehicle must possess high viscosity and practically a gel structure not only

\*Registered trade mark of National Lead Company.

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for suitable wet paint properties but also for proper drying and soundness of film.

As regards the properties of the paint mainly dependent upon the non-volatile vehicle:

Consistency will vary obviously with the viscosity of the vehicle and particularly where aqueous bodying agents are employed according to the wetting and dispersive action of vehicle on the pigment. Low viscosity oils having low acid number (unpolymerized oils) produce puffy uncontrollable consistency with aqueous bodying agents, whereas high acid high viscosity (polymerized) oils do not. However, both types of oils are used, often a small proportion of the uncooked oil being added to obtain a desired effect.

Color of the paint (deviation from whiteness) will usually be affected to a greater extent by the type of resin than any other factor. For example, after-yellowing is most pronounced with resins, such as linseed rosin. However, any component having poor color and color retention will affect the color of the paint.

Drying of the paint, of course, is speeded up by faster drying vehicle—varnishes are usually faster drying than all oil types. Naturally, large percentages of uncooked oils should be avoided where fast drying is desired.

Hardness depends largely upon resin content. On account of high pigmentation the oil length of varnishes is usually kept fairly long—on the order of 100 gallons in length and seldom under 50 gallons to 100 pounds of resin.

Penetration into porous surfaces although dependent upon the pigment-vehicle combination, is most strongly influenced by the vehicle. A penetrating vehicle makes balance between prime pigment-extenders and pvc difficult to attain. The "filter paper ring test" serves as a simple indicator of "non-penetration."

\* The cover of a one half pint friction top can is filled level with the paint, under test and is covered with a piece of Whatman No. 2 filter paper and is allowed to stand for 3 hours. The paper is then removed, the excess paint is scraped off and the width of the transparent oil ring is measured.

## Drier

Lead and cobalt driers are generally used with Tri-nax pigmented flat wall paints. In some cases lead content is provided by the leaded vehicle alone or in combination with added lead drier. While cobalt content is usually on the order of .03% to .06% (Co) on the non-volatile vehicle, lead is maintained 5 to 10 times as high as cobalt. Manganese is generally avoided inasmuch as it does not contribute to drying and harms color.

## Bodying Agents

The use of bodying agents in flat wall paints is largely the result of the need for consistency of the "false body" and also thixotropic type to insure coverage of the surface in the shortest time, or in other words easy working properties of the paint to secure all of its film properties. These bodying agents raise yield value, but in many cases after flow has started it can be maintained at relatively low forces. Thixotropy is evidenced after the force has been removed, such as cessation of stirring or brushing when the paint returns to its original state at the proper rate.

This effect is secured largely through flocculation of the pigment effected by water from the bodying agent dispersed in the paint. Water solutions of alkalis, borax and emulsions, hydrated calcium linoleate pulp, dilute dispersions of soaps in water have all performed this function.

The use of water solutions, however, is not widely practiced now because of difficulty in controlling their effects in most flat paints. Strong bodying action or setting up of flocculated structure results when such solutions are added to many pastes before grinding, rendering grinding difficult or impossible. Depending upon the system there is an optimum ratio of pigment, non-volatile vehicle and thinner at which such solutions should be added, largely dictated by the nature of the vehicle solids. Except with highly dispersing liquids, aqueous solutions should be added to the complete paint completely processed.

Hydrated magnesia-treated linseed oil with the high-

by polymerized oils and varnishes of flat wall paints, will cause a gradual and controlled increase in body. Full stability is reached in a period of days depending upon the system and is maintained thereafter. Contrasted to raw alkaline solutions which are added only in small amounts such as 1%-3%, magnesia oil may comprise a major portion of the vehicle. For faster action though, magnesia oil may be mixed with water and added in smaller amounts. But since the undiluted oil may comprise a major portion of the vehicle, it offers a means of securing the type of body desired with great certainty.

There follows a classic formula, the basis for development of many flat wall paints, illustrating proper combination of the components of a heavy bodied flat wall paint:

#### *For 100 gallons of Paint*

|                                                                            |                            |
|----------------------------------------------------------------------------|----------------------------|
| Titanox-RCHT .....                                                         | 690 Pounds                 |
| Whiting .....                                                              | 172 "                      |
| Litharge .....                                                             | 17 "                       |
| Aluminum stearate .....                                                    | 4.3 "                      |
| Lined rosin varnish (100 gal. oil length, 50 china wood, 50 linseed) ..... | 22.0 Gallons               |
| Hydrated magnesia oil .....                                                | 8.5 "                      |
| Kerosene .....                                                             | 4.3 "                      |
| Mineral spirits .....                                                      | 31.2 "                     |
| Dipentene .....                                                            | 1.3 "                      |
| 6% cobalt drier .....                                                      | 0.2 "                      |
| Pigment—64.4% .....                                                        | Vehicle—35.6%              |
| P.V.C.—60.7% .....                                                         | Non-volatile vehicle—37.5% |

#### **Modified Bentonite — Bentonite 34 as bodying agent**

This material used in Titanox pigmented flat wall paints as suspending agent may also be employed as a bodying agent. The addition of polar solvent\* to the amount of Bentonite 34 suitable for the particular system yields maximum bodying effect.

\* See "Bentonite Handbook" issued by National Lead Company.

#### **Calcicoat and Primer-Flat Paints**

##### **Calcicoater**

Largely as a result of pioneer work of the laboratory of Titanium Pigment Corporation, the flat wall paint applicable directly over calcimined areas particularly ceilings, became a standard item of the paint industry. These had to possess almost all of the qualities of a flat wall paint mentioned on page 175 and, in addition, exceptional adherence and resistance to penetration of porous surfaces. To secure these properties, highly polymerized oils neutralized usually by lime and sometimes magnesia were employed.

Perilla oil at first constituted the vehicle for bodying and lining, but was replaced by linseed and fish oils.

The efficacy of these paints in coating ceilings is derived also from their high dispersive action on Titanox-RCHT which is thoroughly dispersed. Apparently thorough dispersion of pigment provides a pigmented mass which has greater resistance to penetration as a result of the inability of vehicle as such to leave the pigment and enter the voids of the surface.

Calcicoaters are usually of heavy body, fairly long pastes, permitting reduction with 1 volume mineral spirits to 2 volumes of paint.

A typical formula for this type of paint follows:

##### **CALCICOATER**

#### *For 100 gallons of Paint*

|                            |                            |
|----------------------------|----------------------------|
| Titanox-RCHT .....         | 675 Pounds                 |
| Precipitated Whiting ..... | 169 "                      |
| Lined linseed oil .....    | 64.2 Gallons               |
| 6% cobalt drier .....      | 0.17 "                     |
| 1% soap solution .....     | 3.4 "                      |
| Pigment—63.4% .....        | Vehicle—36.6%              |
| P.V.C.—62.5% .....         | Non-volatile vehicle—32.9% |

The lined linseed oil of this formula is of semi-solid consistency at non-volatile content of 35% which contains about 1.6% Calcium (Ca) derived from the reacted lime.

## Primer-Finish Flat Wall Paints

To achieve the degree of "non-penetration" and adherence that would have to be present in a single paint to act as both primer and finish naturally suggested the use of vehicles similar to the calcicoater type. Of course, to meet the general requirements a harder film was demanded in comparison with that of ceiling paint. As a result, experiments on the treatment of highly polymerized varnish with lime and magnesia led to limed varnishes.

A formula typical of a flat wall paint combining priming and finishing qualities in one paint follows:

### For 100 gallons of Paint

|                                                                      |              |
|----------------------------------------------------------------------|--------------|
| TITANOX-RCHT .....                                                   | 555 Pounds   |
| Natural Whiting .....                                                | 238 "        |
| Litharge .....                                                       | 1.2 "        |
| Aluminum stearate (high acid) .....                                  | 5.9 "        |
| Ester gum varnish treated with hydrated lime (60 gal, linseed) ..... | 37.2 Gallons |
| Alkali refined linseed oil .....                                     | 6.4 "        |
| Heavy mineral thinner .....                                          | 23.2 "       |
| 6% cobalt drier .....                                                | 0.3 "        |
| 24% lead drier .....                                                 | 0.8 "        |
| 15% sodium hydroxide solution .....                                  | 0.2 "        |
| Pigment—62.2%                                                        |              |
| P.V.C.—58.7%                                                         |              |
| Vehicle—37.8%                                                        |              |
| Non-volatile vehicle—38.3%                                           |              |
| Oil length—84 gal.                                                   |              |

The ester gum varnish in this paint had viscosity higher than Z-6 at 50% non-volatile indicating its high degree of polymerization. The lime content of the non-volatile portion was about 3%.

The sodium hydroxide solution was added to the complete paint to assure further neutralization of fatty acids in order to release fully the large polymers as well as to impart thixotropy. The paint in this case is of brushable consistency. In formulating primer-fats of brushing consistency particular attention had to be paid to the factors governing package stability.

## Alkyd Flat Wall Paint

The development of alkyd resins having properties of a flat wall paint vehicle has paralleled the development of "odorless" mineral spirits. Such alkyd solutions too are "odorless" as well as being highly polymerized and modified to yield all of the qualities expected of an alkyd resin plus sealing ability of porous surfaces as developed in conventional primer-fats.

High dilution or high thinner content may characterize alkyd flats resulting in low solids of the final vehicle which makes for high total pigment volume concentration. Because an alkyd resin like any true flat wall paint liquid presents a continuous film, such high pvc similar to that of traditional flat wall paints is entirely feasible.

Since the advent of latex paints, emphasis has been directed in laboratory evaluation of flat wall paints to film qualities peculiar to latex paints. The rubber-like nature of the binder of latex paints emphasized cleanliness or stain removal, also "color uniformity" of tints due to lowered penetration of vehicle into porous surfaces.

The suitably designed alkyd flat vehicle offers a binder approaching that of an enamel which accounts for alkyd flats being often designated "flat enamels." And with "non-penetrating" qualities also developed such a film embodying enamel toughness is, when properly pigmented, also highly cleanable and uniform in color over surfaces of varying porosity.

The formulation of flat wall paints with alkyds follows established principles of flat wall paint formulation. But with emphasis being placed upon cleanliness (scrubbability, stain removal) and color uniformity over surfaces of varying porosity particular attention must be given to these two factors:

1. "Non-penetration" of the vehicle.
2. Balance between prime pigment extenders (both as to type and amount) and pigment volume concentration (pvc).

A guide to the first can be gained from the simple "filter paper ring test"—see page 186.

The second factor as discussed on page 183 can be quite critical in alkylid flats especially when pvc must be raised widely to counteract the low total solids by volume laid down in the film. Consistency desired may also require high pvc. Where film porosity of a flat paint is critical the maximum total pvc that should not be exceeded (for a given pigment-extender combination) is in all probability the same as the percentage by volume of total pigment present when the voids between the particles and aggregates of the pigment-extender are filled by non-volatile vehicle.

Pigment volume concentration derived from the actual determination of oil absorption by the spatula method can be used as a guide or indication of this maximum permissible or critical pvc. But the oil absorption of the combination, that is the mixture of pigments and extenders must be determined. It cannot be calculated from the oil absorption of each component. The role of critical pvc in the formulation of flat paints is discussed by F. B. Stieg and D. F. Burns in "The Effect of Pigmentation on Modern Flat Wall Paints," *Official Digest*, Feb. 1954. The concept of critical pvc (CPVC) is discussed by W. S. Asbeck, D. D. Laiderman and M. Van Loo, "Oil Absorption and Critical Pigment Volume Concentration," *Official Digest*, Mar. 1952.

Alkylid flats are no exception to other true wall paints in that they are most effectively and efficiently pigmented with composite TITANOX (futile-calcium) pigments. Because of emphasis on properties related to porosity of film, choice of extender and amount to be used with TITANOX-C-50 or TITANOX-RCHET should be made in relation to critical pvc. At relatively high pvc, fine particle extenders (having high oil absorption and strong flattening effect) added to the already efficiently extended pigment dictate lowering of pvc, while coarse extenders allow pvc to be raised. Because critical pvc or the maximum pvc permissible depends upon the packing of pigment and extender particles and aggregates, combinations of fine and coarse extenders and of different particle shapes may be employed if necessary to maintain a desired pvc.

An exact value of critical pvc for any pigment-vehicle system depends upon the dispersive power of

the vehicle and the method of pigment dispersion in addition to the factors previously mentioned. But using spatula oil absorption as a guide an insight can be gained into the variation of critical pvc with type and amount of extender. It is helpful to a clearer picture of this relationship to express the content of pigment and extenders on a volume basis (% by volume of total pigment). Critical pigment volume concentration as derived from spatula oil absorption of some pigment-extender combinations is shown in Table I and Table II.

TABLE I  
Indication of Critical pvc (as derived from spatula oil absorption determination)<sup>2</sup>

| Extender                                  | TITANOX.                 |                                                        |
|-------------------------------------------|--------------------------|--------------------------------------------------------|
|                                           | Extender<br>%<br>by vol. | C-50<br>%<br>by vol. combination<br>Critical pvc<br>of |
| Atomite Whiting .....                     | 50                       | 50 62.5                                                |
| Non-fer-al Whiting ....                   | 50                       | 50 64.5                                                |
| Snowflake Whiting ....                    | 50                       | 50 65                                                  |
| Duramite Whiting .....                    | 50                       | 50 67                                                  |
| York Whiting .....                        | 50                       | 50 68                                                  |
| Wollastonite P-1 .....                    | 50                       | 50 63                                                  |
| Loriet <sup>1</sup> .....                 | 50                       | 50 60                                                  |
| China Clay (ASP-400) ..                   | 50                       | 50 55                                                  |
| China Clay (ASP-100) ..                   | 50                       | 50 49.5                                                |
| Diatomaceous silica<br>(Celite 281) ..... | 50                       | 50 43                                                  |
| Diatomaceous silica ....                  | 10                       | 50 63                                                  |
| Non-fer-al Whiting ....                   | 40                       | 50 64                                                  |
| Diatomaceous silica ....                  | 10                       | 50 64                                                  |
| York Whiting .....                        | 40                       | 50 64                                                  |

In Table II the "pure" pigment TITANOX-RA is shown at lower content by volume of the pigment-extender combination than are the composite pigments. Higher proportion of composite pigment naturally results from the need for less extender.

<sup>1</sup> National Lead Company—diatomaceous calcium carbonate.  
<sup>2</sup> Fred B. Stieg, "The Determination of CPVC by the Oil Absorption Test Method," Amer. Paint Journal, Sept. 22, 1958.

TABLE II

Critical Pigment Volume Concentration  
(derived from determination of spatula oil absorption)

| Critical pvc for % Titanox-RA by volume<br>(remainder extender) |      | Critical pvc for % Titanox-RCHT by volume<br>(remainder extender) |      |
|-----------------------------------------------------------------|------|-------------------------------------------------------------------|------|
| Whiting A .....                                                 | 20   | Whiting A .....                                                   | 40   |
| Whiting B .....                                                 | 66   | Whiting B .....                                                   | 62.5 |
| Whiting C .....                                                 | 68.5 | Whiting C .....                                                   | 69.5 |
| Whiting D .....                                                 | 69.5 | Whiting D .....                                                   | 66.5 |
| Loridel .....                                                   | 73   | Loridel .....                                                     | 64.5 |
| Diatomaceous silica*                                            | 70   | Diatomaceous silica*                                              | 70   |
| plus Whiting C.....                                             | 60   | plus Whiting C.....                                               | 62.5 |
|                                                                 | 63   |                                                                   | 63   |
|                                                                 | 64   |                                                                   | 63.5 |
|                                                                 | 65   |                                                                   | 62   |
|                                                                 | 66   |                                                                   | 61   |
|                                                                 | 67   |                                                                   | 60   |
|                                                                 | 68   |                                                                   | 60.5 |
|                                                                 | 69   |                                                                   | 62   |
|                                                                 | 70   |                                                                   | 60   |
|                                                                 | 71   |                                                                   | 60   |
|                                                                 | 72   |                                                                   | 62   |
|                                                                 | 73   |                                                                   | 64   |
|                                                                 | 74   |                                                                   | 65.5 |
|                                                                 | 75   |                                                                   | 68   |
|                                                                 | 76   |                                                                   | 69   |
|                                                                 | 77   |                                                                   | 70   |
|                                                                 | 78   |                                                                   | 71   |
|                                                                 | 79   |                                                                   | 72   |
|                                                                 | 80   |                                                                   | 73   |
|                                                                 | 81   |                                                                   | 74   |
|                                                                 | 82   |                                                                   | 75   |
|                                                                 | 83   |                                                                   | 76   |
|                                                                 | 84   |                                                                   | 77   |
|                                                                 | 85   |                                                                   | 78   |
|                                                                 | 86   |                                                                   | 79   |
|                                                                 | 87   |                                                                   | 80   |
|                                                                 | 88   |                                                                   | 81   |
|                                                                 | 89   |                                                                   | 82   |
|                                                                 | 90   |                                                                   | 83   |
|                                                                 | 91   |                                                                   | 84   |
|                                                                 | 92   |                                                                   | 85   |
|                                                                 | 93   |                                                                   | 86   |
|                                                                 | 94   |                                                                   | 87   |
|                                                                 | 95   |                                                                   | 88   |
|                                                                 | 96   |                                                                   | 89   |
|                                                                 | 97   |                                                                   | 90   |
|                                                                 | 98   |                                                                   | 91   |
|                                                                 | 99   |                                                                   | 92   |
|                                                                 | 100  |                                                                   | 93   |

\* National Lead Company—diatomaceous calcium carbonate.  
\* Diatomaceous silica held at 10% of total pigmentation by volume, Titanox varied as shown, Whiting remainder.

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The combination of 50% Titanox-C-50 and 50% extender by volume of total pigment is comparable to the pigmentation of high hiding white alkyl flats as exemplified in the following illustrative formula:

## WHITE ALKYD FLAT WALL PAINT

## For 100 gallons of Paint

|                                                                          |     |         |
|--------------------------------------------------------------------------|-----|---------|
| Titanox-C-50 .....                                                       | 400 | Pounds  |
| Whiting .....                                                            | 320 | "       |
| Bentone 34 .....                                                         | 5   | "       |
| Alkyd Resin Solution ("non-penetrating" type for flat wall paints) ..... | 57  | Gallons |
| Mineral Spirits .....                                                    | 13  | "       |
| Driers and anti-skinning agent.....                                      | 0.9 | "       |

This formula follows accepted principles of flat wall paint formulation as do the following designed for lower hiding and suitability for tint bases.

## Example of

## ALKYD FLAT WALL PAINT

## (Suitable for tint base)

## For 100 gallons of Paint

|                                          |     |         |
|------------------------------------------|-----|---------|
| Titanox-C-50 .....                       | 340 | Pounds  |
| Whiting .....                            | 385 | "       |
| Aluminum stearate .....                  | 3.5 | "       |
| Special Alkyd ("odorless") .....         | 46  | Gallons |
| 40% solids .....                         | 24  | "       |
| "(Odorless)" Mineral Spirits (heavy) ... | 24  | "       |
| Driers and anti-skinning agent.....      | 0.7 | "       |

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# Example of

## ALKYD FLAT WALL PAINT For 100 gallons of Paint

|                                      |      |         |
|--------------------------------------|------|---------|
| TIRANOX-C-50 .....                   | 320  | Pounds  |
| Low oil Abs. Whiting .....           | 310  | "       |
| Diatomaceous silica .....            | 50   | "       |
| Bentone 34 .....                     | 3    | "       |
| Alkyd Resin Solution .....           | 48.5 | Gallons |
| Mineral Spirits .....                | 23   | "       |
| Driers and anti-skinning agent ..... | 0.6  | "       |

"Non-penetrating" qualities are readily developed in alkyd vehicles. As a result, alkyd primer-flats can be readily formulated, as well as highly pigmented paints for ceilings, such as the following:

# Example of

## ALKYD FLAT CEILING WHITE For 100 gallons of Paint

|                                      |      |         |
|--------------------------------------|------|---------|
| TIRANOX-RCHT .....                   | 425  | Pounds  |
| Whiting (14 micron type) .....       | 225  | "       |
| Calcined clay .....                  | 125  | "       |
| Diatomaceous silica .....            | 50   | "       |
| Bentone 34 .....                     | 3    | "       |
| Soya lecithin .....                  | 4    | "       |
| Alkyd Flat Liquid (40% N.V.) .....   | 34.5 | Gallons |
| Long oil alkyd (70% N.V.) .....      | 3.0  | "       |
| Mineral Spirits .....                | 28.0 | "       |
| Driers and anti-skinning agent ..... | 0.5  | "       |

## Water thinned Flat Wall Paints

Interest in water reducible flat wall paints arose largely from the convenience and cheapness of water as thinner and its lack of odor. Of course, this type of paint is an outgrowth of water paints in which casein, soya protein or water dispersible gums serve as binder. While pigments having lower refractive index meet the requirements imposed by ordinary water paints, particularly as the result of excessively high content of pigment, TIRANOX pigments have been a part of these water paints for many years. A typical casein paint composition may consist of 5% TIRANOX-A-WD, 25% talc, 40% barytes, 10% china clay or bentonite, 10% hydrated lime and 10% casein.

It is not surprising that the earliest types of water reducible paint were simply emulsions of oils, varnishes or resins such as alkyds in casein paints, for this is a logical and simple approach. There follows a formula for an oil-reducibles emulsifiable flat wall paint in which casein probably acts as both emulsifier and protective colloid. Products made according to this formula as indicated by tests made in the laboratories of Titanium Pigment Corporation will meet the requirements of Federal Specification TT-P-88a:

## INTERIOR EMULSION PAINT

### For 100 gallons of Paint

|                                      |      |         |
|--------------------------------------|------|---------|
| TIRANOX-A .....                      | 208  | Pounds  |
| China clay .....                     | 490  | "       |
| Dowicide A (preservative) .....      | 4.5  | "       |
| Sodium hydroxide .....               | 1.4  | "       |
| Isster gum-linsed oil solution ..... | 5.9  | Gallons |
| Blown soya bean oil .....            | 8.4  | "       |
| Ianolin .....                        | 0.1  | "       |
| Casein .....                         | 3.3  | "       |
| Water .....                          | 52.3 | "       |
| Pine oil .....                       | 0.4  | "       |
| 24% Lead naphthenate .....           | 0.6  | "       |
| 60% Cobalt naphthenate .....         | 0.2  | "       |
| Pigment—53.6%                        |      |         |
| PVC—62.0%                            |      |         |
| Vehicle—46.4%                        |      |         |
| Non-volatile vehicle—25.8%           |      |         |



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TABLE III

Some Emulsifying Agents

- Aromatic condensation products\*
- Aromatic monosodium sulphionate
- Diglycerol laurate
- Dioctyl sodium sulphosuccinate
- Emulsor AG (unknown composition)
- Fatty alcohol sulphates\*
- Higher sulphonated alcohol derivatives
- Mannide monooleate
- Mineral oil sodium sulphonates
- Mineral oil sulphonates
- Mulsor (unknown composition)
- Non-ionic LD (unknown composition)
- Octyl alcohol—polyethylene oxide condensation product\*
- Polypeptide—fatty acid condensate\*
- Sodium alkyl aryl sulphonates
- Sodium salt of alkylated sodium sulphonate\*
- Sulphonated fatty acid esters
- Sulphonated glyceryl amid
- Sulphonated ethers\*
- Sulphonated fats
- Sulphonated vegetable oils
- Tetra-hydro oxyazine
- Triethanolamine

\* Suitable for use with TITANOX-RCHT and TITANOX-C-50.

TABLE IV

Some Protective Colloids

- Albumen
- Alginate
- Casein
- Dextrin\*
- Gelatin\*
- Lecithin
- Hydroxy ethyl cellulose\*
- Methyl Cellulose\*
- Soya Proteins
- Starches\*
- Water soluble gums (Gum Arabic, etc.)\*

\* Suitable for use with TITANOX-RCHT and TITANOX-C-50.

Through a knowledge of emulsions, water thinned flat wall paints may be made not only with TITANOX unextended titanium dioxide pigments but also the rutile-calcium pigments TITANOX-RCHT and TITANOX-C-50.

This involves judicious use of emulsifiers and protective colloids to secure stable pigmented emulsion systems. Among emulsifying agents and protective colloids, such as those listed in Tables III and IV, interesting combinations may be found to yield paints as exemplified by the following formula:

WATER THINNED FLAT PAINT  
For 100 gallons of Paint

|                                       |      |         |
|---------------------------------------|------|---------|
| TITANOX-RCHT .....                    | 655  | Pounds  |
| Diatomaceous silica .....             | 60   | "       |
| Dowicide "A" (preservative) .....     | 0.4  | "       |
| Forty gal. length varnish.....        | 24   | Gallons |
| Sulphonated castor oil (75% non-vol.) | 3.6  | "       |
| Emulsifying agent* .....              | 2.5  | "       |
| 10% sodium hydroxide solution.....    | 2.5  | "       |
| 25% starch solution.....              | 19.3 | "       |
| Water .....                           | 19.7 | "       |
| 24% lead naphthenate .....            | 1.1  | "       |
| 6% cobalt naphthenate.....            | 0.4  | "       |

\* Isopal CTA: Wetting Agent C.

Latex — water thinned flats

Knowledge of the emulsification of earlier vehicles—oils, varnishes and alkyl resins—is applied directly by the experienced formulator to aqueous dispersions of rubber-like polymers—synthetic latices.

Some of the outstanding features of paints properly formulated with synthetic latices are:

1. Lack of organic solvent odor.
2. Ease of cleaning brushes, rollers and other things involved in the paint job, simply with water.
3. Ease of application over a variety of surfaces.
4. Rapid drying.
5. Minimum elapsed time between coats.
6. Uniformity of appearance over non-uniform surfaces.
7. Ability to bridge or seal openings of porous surfaces.
8. Stability to reworking of the film.
9. Relatively good cleanliness of the fully dried film.

As with earlier emulsion systems, judicious selection of emulsifier and protective colloid is essential. In addition a dispersant is often required and also a defoamer to prevent troublesome foaming during manufacture of the paint. Any latex, regardless of its use, varies in stability according to the nature and content of electrolytes in the water. Therefore care must be exercised in maintaining certain pH limits depending upon the latex.

TIRANOX pigments being chemically inactive are completely adaptable to synthetic latex vehicles. However, where the electrolyte balance of the water in which the polymer is dispersed is critical, water dispersible anatase titanium dioxide, TIRANOX-AWD is not used even if there would be a desire to use anatase pigment. Among the rutile pigments for some critical systems some formulators feel that titanium dioxide as free as feasible from electrolytes should be employed such as TIRANOX-RA-10. But in general the most efficient pigments such as TIRANOX-RA-51 are completely compatible with latices, in properly formulated paints.

Modern emulsion paint systems, perhaps to a greater

extent than any other, require a delicate balance among many factors in order to secure the best performance from the pigmentation.

Pigmentation is governed by the principles generally applicable to flat wall paints, except that some components may be chosen not only for their usual functions, but also specialized ones. For example, some extenders such as calcium carbonates and calcium silicates may also be used to control pH.

In the earliest latex flat paints, pigment volume concentration had to be kept low in order for the binder to yield a continuous film. As a result pvc ranged from 30% to a maximum of about 45%, depending upon the type of latex and type and amount of extenders.

For whites in which highest hiding was demanded, unextended titanium dioxide was preferred for the low pvc. Because of exceptional ease of dispersion and high hiding, TIRANOX-RA-50 was early used in these paints, and as much as possible of high oil absorption and flattening type of extenders had to be used to secure flatness, high reflectance and sufficient hiding. Balance between prime pigment-extender and binder could be critical and highly flattening extender had to be limited to a safe maximum.

Butadiene-styrene, the first latex to be used, would yield only low pvc paints, and frequently casein was the sole choice as protective colloid that would impart suitable consistency and flow. A typical early white paint was formulated with this latex along these lines (for 100 gallons of paint):

|                                         |     |         |
|-----------------------------------------|-----|---------|
| TIRANOX-RA-50 .....                     | 246 | Pounds  |
| China Clay .....                        | 84  | "       |
| Butadiene-styrene latex (48% solids) .. | 48  | Gallons |
| Casein solution .....                   | 17  | "       |
| Water .....                             | 24  | "       |
| Defoamer .....                          | 0.2 | "       |

## Butadiene-styrene plus other emulsions

Among first attempts at raising the pvc of butadiene-styrene emulsion paints was the use of this latex in combination with earlier types of emulsions such as those of varnishes and alkylid resins. It was observed that the maximum pvc that would allow the paint to retain its cleanliness varied with alkylid content about as follows:

| Butadiene-styrene % | Alkylid % | Approx. Maximum pvc % |
|---------------------|-----------|-----------------------|
| 100                 | 0         | 33                    |
| 75                  | 25        | 40                    |
| 50                  | 50        | 45                    |

An example of formulation utilizing an alkylid plus butadiene-styrene emulsion also employed TITANOX-C-50 (with suitable additives selected from those listed on page 198):

### For 100 gallons of Paint

|                                      |      |         |
|--------------------------------------|------|---------|
| TITANOX-C-50                         | 500  | Pounds  |
| Mica                                 | 45   | "       |
| Preservative                         | 4    | "       |
| Butadiene-styrene latex (48% solids) | 24.5 | Gallons |
| Long oil alkylid resin (100% solids) | 11.5 | "       |
| 10% sodium hydroxide solution        | 2.0  | "       |
| Non-ionic emulsifier                 | 3.3  | "       |
| 15% starch solution                  | 15.5 | "       |
| Water                                | 16.6 | "       |
| Defoamer                             | 0.1  | "       |
| Driers                               | 1.2  | "       |

It will be noted that in the above formula, in order to make the emulsion compatible with TITANOX-C-50, a non-ionic emulsifier or dispersant is used, while casein has been eliminated and replaced by starch.

## Increased Stability of latices allows higher pigment volume concentration

In earliest butadiene-styrene latices while pvc had to be restricted to a maximum of some 33% and could be raised as indicated above through use with other emulsions, improved latices of this type allow maximum pvc of 45-50% and higher.

Similarly with other types of latex in general use, maximum pigment volume concentration permissible has been increased due to improvement in latex stability, so that these latices compare about as follows:

| Type of Latex     | Maximum % pvc allowable for relatively non-porous or cleanable film of flat |
|-------------------|-----------------------------------------------------------------------------|
| Butadiene-styrene | Early 33 Current 45-50+                                                     |
| Polyvinyl acetate | 55 60-65                                                                    |
| Acrylic           | 45 50-55                                                                    |

With further improvement in stability and other qualities of latices, restriction of pigment volume concentration below the range ordinarily suitable for flat wall paints, is no longer necessary.

## Improvement in latices plus control of additives increase compatibility with the TITANOX "C" pigments

Although the prominent types of latex, early unstable, have been improved in stability, the additives needed in formulation still must be properly selected, and in any case, the order of addition of ingredients must be carefully controlled to yield stable paints.

With prime pigment, extenders and latex established, the dispersant, wetting agent, protective colloid, anti-foam agent, coalescing agent, freeze-thaw stabilizer, and fungicide or mildewicide, must be selected and properly proportioned.

## The Selection and Proportioning of Additives Dispersing Agents (for pigments and colors)

For dispersing the pigments in water, dispersants often used are: tetrasodium pyrophosphate, sodium hexametaphosphate, potassium tripolyphosphate, soya lecithin, and various proprietary products such as Daxad 30 (Dewey and Almy-Grace Chemical) and Tamol 731 (Rohm and Haas).

The phosphates mentioned above and other anionic dispersants should not be used with the TITANOX "C" pigments, instead non-ionic surfactants such as Tamol 731, soya lecithin (water soluble grade), or other equivalent substances are employed. The anionic dispersants must be excluded when the "C" pigments are used because this type of dispersant is reactive with calcium sulfate.

In general, 0.2% to 1.0% of dispersant based on dry pigment, depending upon the dispersant is required.

### Wetting and Emulsifying Agents

Wetting agents used to reduce surface and interfacial tension, also help pigment dispersion. Ordinarily 0.5 gallon of wetting agent per 100 gallons of paint is suitable.

In butadiene-styrene latex paints using TIRANOX "C" pigments, a non-ionic emulsifying agent added to the pigment slurry (which, of course, should also have a non-ionic dispersant) before addition of the latex will further prevent coagulation of the latex in case it carries an anionic emulsifier which would react with calcium.

Among non-ionic emulsifiers are:

Advantel #33.....Advance Solvents and Chemicals  
Irgal CTA 639.....General Dyestuffs  
Nomic 260.....Sharples Chemicals  
Tergitol NPX.....Union Carbide Chemical  
Triton X-100.....Rohm and Haas

Earliest polyvinyl acetate latices were usually stabilized with large amounts of polyvinyl alcohol and were reactive with calcium ions, but polyvinyl alcohol has been replaced in most current latices by non-reactive stabilizers so that stability with TIRANOX "C" pigments is not a problem. The addition of a non-ionic wetting agent, however, usually helps to prevent crawling of polyvinyl acetate paints applied to smooth, non-porous surfaces.

In acrylic latex paints, neither wetting agents nor emulsifying agents are required, as these systems generally are completely stable with calcium-base pigments.

### Protective Colloids and Thickeners

The protective colloid in any latex paint formula-thion thickens the water phase and reduces settling and phase separation.

While proteinaceous colloids (casein and soya protein) as listed on page 198, may not be used with the TIRANOX "C" pigments, specially treated caseins are available (Borden's "Cascolac" and Sheffield's "Shet-Tex") that are compatible with these pigments.

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Protective colloids include natural materials such as gum arabic; cellulosic materials such as methylcellulose, carboxymethylcellulose (CMC) and hydroxyethyl cellulose; substances such as sodium polyacrylates; and colloidal clays, such as china clays and Ben-O-Gel (National Lead Company).

Of these, the most widely used are the celluloses, and as indicated on page 198, the celluloses (carboxymethyl cellulose, methyl cellulose and hydroxyethyl cellulose) and starch are suitable for use with the TIRANOX "C" pigments.

### Anti-foam Agents or "Defoamers"

Inasmuch as defoamers operate through effect on surface tension, a specific defoamer may not be effective in any latex paint selected at random. An excessive amount of defoamer may cause local areas of high surface tension and contribute to crawling.

Among defoamers are tributyl phosphate, octyl alcohol, polyglycols, pine oil and proprietary products such as Nopco JMY (Nopco Chemical), Foamicide 581B, Collond 581B (Collonds, Inc.).

### Coalescing Agents

Substances that promote the flowing together of globules or particles of resin to form a continuous binder film with the pigment dispersion, especially at low temperatures, are regular additives to latex flats. As would be expected such substances are closely related to classic plasticizers of coatings, so it is not surprising to find these materials being used: dibutyl phthalate, Carbitol acetate, hexylene glycol, Butyl Cellosolve Acetate. On the order of 2 gallons of Carbitol Acetate per 100 gallons of paint has been found suitable.

### Freeze-thaw Stabilizers

For all practical purposes, these are anti-freezes. Ethylene glycol, propylene glycol, and diethylene glycol are commonly used. Two to three gallons per 100 gallons are usually suitable.

### Fungicides and Mildewicides

These are used to prevent bacterial growth in the package and mildew growth on coated surfaces. Phenyl mercurial salts are commonly used, and of course, all precautions necessary in the handling of these and related to their presence in the paint must be observed.

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## Latices

Although new latices and modifications of existing ones are constantly being offered, three general types are still dominant:

butadiene-styrene  
polyvinyl acetate  
acrylic

### Some Butadiene-styrene Latices

| Name          | Supplier              |
|---------------|-----------------------|
| Gen-Alo 67    | General Tire & Rubber |
| Gen-Alo 671   | General Tire & Rubber |
| Polyco 2426   | Borden Chemical Co.   |
| Dow 300; 762W | Dow Chemical Co.      |

### Some Polyvinyl Acetate Latices

| Name         | Supplier            |
|--------------|---------------------|
| Flexac FA5   | Air Reduction Chem. |
| Ucar W-C-130 | Union Carbide       |
| Polyco 522   | Borden Chemical Co. |
| Wallpol 9301 | Reichold Chemical   |

### Copolymer Type

| Name         | Supplier               |
|--------------|------------------------|
| CL-202       | Celanese Chemical      |
| Flexbond 800 | Air Reduction Chemical |
| Resyn 12K55  | National Starch        |
| Wallpol 9120 | Reichold Chemical Co.  |
| Polyco 804   | Borden Chemical Co.    |
| Polytex 600  | Jones Dabney           |
| Everflex G   | Dewey and Almy         |

### Some Vinyl-acrylic Latices

| Name           | Supplier              |
|----------------|-----------------------|
| CL-205         | Celanese Chemical     |
| Resyn 2243     | National Starch       |
| Polyco 2151    | Borden Chemical Co.   |
| Flexbond 815   | Air Reduction Chem.   |
| Polytex 601    | Jones Dabney          |
| Wallpol 40-124 | Reichold Chemical Co. |

### Some Acrylic Latices

| Name          | Supplier         |
|---------------|------------------|
| Rhoplex AC-34 | Rohm & Haas      |
| Polyco 2719   | Borden Chemical  |
| Dow 2627      | Dow Chemical Co. |

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## Manufacturing Processes and Equipment

Latex flats may be made on any type of grinding equipment, such as roller mills, pebble mills, and others. The choice depends upon the viscosity characteristics and other properties of the suspension. Paste-like suspensions having sufficient length of body may be applicable to roller milling, provided of course, other properties such as abrasiveness are suitable. Similarly depending upon viscosity and flow, pebble milling may be selected. Most formulations however, yield consistency most suitable for the high speed mixer type of disperser such as the Hockmeyer, Cowles, or Kady. For these machines, slurry viscosity and other characteristics can be readily adjusted for the attainment of suitable dispersion.

Generally, the first step in making these paints is the dispersion of the Tironox pigment in the water. Often there is a tendency to try to disperse too much pigment in too little water (or at too high pigment content). It is advisable to operate sufficiently below maximum pigment content to assure proper dispersion at an efficient rate. Overpigmented slurries are apt to show dilatancy, or increase in viscosity as agitation proceeds. This can hinder dispersion and even cause damage to the equipment.

### Importance of Order of Addition of Ingredients

Once achieved in the mixing and dispersing step, the degree of dispersion of the pigment must be protected through the let-down and the final paint. Formation of clusters or flocculates of pigment must be prevented. It is well to remember that at any instant in the processing of a water emulsion paint, the water phase is involved in an equilibrium that determines the degree of dispersion of the binder or globules of resin and especially of the pigment. This is affected by changes in viscosity, surface tension, polarity, and other factors related to miscibility and solubility of the ingredients in water. Thus, the order and rate of addition of these ingredients is important and for any given formulation must be established and maintained.

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## Example of an Order of Addition of Ingredients of a Latex Flat White

### The Grinding Slurry or Suspension

To the water, are added in order, reading left to right, and with suitable agitation during and after each addition:

1. The mildewicide; part of the anti-foam agent; the anti-freeze such as ethylene glycol; the pH stabilizer (if needed); the corrosion inhibitor.
2. The dispersant or dispersants, such as potassium tripolyphosphate if TITRANOX-"RA" type pigment is involved, or a non-ionic dispersant if TITRANOX-"C" pigment is to be dispersed.
3. TITRANOX pigment.
4. The extenders.

The completed suspension will usually run 60-70% by weight total pigment, and is then suitably ground.

### The Let-down of the Ground Slurry or Suspension

To the ground suspension are added:

5. All or part of the protective colloid or thickener solution; the wetting agent; the coalescing agent.
6. The latex emulsion; remainder of the anti-foam agent; water or thickener to adjust body if needed.

The above, of course, may have to be modified to meet the requirements of various ingredients of different formulations, but should serve as a useful guide. It is advisable to investigate combinations involving new ingredients for effects of variation of order of addition. Certain procedures must be positively avoided, such as the addition of dry methyl cellulose to dry pigment before addition to the water.

With the newer latices, plus selection and control of ingredients, pigmentation of latex flats is now closely related to traditional flat wall paint pigmentation.

Following is an example of a white butadiene-styrene formulation. In great contrast to early flats made with this type of resin, the pigment volume concentration is 61.5%. Only a minor amount of added extender is needed with TITRANOX-C-50. Naturally the small addition includes some highly flattening type:

#### For 100 gallons of Paint

|                                                                                                     |     |         |
|-----------------------------------------------------------------------------------------------------|-----|---------|
| TITRANOX-C-50 .....                                                                                 | 425 | Pounds  |
| China Clay .....                                                                                    | 75  | "       |
| Diatomaceous silica .....                                                                           | 30  | "       |
| Non-ionic dispersant* .....                                                                         | 6   | "       |
| Water .....                                                                                         | 48  | Gallons |
| Butadiene-styrene latex<br>(such as Gen-flu 671) .....                                              | 27  | "       |
| Total of wetting agent, thickener,<br>coalescing agent, defoamer,<br>anti-freeze, mildewicide ..... | 4.6 | "       |
| * Tamol 731 (25%) or equivalent.                                                                    |     |         |

In this same latex, a rutile "pure" titanium dioxide pigmentation, naturally required more extender. For a comparable paint, pvc was 52% with pigmentation per 100 gallons of paint as follows:

|                                      |     |        |
|--------------------------------------|-----|--------|
| Rutile "pure" TiO <sub>2</sub> ..... | 225 | Pounds |
| China Clay .....                     | 125 | "      |
| Calcium Carbonate .....              | 100 | "      |

Generally, the amount of rutile "pure" TiO<sub>2</sub> required as the sole prime white pigment, follows closely that of organic solvent flats:

| Latex flat type       | Pounds TiO <sub>2</sub> per gallon of paint |
|-----------------------|---------------------------------------------|
| White .....           | 2.00-2.50+                                  |
| Light tint base ..... | 1.50-2.00                                   |
| Deep tint base .....  | .50-1.50                                    |

To secure higher hiding in latex flats pigmented with "pure" TiO<sub>2</sub>, special types have been developed and are usually characterized by higher oil absorption than regular grades such as TITRANOX-RA and TITRANOX-RA-50. In the TITRANOX line, the new pigments TITRANOX-RA-46 and TITRANOX-RA-51 usually give



higher hiding in latex flats than TIRANOX-RA-50, as discussed on page 28 of this HANDBOOK.

When circumstances dictate that "pure"  $\text{TiO}_2$  plus extender should be used instead of the TIRANOX "C" pigments, the TIRANOX "RA" pigments are applicable to latex flats made with all types of latices. Where highest dry hiding is paramount, TIRANOX-RA-46 is usually first choice.

The residual films of high polymers deposited from latex coatings were early noted to have good sealing properties. And, as a result, primer-sealers were developed readily that called for rutile  $\text{TiO}_2$  pigment. An early butadiene-styrene type called for only one-half pound rutile  $\text{TiO}_2$  per gallon of paint, inasmuch as the objective was to obtain a seal coat which must not be spread too thin.

#### BUTADIENE-STYRENE PRIMER-SEALER

##### For 100 gallons of Paint

|                                 |             |
|---------------------------------|-------------|
| TIRANOX-RA-50 .....             | 50 Pounds   |
| China Clay .....                | 80 "        |
| Mica .....                      | 80 "        |
| Tetrasodium pyrophosphate ..... | 1.3 Gallons |
| Butadiene-styrene latex .....   | 52 "        |
| Casein solution .....           | 34 "        |
| Pine oil .....                  | 0.5 "       |
| Defoamer .....                  | 0.1 "       |
| Water .....                     | 4.8 "       |

An example of a current paint of this type designed to be applicable to Federal Specification TT-P-650a for a latex primer-sealer:

#### POLYVINYL ACETATE LATEX PRIMER-SEALER

##### For 100 gallons of Paint

|                                                                  |              |
|------------------------------------------------------------------|--------------|
| TIRANOX-RA-46 .....                                              | 100 Pounds   |
| China Clay .....                                                 | 150 "        |
| Potassium triphosphate .....                                     | 1.0 "        |
| Polyvinyl acetate latex .....                                    | 31.4 Gallons |
| Water .....                                                      | 26.3 "       |
| Methyl cellulose .....                                           | 30 "         |
| Total of anti-freeze, mildewicide, wetting agent, defoamer ..... | 2.5 "        |

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Here are some examples of TIRANOX "C" pigmentations. In general, these yield equal or higher hiding than comparable pigmentations utilizing rutile "pure"  $\text{TiO}_2$  pigments, and at lower cost.

In each case extenders selected to be added to the "C" pigments provided the sheen and all other properties that depend upon extension of prime pigment in the particular binder and at the total pvc involved.

##### For 100 gallons of Paint

| Type of Latex Paint             | TIRANOX lbs. | Extenders lbs.                                                 | % pvc |
|---------------------------------|--------------|----------------------------------------------------------------|-------|
| Acrylic                         | RCHT 300     | Barytes 150<br>Whiting 175                                     | 65    |
| Butadiene-styrene flat          | RCHT 325     | Clay 120<br>Colloidal $\text{SiO}_2$ 20                        | 61    |
| Butadiene-styrene flat          | C-50 425     | Clay 75<br>Diat. $\text{SiO}_2$ 30                             | 61.5  |
| Polyvinyl acetate flat          | C-50 200     | Whiting 172<br>Silica 75<br>Diat. Silica 25                    | 55.0  |
| Polyvinyl acetate tint base     | C-50 100     | Whiting 172<br>Clay 75<br>Silica 75<br>Diat. $\text{SiO}_2$ 25 | 55.0  |
| Polyvinyl acetate flat          | C-50 200     | Whiting 100<br>Clay 50<br>Silica 25<br>Diat. Silica 25         | 54.5  |
| Butadiene-styrene flat          | C-50 192     | Whiting 104<br>Talc 85                                         | 53    |
| (to meet Fed. Spec. TT-P-29a)   |              | Clay 50                                                        |       |
| Polyvinyl acetate flat          | C-50 300     | Talc 86.5                                                      | 40    |
| Polyvinyl acetate Primer-Sealer | C-50 238     | Whiting 18                                                     | 30    |

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### Importance of Additives or minor Ingredients of Latex Flats

While pigmentation and film-forming solids or binder determine the main qualities of water emulsion paints, there are important properties that depend upon the minor ingredients.

One of these is tintability or the ease with which full depth of tint is secured with either a specialized or a universal tube color.

Lack of full depth of tint after addition of color to a white base is commonly caused by improper kind or amount of wetting agents in the white paint. This condition may be caused quite inadvertently as these agents can be chosen to insure good performance of the white paint as such rather than as a tinted paint. By correcting the wetting and dispersing agents in the white paint, its tintability is improved.

As an example, it was found that some white polyvinyl acetate emulsion paints contained from 0.2% to 1.0% or the optimum amounts (on the pigmentation) of dispersing agents for full stability of the white paints.

Nevertheless, when a universal tube green was added to these paints, full depth of tint was not developed; brightness being 63-70% instead of the 45% that was desired.

By adding a quantity of a non-ionic dispersant to the dispersants already employed, the white paints could readily be tinted to the desired brightness with the same amount of color. In addition, this correction did not alter the color of the white paint.

Of course, any ingredient that in itself may be hazardous in handling, or in any other way, should be used properly and in proper proportion, such as acids and alkalis that might be used in pH adjustment.

Of equal importance is the toxicity of any ingredients in relation to their handling, and especially to their concentration in the residual film of the paint.

The mildewicides containing mercury must be considered in relation to their poisonous nature and all precautions must be taken in all pertinent aspects of their handling and application to the paint.

### Enamel Undercoats

Enamel undercoaters are essentially must cover a surface properly and for an enamel. Flatness in itself is able since it means microscopic rough present greater surface for adherence. A satisfactory enamel undercoater following qualities:

1. Ease of application
2. High hiding
3. Smooth leveling without run
4. Good sealing—lack of undu
5. Ease of sanding
6. Enamel holdout—allowing f  
ment in the enamel or des  
enamels having less than f

In comparison with flat wall paints of enamel undercoaters is generally from 45%-55% pvc; the vehicle g more varnish or resin, the oil len vehicle in the range of 20-60 gallon resulting from too much resin in ole must be avoided. Extenders are cho to friability so that sharp sanding w may be obtained. For this reason, calcium carbonate as employed in en Pigmentation may utilize TITANOX exceptionally high hiding for thin desired for flexibility.

TITANOX-RCHT or TITANOX-C-50 pigment in white enamel undercoa volume selected along with vehicle hardness. But, of course, pigment be increased to the point where en be impaired as a result of film poro. of an enamel undercoater in which is the sole pigment, follows:

# For 100 gallons of Paint

|                                                              |      |         |
|--------------------------------------------------------------|------|---------|
| Tranox-RCHT .....                                            | 775  | Pounds  |
| Litharge .....                                               | 1.5  | "       |
| Aluminum stearate (low acid) .....                           | 3.9  | "       |
| Ester gum varnish (30 gal., leaded tung 24, linseed 6) ..... | 38.2 | Gallons |
| Bodied Linseed Oil (O-P) .....                               | 6.5  | "       |
| Mineral Spirits .....                                        | 25.9 | "       |
| 2% Cobalt drier .....                                        | 0.8  | "       |
| Pigment—60%                                                  |      |         |
| PVC—54%                                                      |      |         |
| Vehicle—40%                                                  |      |         |
| Non-volatile vehicle—40%                                     |      |         |
| Oil length—45 gal.                                           |      |         |

Interest in lime or magnesia treated varnishes on account of penetration resistance extended to enamel undercoaters. There follows a formula utilizing this type of vehicle and also exemplifying the principles of enamel undercoater formulation. At total pvc of 52% irregular shaped friable extender is added, while high hiding is attained by the use of Tranox-C-50. A lined varnish of 60 gallons oil length constitutes the vehicle.

## ENAMEL UNDERCOATER

### For 100 gallons of Paint

|                                                    |      |         |
|----------------------------------------------------|------|---------|
| Tranox-C-50 .....                                  | 375  | Pounds  |
| Natural calcium carbonate Whiting ...              | 185  | "       |
| Talc (magnesium silicate) .....                    | 65   | "       |
| Litharge .....                                     | 1.3  | "       |
| Aluminum stearate .....                            | 2.5  | "       |
| Lime treated ester gum varnish (60 gal. linseed) * |      |         |
| Mineral spirits .....                              | 52   | Gallons |
| 6% cobalt drier .....                              | 22.5 | "       |
| 6% cobalt drier .....                              | 0.8  | "       |

\* This varnish has viscosity higher than Z-6 (Gardner-Holdt) at 30% non-volatile and about M viscosity at 45% non-volatile.

Alkyd resins developed for flat wall paints are also applicable to enamel undercoaters. In using alkyds in enamel undercoaters the first requisite is that the alkyd or combination of alkyds be suitable in all respects for this usage. Exceptionally long oil alkyds should be used in combination with alkyds of shorter oil

length to secure hardness needed. Enamel hold-out is of special importance. An example of variation in enamel hold-out of an undercoater maintained constant in pigmentation but made from two different alkyds called simply A and B follows:

|                |                                                         |
|----------------|---------------------------------------------------------|
| Alkyd Solution | 60° Gloss of semi-gloss enamel applied over undercoater |
| A              | 31                                                      |
| B              | 15                                                      |

The influence of alkyds on enamel hold-out, being related to penetration, can be judged by the "filter paper ring test" as described on page 186.

Although the concept of "critical pvc" as discussed on page 192 is particularly applicable to enamel undercoaters, the accepted range of pvc for these products has almost universally been below the critical point at which enamel hold-out begins to fall off. Excessive amounts of flattening and irregularly shaped extenders must be avoided. Lower oil absorption types of extenders balance the amounts of the flattening extenders needed so that pvc is maintained below the critical value.

The principles of alkyd enamel undercoater formulation are exemplified in the following formula submitted only for illustrative purposes:

## ALKYD ENAMEL UNDERCOATER

### For 100 gallons of Paint

|                                                     |     |         |
|-----------------------------------------------------|-----|---------|
| Tranox-C-50 .....                                   | 370 | Pounds  |
| Natural Whiting .....                               | 165 | "       |
| Talc .....                                          | 51  | "       |
| Aluminum stearate or Bentone 34.....                | 2   | "       |
| Resin modified alkyd (39% solids) <sup>1</sup> .... | 40  | Gallons |
| Soya modified alkyd (70% solids) <sup>2</sup> ...   | 14  | "       |
| Mineral spirits .....                               | 22  | "       |
| Driers and anti-skinning agent .....                | 0.5 | "       |

<sup>1</sup> Such as Synrex 131, Jones-Dabney Co. } or equivalent

<sup>2</sup> Such as Synrex 40, Jones-Dabney Co. } solution or solutions

## Semi-gloss Finishes

As the name implies, semi-gloss finishes are about half way between full gloss and flat paints. It is well recognized that being neither gloss nor flat, this type of paint should be formulated so that conditions during manufacture can be controlled to avoid tendency either to high gloss or flatness. Thus the following conditions are recognized:

1. A combination of prime pigment and extender for the selected vehicle must be so chosen as not to present a very narrow range of pvc at which the low lustre or semi-gloss can be produced.
2. The amount of grinding must usually be kept below that required for highest degree of dispersion.
3. A highly flattening type generally must not constitute the entire content of extender.
4. Special types of extenders easily dispersed and conducive to high gloss are usually avoided.
5. A formulation which under variation in manufacturing conditions will vary toward too much gloss is preferable to one varying toward flatness since the lowering of gloss is a simpler process than raising it.

On account of the intermediate pvc needed for low lustre, composite titanium pigments TIRANOX-RCHT and TIRANOX-C-50 are preferable to straight titanium dioxide and extender. Sufficient hiding is derived from TIRANOX-RCHT usually to permit the inclusion of selected extender to achieve the gloss effects desired. Added extender need not be employed with TIRANOX-C-50 at highest hiding levels, but if extender is needed, this pigment will always leave room for it.]

Vehicles are of the varnish type either as a processed varnish or a blend of resin solution and bodied drying oils. Their hardness is higher than that of flat wall paint vehicles because of lower pigment content so that oil length may vary between 20 and 60 gallons, or resins such as alkyds may be used. Consistency and flow characteristics of the paint are secured through the viscosity characteristics of the non-volatile vehicle components usually avoiding body-

ing agents such as water solutions of alkalis, soaps, etc., and excess quantities of aluminum stearate. In many cases, however, aluminum stearate must be included to aid package stability inasmuch as the non-volatile content of the vehicle may run below 45%. Similarly other suspending agents such as Bentone 34 must not be added in excessive amounts that promote flatness.

Many of the principles of vehicle formulation for flat wall paints are applicable to semi-gloss paints which present similar requirements for application and film properties with, of course, the exception of gloss.

The trend to satiny sheen in some modern flat wall paints in which exceptional cleanliness accompanies high sheen, simply may require a reduction of pigment volume concentration for conversion to semi-gloss.

In the following formula, gloss is dependent upon pvc of the combination of TIRANOX-RCHT and precipitated calcium carbonate extender. The vehicle is a well bodied combination of dehydrated castor and linseed oils, leaded (viscosity V at 71% non-volatile). A tung-linseed oil may also be used or straight linseed, of course, at much higher viscosity. The resin content is furnished by a dispersion of ester gum in mineral spirits.

### OLEORESINOUS SEMI-GLOSS

#### For 100 gallons of Paint

|                                                                       |      |         |
|-----------------------------------------------------------------------|------|---------|
| TIRANOX-RCHT .....                                                    | 550  | Pounds  |
| Precipitated whiting .....                                            | 140  | "       |
| Lihtarge .....                                                        | 14   | "       |
| Aluminum stearate (high acid) .....                                   | 3.5  | "       |
| Bodied dehydrated castor-linseed oil (40:60:50 mineral spirits) ..... | 34.4 | Gallons |
| Ester gum cut (60% non-vol.) .....                                    | 10.9 | "       |
| Kerosene .....                                                        | 3.4  | "       |
| Mineral spirits .....                                                 | 24.2 | "       |
| 6% Cobalt drier .....                                                 | 0.3  | "       |
| Pigment—56.6% .....                                                   |      |         |
| PVC—48.5% .....                                                       |      |         |
| Vehicle—43.4% .....                                                   |      |         |
| Non-volatile vehicle—45% .....                                        |      |         |

Where straight resin vehicles are employed it may be necessary to furnish increased body and reduced flow through the use of body and flow regulators such

as extremely highly polymerized oils held in dispersion for example by rosin. Such agents also tend to improve brushability which otherwise might be difficult.

By way of example, the following formula presents an alkyl type semi-gloss utilizing a blend of two alkyl solutions of the soya modified type and a body regulator. TIRANOX-C-50 furnishes high hiding so that only a small amount of flattening extender (magnesium silicate) is required to reduce gloss to the semi-gloss range. At 40% pvc of this pigmentation, a flattening extender of irregular particle shape is required, of course, to counteract the strong pigment dispersive action of the alkyl. Zinc oxide is employed for improvement of color retention. It must be remembered though that alkyls compatible with zinc oxide must be used when this pigment is included.

It should be borne in mind that highly flattening siliceous and abrasive extenders are often best added after the prime pigment has been ground. These extenders are often added to the final paint under agitation to reduce gloss.

#### ALKYL SEMI-GLOSS

##### For 100 gallons of Paint

|                             |      |         |
|-----------------------------|------|---------|
| TIRANOX-C-50                | 540  | Pounds  |
| Zinc oxide <sup>1</sup>     | 30   | "       |
| Talc <sup>2</sup>           | 20   | "       |
| Glyptal 2466 <sup>3</sup>   | 37   | Gallons |
| Glyptal 2464 <sup>3</sup>   | 14.5 | "       |
| Body Regulator <sup>4</sup> | 1    | "       |
| Thinners and driers         | 27.5 | "       |
| Pigment—50%                 |      |         |
| PVC—40%                     |      |         |
| Vehicle—50%                 |      |         |
| Non-volatile vehicle—45%    |      |         |

<sup>1</sup> Low reactivity zinc oxide.

<sup>2</sup> Asbestos X, others may be used, however.

<sup>3</sup> Other equivalent alkyls may be used.

<sup>4</sup> Fatkovar VR-10 was used, but equivalent agents are applicable.

In formulations of this type added extender may be deleted while pvc is raised to about 50%, but care must be exercised not to increase pvc so much as to rob the pigment of binder. Elimination of added extender and

increase of pvc may not be feasible where the alkyl semi-gloss is to be applied over relatively porous surfaces. Excessive amounts of thinner may be required for proper consistency (thus resulting in decreased solids and increased penetration). With highly polymerized alkyls specially designed not only for finishes other than full gloss enamels but also to reduce penetration it is usually safer to maintain a relatively low pvc—say 38 to 40—while securing gloss reduction through minimum of flattening extender. A formulation illustrating this principle and also providing exceptionally high hiding power follows:

#### ALKYL SEMI-GLOSS

##### For 100 gallons of Paint

|                                     |     |         |
|-------------------------------------|-----|---------|
| TIRANOX-C-50                        | 390 | Pounds  |
| TIRANOX-RA                          | 155 | "       |
| Diatomaceous silica                 | 35  | "       |
| Special alkyl solution <sup>1</sup> | 54  | Gallons |
| Thinners and driers                 | 26  | "       |
| PVC about 39%                       |     |         |

<sup>1</sup> Such as Synex 70, Jones-Babney Co.

In a formulation of this type, hiding power may be lowered by replacing TIRANOX-C-50 by TIRANOX-RCHT, by eliminating the "pure" oxide, of course, while maintaining prime pigment volume constant.

For tint base semi-glosses, TIRANOX-RCHT and of course, fastest dispersing TIRANOX-RCHTX, exert higher tinting strength than mixtures of rutile "pure" TiO<sub>2</sub> and extenders that require so much extender to crowd the TiO<sub>2</sub> particles, lower their strength and degrade tone of tint.

Here is an example of a pigmentation with TIRANOX-RCHTX:

#### ALKYL SEMI-GLOSS TINT BASE

##### For about 89.5 gallons of Paint

|                                             |     |         |
|---------------------------------------------|-----|---------|
| TIRANOX-RCHTX                               | 400 | Pounds  |
| Whiting (5 micron type)                     | 75  | "       |
| Zinc oxide                                  | 10  | "       |
| Aluminum stearate                           | 2.5 | "       |
| Alkyl flat liquid (40% N.V.)                | 36  | Gallons |
| Long oil alkyl (70% N.V.)                   | 25  | "       |
| Total Thinners, driers, anti-skinning agent | 10  | "       |
| PVC about 39%                               |     |         |



## Gloss Finishes

### (Gloss Paints and Painters' Enamels

Interior gloss finishes have been classified into gloss paints, painters' enamels and enamels. The first two are usually considered one group. This seemingly unnecessary division is a result of the difference in application and quality requirements.

Gloss paints and painters' enamels are designed for quick and easy application in one coat over varying repaint surfaces, sometimes necessitating heavy coats. As compared with full enamels, pigment volume is higher, body is usually tighter and somewhat thixotropic, while levelling and flow are usually less.

The attainment of hiding power is no problem in pigmenting gloss paints and painters' enamels with Tiranox pigments.

Gloss and its retention are secured through well known principles which involve:

1. Sufficient mixing and grinding.
2. High dispersive action of vehicle especially resin. Oils must usually have polymeric structure.
3. Compatibility of vehicle components so that a gloss reducer will not separate or vehicle lose dispersive action.
4. Avoidance of coarse extenders, also reactive pigments that may form soap films.
5. Avoidance of agents which may cause undue flocculation of pigment, such as aqueous solutions for bodying, or appreciable amounts of any gloss reducer such as insoluble soaps, aluminum stearate for example.

The consistency and flow of gloss paints and painters' enamels present the most interesting and difficult problem to the formulator. The difficulty arises from the fact that methods of reducing flow especially in the film to prevent running and sagging may also tend to reduce gloss.

Agents which set up a structure in the film to prevent its flow after the brushing force has been removed are employed such as soya lecithin and extremely highly polymerized oils such as "body varnish."

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Raw fatty acids such as those from linseed oil, decrease flow in pigment-vehicle systems of these paints. These acids may be provided as such or through unpolymerized oil itself. Thus in the following formula a proportion of high acid un bodied linseed oil accompanies a high acid Z-5 bodied linseed oil.

### OLIORESINOUS (Gloss PAINT

#### For 100 gallons of Paint

|                                            |      |         |
|--------------------------------------------|------|---------|
| Tiranox-RCHTX .....                        | 395  | Pounds  |
| Precipitated whiting .....                 | 105  | "       |
| Natural whiting .....                      | 105  | "       |
| Heat bodied linseed oil (Visc. Z-5) ....   | 19.9 | Gallons |
| Grinders' linseed oil (acid No. 9-12) .... | 6.0  | "       |
| Linseed rosin (10 lb. cut) .....           | 36.2 | "       |
| Mineral spirits .....                      | 13.3 | "       |
| 6% Cobalt drier .....                      | 0.2  | "       |
| 24% Lead drier .....                       | 0.6  | "       |

This is a low cost gloss paint having desirable working and film qualities for this type of product.

The precipitated whiting is of the fine particle size and high oil absorption type. Similarly the natural whiting is of the highest oil absorption and finest particle size available in natural whiting. This type of extender contributes to reduction in running and sagging as well as to increased consistency.

By replacing the high oil absorption precipitated whiting with natural whiting and increasing the proportion of Tiranox-RCHTX so that the pigmentation is 510 pounds Tiranox-RCHTX and 95 pounds natural whiting, hiding will be increased, consistency reduced and flow increased, permitting the product to be classified as a painters' enamel. For better color retention and less flow the 10 pound linseed oil may be replaced with a ten pound low acid ester gum cut. In formulations of this type, still higher hiding may naturally be obtained by using Tiranox-C-50 without added extender at total pvc of about 40% at about 6 pounds of pigment per gallon of painters' enamel.

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## Architectural Enamels

The requirements of sharpest gloss at high hiding especially for the highest grade of white enamel suitable for the most exacting use on architectural interiors has generally imposed the condition of low pvc. For this reason, "pure" titanium dioxide is the accepted type of pigment. Other familiar requirements—quick drying, easy brushing, gloss retention, color, color retention, cleanability and repaintability impose conditions largely met by the vehicle. Of course, the pigment must be highly dispersible and possess low oil or vehicle requirement to assure smoothness of film and resulting high gloss.

Prior to the advent of alkylid resins, best color and color retention was secured through the use of selected dammar gum dispersed in thinner, but all other properties were inferior to those obtainable with varnishes specially formulated for these enamels. Such varnishes utilize resins having suitable durability, color and color retention effects (usually avoiding the phenolic types and lined rosin), and combination of oils providing good durability.

There follows an oleoresinous enamel having high hiding as a result of an economical pigmentation with TITANOX-C-50.

### WHITE ARCHITECTURAL ENAMEL (Oleo-resinous)

#### For 100 gallons of Enamel

|                                                                  |      |         |
|------------------------------------------------------------------|------|---------|
| TITANOX-C-50 .....                                               | 400  | Pounds  |
| 25 gallon dehydrated castor oil (2)—                             |      |         |
| insced oil (1)—ester gum varnish                                 |      |         |
| having viscosity of G-H (Gardner-Holdt) at 60% non-volatile..... | 74   | Gallons |
| Highly leaded, dehydrated castor oil                             |      |         |
| having viscosity greater than Z-6                                |      |         |
| (Gardner-Holdt) at 65.8% non-                                    |      |         |
| volatile .....                                                   | 0.3  | "       |
| Mineral spirits .....                                            | 10.9 | "       |
| 6% Cobalt naphthenate .....                                      | 0.4  | "       |
| 24% Lead naphthenate .....                                       | 0.7  | "       |
| PVC—26%                                                          |      |         |

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## TITANOX-RA-45 for Maximum Gloss,

### Whiteness, Hiding

In alkylid enamels, ready attainment of sufficient gloss, hiding, whiteness, color retention and package stability is assured through use of TITANOX-RA, TITANOX-A-168-LO, TITANOX-C-50 and TITANOX-RCHTX or combinations of these pigments, with alkylids recommended for the purpose, usually medium to long soya modified types. A preference for "pure" titanium dioxide exists though, at the low level of pigment content (2-4 lb.  $\text{TiO}_2$  per gallon) in view of high hiding at low pigmentation. The chart on page 224 presents an example of the difference in hiding in an alkylid vehicle (60% solids) between rutile titanium dioxide (TITANOX-RA), anatase titanium dioxide (TITANOX-A-168-LO), TITANOX-C-50 and TITANOX-RCHT.

Because of exceptional ease of dispersion to a high degree to yield high gloss and maximum opacity at low pigment volume concentration, plus high brightness and adaptability to bluer whites, TITANOX-RA-45 is first choice.

The high hiding of TITANOX-RA-45 is indicated in the chart on page 225.

When the extra opacity of TITANOX-RA-45 is not of paramount interest, and other qualities dominate, such as suitability for use indoors plus greater resistance to the weather, if used outdoors, TITANOX-RA-NC may be preferred.

In a white alkylid enamel which is not blued to tone whiteness, rare in practice, TITANOX-RA produces a yellower white than TITANOX-A-168-LO (rutile versus anatase), but generally the rutile pigment reduces the degree of after-yellowing. The lesser change in color index (relative yellowness) as determined from reflection values (Hunter) taken on a number of white alkylid enamels before and after exposure to diffused light for six months is shown, for example, in the following table:

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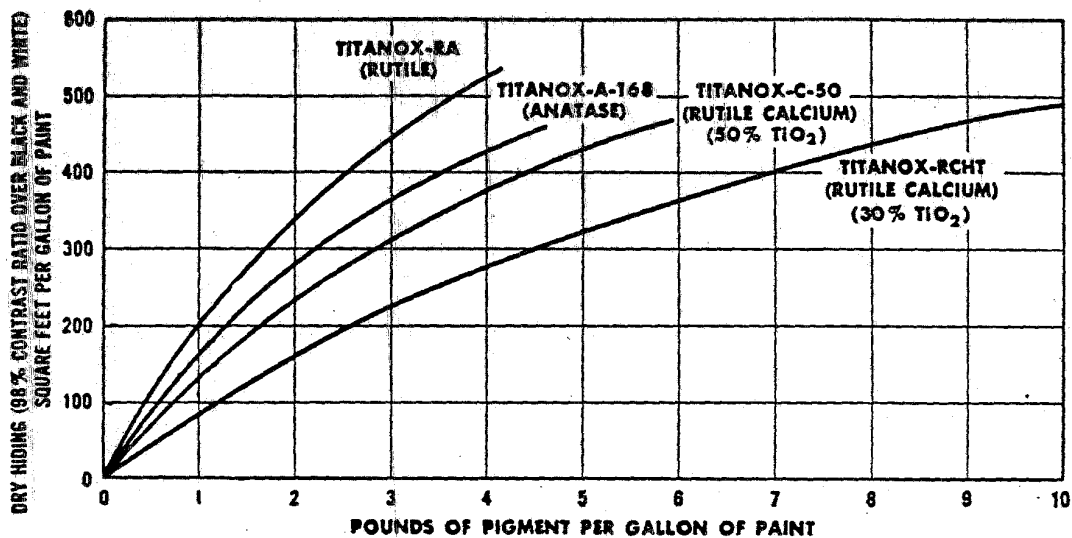
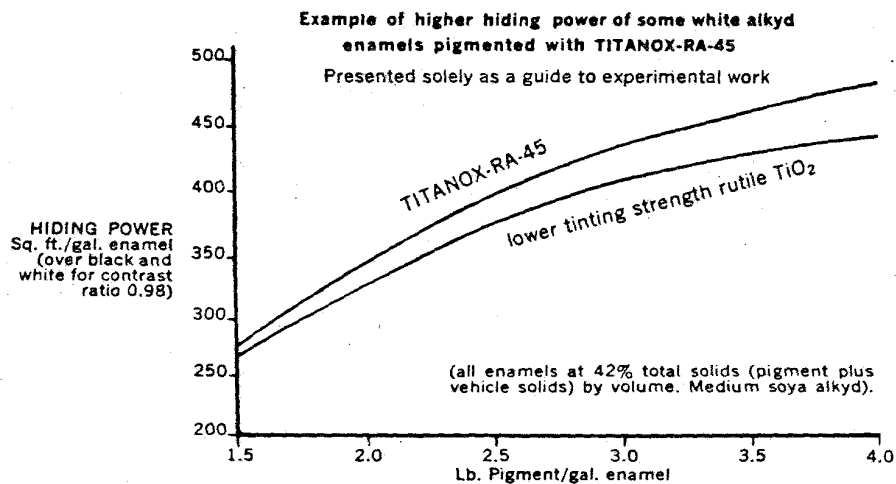


FIGURE VII-A

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# EXAMPLE OF WHITENESS RETENTION OF ALKYD ENAMELS

| Pigment           | Initial    |         | After Exposure to Diffused Light 6 months |         |
|-------------------|------------|---------|-------------------------------------------|---------|
|                   | Bri. Index | % Color | Bri. Index                                | % Color |
| TIRANOX-A-168-LO  | 88.5       | 2.5     | 88.3                                      | 8.8     |
| TIRANOX-RA        | 89.8       | 4.4     | 89.5                                      | 9.0     |
| <i>Amber-Blue</i> |            |         |                                           | 4.5     |
| <i>Green</i>      |            |         |                                           |         |

With the exception of TIRANOX-RA-10, all of the TIRANOX "RA" pigments retard the after yellowing of vehicles and are suitable for use in white and tinted high gloss architectural enamels, of course, including alkyds.

After-yellowing is more pronounced with resins having greater oil modification. Thus, in change of color index between short and long soya bean oil modified alkyds in white enamels, the following average was found in an extended series of tests:

| Soya Oil Modification | Change in Color Index (Increase-yellowing) |
|-----------------------|--------------------------------------------|
| Short .....           | 2.5                                        |
| Medium .....          | 3.2                                        |
| Long .....            | 6.2                                        |

Other resins added for extension of the alkyd may harm or improve whiteness retention. Ester gum, rosins and the like and phenolics generally will cause more after-yellowing.

Color effects of alkyds like all other unsaturated film formers are greatly influenced by the amount of drier used. Quantities in excess of those needed for good drying should be avoided. Instances of drastic color differences between normally 0.04% Co and abnormal content of 0.08% Co have been noted for example.

Although the TIRANOX pigments suggested, retard after-yellowing, zinc oxide is used for this purpose with alkyds with which it is compatible. After-yellowing is not a serious problem since alkyds regardless

of length of oil modification with soya are generally superior to oleoresinous varnishes. However, because alkyd resins are by nature generally viscous and sticky they not only must be increased in oil content as far as possible but also with added oils or other agents. The reason for this is to secure improved brushability through reducing the "pull" which exists on brushing a straight alkyd.

To reduce further the after-yellowing of some alkyd combinations the superior "non-yellowing" dammar gum may be utilized. But consideration must be given to the type of alkyd, comparability of the resins, solvent properties of the thinners and such properties as film flexibility and washability. The optimum proportion of dammar gum to be added must be determined. Some formulators consider about 10% of the resin as dammar to be about the maximum that may be used with a medium oil alkyd.

It must be remembered though, that it is possible to modify alkyd resins during their manufacture to be entirely suitable for brushing enamels without recourse to additives in the enamel. The compatibility of TIRANOX pigments with any type of synthetic resin is particularly valuable in utilizing new and improved resins. For example, styrene-alkyd resins appear to present excellent film properties including color retention and, in addition, pigment dispersive properties so that if desired, TIRANOX-RCHTX or TIRANOX-C-50 may be used at high pigment volume.

In the neighborhood of 20% pvc, a range of pigment composition is 92-98% TIRANOX "RA" pigment and 2-8% zinc oxide. Generally a fine particle size French process zinc oxide is most effective.

For enamels having less than full gloss, TIRANOX-C-50 at higher pvc is admirably suitable to yield both high hiding and pleasing lustre usually unattainable with rattle "pure" titanium dioxide and available extenders at the same cost.

There follows a formula which exemplifies the balancing of components to secure a combination of high gloss, high hiding, whiteness and color retention compatible with brushability and sag-resistance.

*For 100 gallons of Paint*

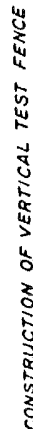
\* Low reactivity zinc oxide.

## Water Reducible Gloss Paints

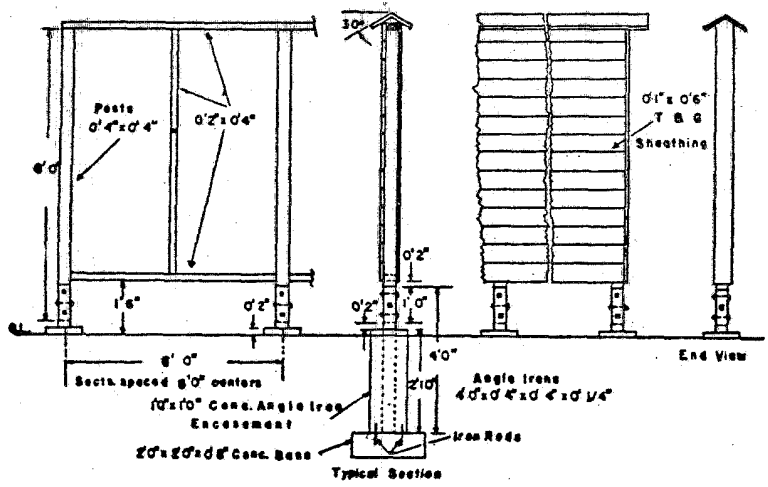
Latices that have small globule size would seem to be particularly adaptable to the development of latex gloss finishes.

TITANOX-RCHTX or TITANOX-C-50 as sole white pigment with latexes, yield high sheen and gloss depending upon pigment volume concentration.

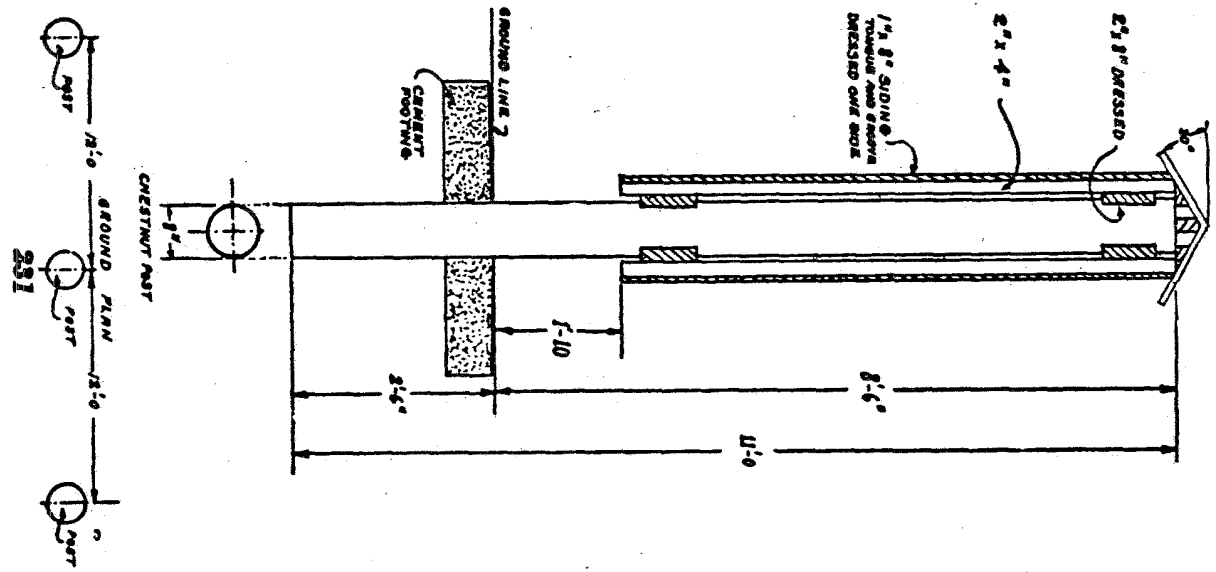
Thus, TITANOX-RCHTX and TITANOX-C-50 should bring to latex gloss finishes, the economy and high quality with which they are associated in latex flats.



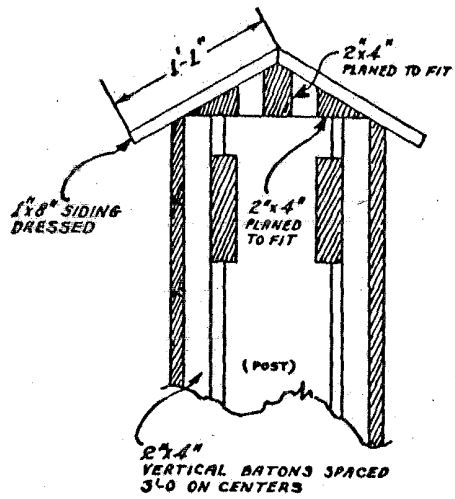
# Newest Construction of Vertical Test Fence



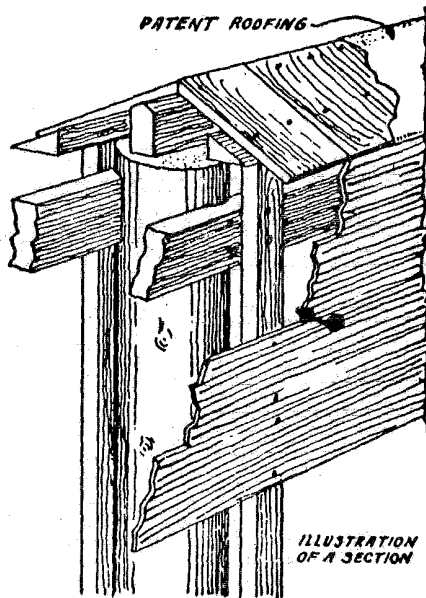
230



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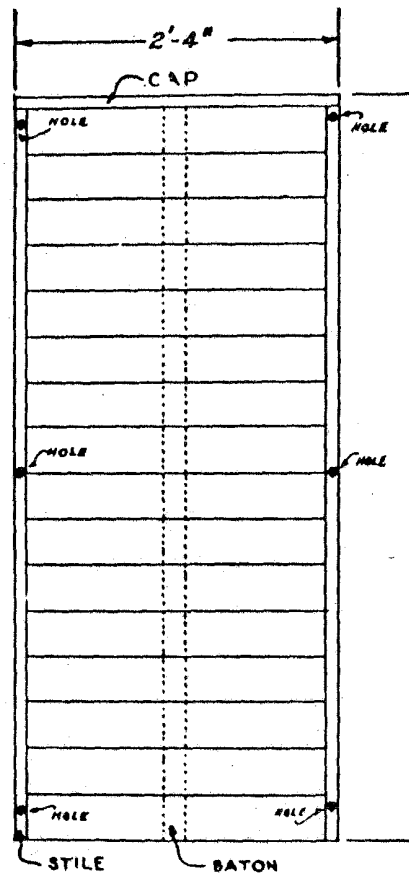


PATENT ROOFING



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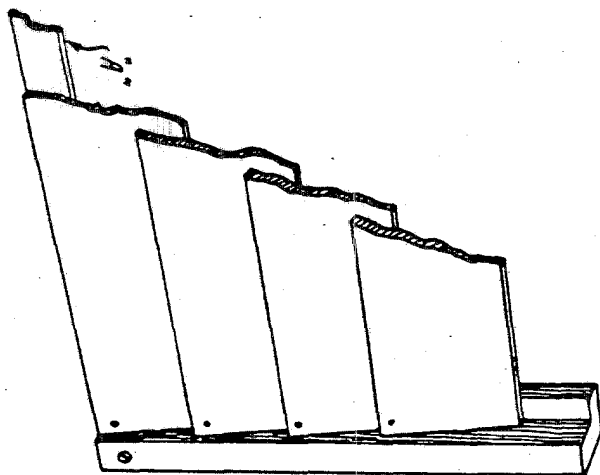
# Construction of a Test Panel



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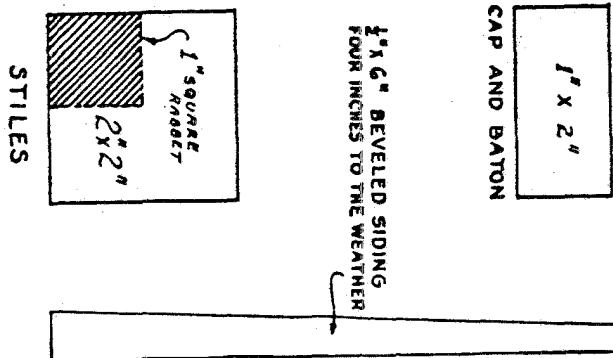
# Construction of a Test Panel



Method of fastening beveled siding to rabbeted channel of stile. "A" is a 2" piece of siding ripped from top lap.

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# Construction of a Test Panel

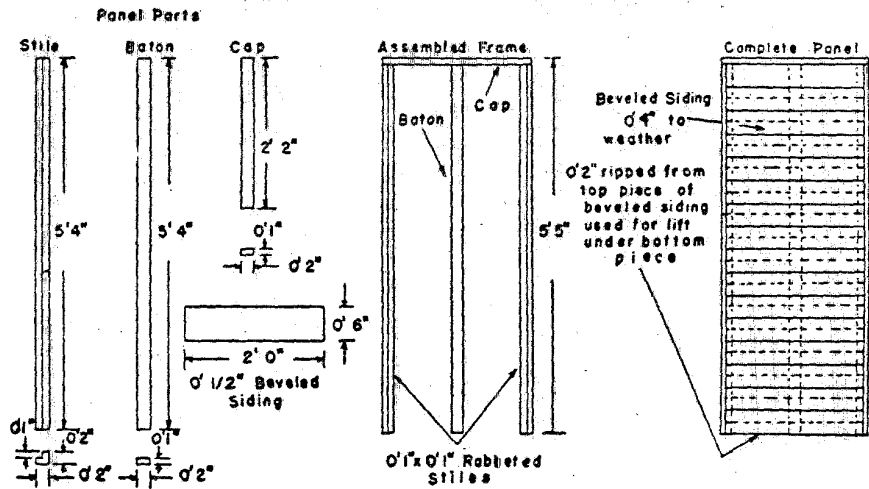


Material

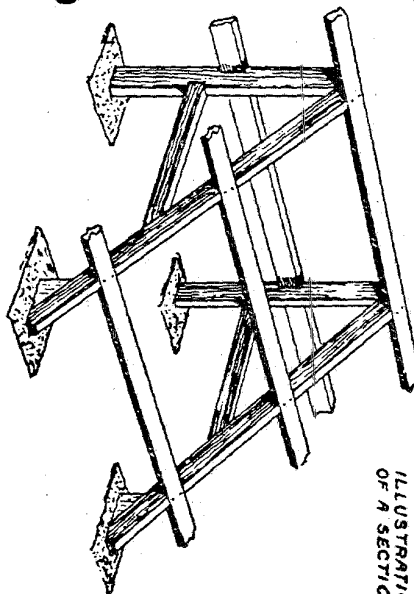
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# Newest Construction of Test Panel



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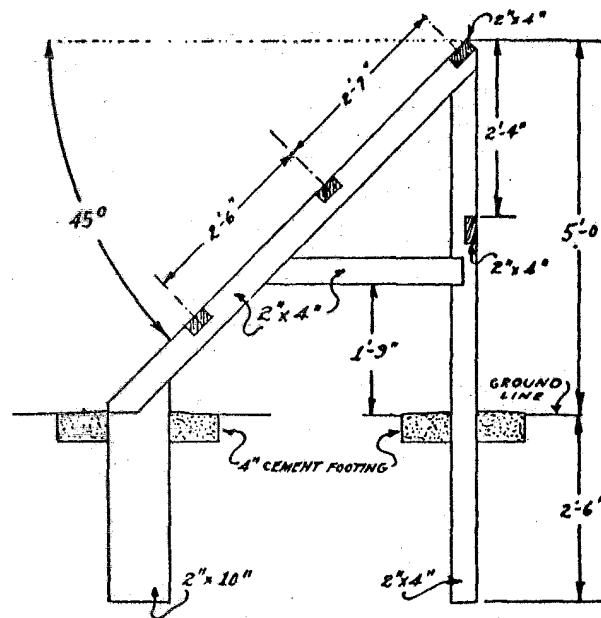
Early Construction  
of a  
45° Test Fence

ILLUSTRATION  
OF A SECTION

237

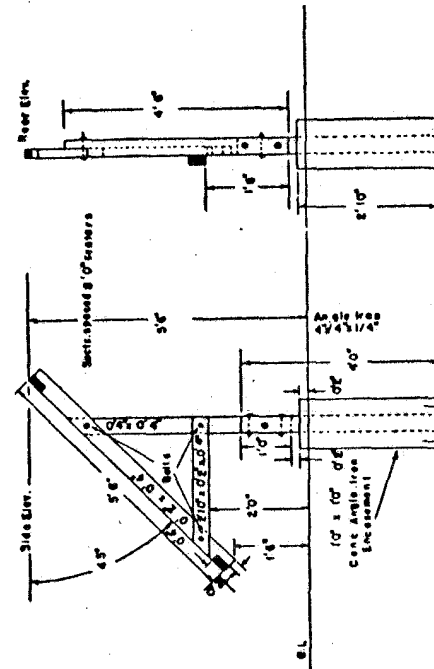
NLI 121374

# Early Construction of a 45° Test Fence Side Elevation



2" x 10" FOOTINGS SPACED  
3' 11" ON CENTERS

# Newest 45° Test Fence



## HOUSE PAINTS—EXTERIOR

### White

THE outstanding quality demanded of white paints for the exterior of houses is uniform whiteness, initially and as long as repainting can be deferred. This does not mean this type of paint should not be durable, for any marked deficiency of the film will reduce uniform whiteness or hasten the need for repainting.

Effective whiteness of the paint—its appearance when observed on the house, is of course a result of the whitening power of the pigment assured through high opacity. Recognition of this fact resulted in immediate interest in titanium pigments for white house paints as soon as these pigments were made available to the paint industry. Retention of effective whiteness during weathering of the paint depends upon:

1. Freedom from excessive accumulation of dirt and other unsightly substances such as mildew on the film during the period after complete drying until the effects of weathering set in.
2. Wear of the paint film through gradual uniform chalking.
3. Retention of whiteness of the pigment itself as a result of its resistance to sunlight, gases in the atmosphere such as hydrogen sulfide and other agents that might be encountered.
4. Freedom from defects in the film such as checks and cracks conducive to loss of adherence, protection and effective whiteness.
5. Resistance to the solvent action of water through freedom from excess quantities of substances appreciably soluble in water.
6. Freedom from "erosion" that is the rapid disappearance of the film from the substrate as a result of heavy chalking, washing, or reaction of pigment with atmospheric agents.

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### Pigment and Vehicle

Through balanced pigmentation—(1) titanium pigment for whiteness, whiteness retention, hiding and chalking, (2) white lead for building the film through reaction with linseed oil and also promotion of adherence, (3) zinc oxide for promotion of initial hardness and contribution to washing effect and (4) extender to promote reduction of cracking after long exposure—at pigment volume concentration (pvc) of 28%-33% in linseed oil, the qualities demanded in these paints have been achieved. The range of proportions of the components of the pigmentation has run about:

10-20% Titanium dioxide  
20-41% White lead  
20-30% Zinc oxide  
15-47% Extender

Prior to World War II, the vehicle of these paints consisted on the average of 85-90% linseed oil, the remainder thinner and drier. Of this oil, often 10% to 17% was bodied, the remainder raw or refined linseed oil. The familiar oil conservation program during the war, however, led to higher content of bodied linseed oil as a result of increased content of thinner. Such vehicles will run equal parts of bodied linseed (min. Z-2), raw or refined linseed and mineral spirits plus drier—the total oil content of the vehicle by weight running 65%-75%. Increased thinner content of the paint has resulted in higher pigment volume concentration, so that instead of the average of 28%-30% prevalent before the war, values as high as 35% may be found in titanium-lead-zinc-extender paints. Soya bean oil is also widely used. In our experience, thus far, durability is maintained while drying is satisfactory where the total amount of soya bean oil does not exceed 30% of the total oil content. Other bodied oils, especially dehydrated castor oil may be used successfully as the bodied oil portion of the vehicle.

The quality of exterior paints containing the higher content of thinner as a result of the newer type of vehicle is generally superior to that associated with the pre-war vehicle. This result is not at all surprising, for in the testing experience of Titanium Pigment Corporation, bodied oil vehicles have proven satisfactory in properly formulated exterior house paints in a test program spanning more than twenty-five years.

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### Dirt Collection and Chalking

Freedom from unsightly collection of dirt as dependent upon the degree of chalking of the paint is governed by the presence of air borne particles and the climate where the paint is exposed. The ability of the paint film to "clean itself" depends largely upon three factors. In the established all oil vehicle of white house paints, these are:

1. Kind and amount of titanium pigment.
2. Kind and amount of lead and zinc pigments (reactive pigments).
3. Pigment volume concentration.

These must be balanced to secure the rate of chalking attainable under the atmospheric conditions to which the paint is exposed. It should be mentioned that mildew is classed with dirt and is often removed with it through chalking. But in warm and humid regions mildew may not be removed sufficiently through chalking so that a fungicide may have to be added to the formula to inhibit the growth of mildew.

In multiple component pigmentations of established all oil vehicles of house paints, TITANOX titanium pigments differ basically, thus far, as between the anatase and rutile crystal structures in respect to chalking. In comparable grades, the rutile pigments are slower chalking.

The chalking types, often called *free chalking* or *fast chalking* pigments, are the anatase titanium dioxides:

TITANOX-A-CG  
TITANOX-A-MO  
TITANOX-A-168

These anatase titanium dioxides are most valuable in regulating the degree and rate of chalking. The rutile titanium dioxide analogous to TITANOX-A-MO is TITANOX-RA-10 but this pigment is not free chalking but rather approaches the *slower chalking* types.

These *slower chalking* pigments are TITANOX-RA (rutile titanium dioxide), TITANOX-RC-HT (rutile calcium, 30%  $\text{TiO}_2$ ) and TITANOX-C-50 (rutile calcium 50%  $\text{TiO}_2$ ) which are slightly slower chalking than the anatase pigment in this class—TITANOX-A—often called *semi-chalking*.

The slowest chalking pigments are "non-chalking."

rutile titanium dioxide TITANOX-RA-NC and rutile calcium pigment TITANOX-RC.

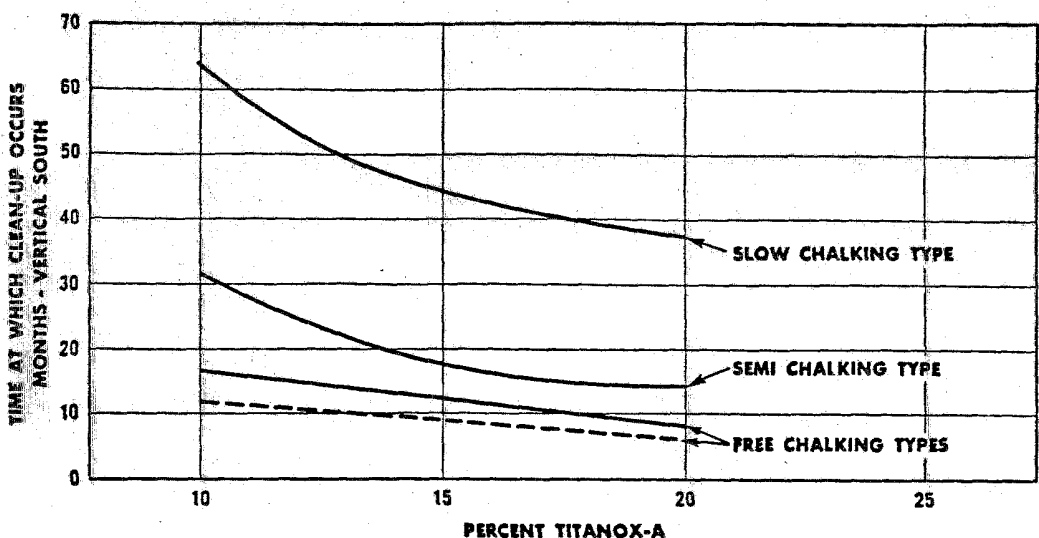
As would be expected, generally, a shorter time is required for the paint to chalk sufficiently for dirt removal or "clean-up" by the use of the chalking type of pigment, and this is prolonged by the slower chalking types. However, as the percentage of titanium dioxide is increased, the time for "clean-up" to take place is shortened. As a result, at high titanium dioxide content, a more chalk-resistant type of titanium dioxide may be used. A classic example of these effects is depicted in Figure VII.

### Slower chalking rutile pigments supplemented by chalking anatase

But even at high titanium dioxide or titanium pigment content, the slower or delayed-chalking rutile pigments may under some exposure conditions retard chalking too much and interfere with dirt removal. Extensive weathering tests indicate that the rutile pigment should be used along with a proportion of anatase chalking pigment for suitable rate of chalking and "clean-up". A typical comparison taken from many weathering tests revealed that a paint containing TITANOX-RA at 20% of a typical titanium-lead-zinc-extend pigment did not begin to chalk until after eight months of exposure during which time the film was dirty although after three years it had cleaned up. However, with TITANOX-RA at 10% plus TITANOX-A-MO at 10% the film started to chalk after three months exposure and presented a clean white film at six months, with excellent appearance after three years. These exposures were at Sayville, N. Y. vertical south.

The slower chalking is the rutile pigment, the larger the amount of chalking type anatase TITANOX-A-MO that should be used with it. Although some formulators prefer to use the slowest chalking pigments TITANOX-RA-50, TITANOX-RA-NC or TITANOX-RC by adding a large proportion of TITANOX-A-MO, the use of the "non-chalking" pigments may not be safe for paints exposed in heavily contaminated atmospheres. Greater assurance of securing a clean white paint on weathering lies in combinations of TITANOX-A-MO with TITANOX-RC-HT or with TITANOX-RA.

FIGURE VII



An example of reduction in dirt collection through the use of TITANOX-A MO (chalking type anatase  $\text{TiO}_2$ ) plus TITANOX-RCHT is shown in Table VII.

TABLE VII

| Exposed Vertical South | Dirt Collection* |    |    |    |    |    |
|------------------------|------------------|----|----|----|----|----|
| Pigment                | Months           | 4  | 8  | 12 | 16 | 20 |
| 50% TITANOX-RCHT       | }                | VS | VS | VS | VS | VS |
| 50% Leaded Zinc (35%)  |                  | VS | VS | VS | VS | VS |
| 35% TITANOX-RCHT       |                  | VS | VS | VS | VS | VS |
| 5% TITANOX-A MO        |                  | VS | VS | VS | VS | VS |
| 10% Extender           |                  | VS | VS | VS | VS | VS |
| 50% Leaded Zinc (35%)  |                  |    |    |    |    |    |

\* S—Slight  
V—Very

In any case experience from extensive and prolonged testing indicates certain limits for pairing up each rutile type of TITANOX with TITANOX-A MO to retain desirable "clean-up". These limits—presented to serve only as guides to the optimum ratio between these pigments—are given in Table VIII.

TABLE VIII

Pairings of TITANOX-A MO and TITANOX rutile pigments in white house paints

|                                    | Of the total TITANOX (Titanium pigment) portion, % by weight |
|------------------------------------|--------------------------------------------------------------|
| TITANOX-RA-NC                      | not more than 25                                             |
| TITANOX-A MO                       | not less than 75                                             |
| TITANOX-RA-50                      | not more than 25                                             |
| TITANOX-A MO                       | not less than 75                                             |
| TITANOX-RA                         | not more than 50                                             |
| TITANOX-A MO                       | not less than 50                                             |
| TITANOX-C-50 (50% $\text{TiO}_2$ ) | not more than 67                                             |
| TITANOX-A MO                       | not less than 33                                             |
| TITANOX-RCHT (30% $\text{TiO}_2$ ) | not more than 87                                             |
| TITANOX-A MO                       | not less than 13                                             |

As an example of a pigmentation guided by Table VIII, consider a white house paint containing 65% pigment by weight consisting of 20% titanium dioxide.



50% lead and zinc pigments and 30% extender. In this case the titanium dioxide content might be made up of a maximum of 25% TITANOX-RA-NC the remainder being TITANOX-A-MO, so that the pigment portion of the paint would then consist of:

15% TITANOX-A-MO, 5% TITANOX-RA-NC, 50% lead and zinc pigments, 30% extender.

In the drying oil vehicle established for house paints, the reactive pigments—white lead and zinc oxide—must be used in proper amount to provide a film in which titanium pigment may contribute to "clean-up." Of course, in this type of vehicle, zinc oxide contributes to initial hardness of film essential to resistance to collection of air borne particles. In general, of the total pigment by weight, a useful guide is a minimum of 35% and a maximum of 50% reactive pigment of which about one-half should be zinc oxide. The reactive pigment in balance with titanium pigment and extender promotes a gradual rate of chalking.

There is a great deal of evidence supporting improved "clean-up" as a result of increased pigment volume concentration. Generally, since the adoption of a higher content of bodied oil and also of thinner resulting in higher pvc, chalking characteristics of white house paints have improved. Many comparisons of present day pigmentations at 33-35% pvc with the same pigmentation at 28-30% pvc show definite improvement in "clean-up". The principle of critical pvc as discussed on page 208, although not exactly correlated with weathering of white house paints does apparently have an influence. An evidence of this is the overloading of a pigmentation with extender having high oil demand with the result that extremely fast chalking and resultant erosion occur probably due to lack of "free binder". Although in such a case reduction of the amount of reactive pigment also contributes to fast chalking.

### Durability

Before the advent of rutile pigments it was firmly established that with increase in titanium dioxide content there is also an increase in the period of time before checking of the film is observed. Also this time is prolonged by increased resistance to chalking of the titanium dioxide but the delay in checking

parallels delay in chalking and increase in dirt collection. As a result white paints before the advent of rutile had largely to be formulated with chalking type anatase pigment.

Pigmentation, of course, was balanced to prevent early checking and resultant cracking to maintain good reparability while titanium pigmentations were much superior generally to non-titanium pigmentations.

### Rutile Pigments Improve Durability

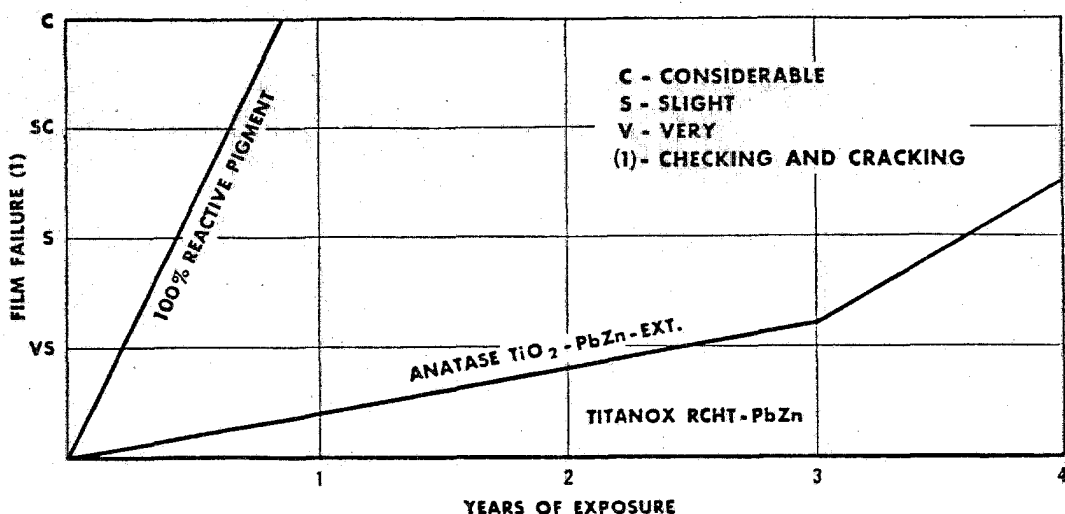
The principle of delayed checking through increased titanium content still holds but it is now supplemented by one of greater importance, namely that rutile type pigments in balanced formulation retard checking and cracking to a greater extent than do anatase pigments. Many tests indicate that rutile pigments actually prevent these failures within the useful life of the paint and it is felt that TITANOX rutile pigments account for the greatest single improvement in the durability of house paints.

Some of the earliest comparisons involved simply the rutile-calcium pigment TITANOX-RCHT as the rutile pigment. Inasmuch as TITANOX-RCHT carries its own excellent extender, no additional extender was added but simply lead and zinc pigments. A classic example of the prevention of checking and cracking by this type of pigmentation is shown in Figure VIII in which the usual combinations of anatase titanium dioxide-lead-zinc-extender as well as 100% reactive pigment are compared with the rutile pigmentation.

### A Greater Benefit Accompanies "Clean-up"

Extensive testing over the past ten years indicates that checking and cracking are still delayed or prevented when anatase chalking pigment is used along with rutile. This greater benefit accompanies the desirable chalking rate and "clean-up" secured through anatase-rutile pigment combinations. An example of delay in checking as dependent upon the chalking resistance of the pigment and the use of rutile titanium dioxide is shown in Table IX for an exposure period of three years vertical south at Sayville, N. Y. This is one example of many that illustrate improved durability plus appearance through properly balanced pigmentation, which means not only proper ratio of

FIGURE VIII



anatase to rutile but also reactive pigment content too. These reactive pigments—the other prime pigments—white lead and zinc oxide are usually not allowed to comprise more than 60% of the total pigmentation. In lead free paints, the optimum amount of zinc oxide is about three pounds per gallon of paint or between 30% to 40% of the total pigmentation. Inasmuch as all paint qualities are related, these proportions are the optimum for securing cleanliness plus durability.

### Hiding Power

Increasing titanium dioxide content of white exterior house paints is naturally a result of the desire for greater effective whiteness secured through higher hiding power.

The transformation of chalking, as secured through balanced formulation, into a merit rather than a defect has also stimulated increase in the titanium pigment content of these paints. Today it is not unusual for the total pigment portion of the paint to contain 20% or more by weight of titanium pigment expressed as titanium dioxide.

The outstanding quality of rutile type pigment—its higher hiding power than that of anatase—is of course evident in white house paints. But the increase in hiding of the paint accompanying increase in titanium dioxide content is probably more notable. Figure IX depicts an example of these increases caused by replacing extender in the base formula 10% titanium dioxide, 40% white lead and 25% magnesium silicate at 29% pvc. The point (X) in Figure IX locates the hiding power of the pigmentation:

50% Titanox-RCHT (rutile-calcium, 30%  $TiO_2$ )  
50% Leaded Zinc (35%)

at 29% pvc. The hiding power of this pigmentation being higher than that of 15% Titanox-RA (rutile "pure"  $TiO_2$ ) gives a clue to the higher hiding efficiency of Titanox-RCHT (30%  $TiO_2$ , rutile-calcium pigment). This high hiding per pound of Titanox-RCHT accommodates the addition of chalking type anatase pigment without an appreciable sacrifice in hiding power of the paint. Where highest hiding per dollar of pigment is important, the coalesced composite Titanox pigments should be considered especially as they also provide an excellent extender. But in any

TABLE IX

*Example of Chalking, Checking and Appearance  
Vertical South Exposure—3 years*

Pigmentation: 20% TITANOX—50% Lead Zinc Oxide—30% Magnesium Silicate  
33% Pigment Volume Concentration

Vehicle: —75% Refined Linseed Oil—25% Z2 Linseed Oil—25% Volatile

| Type of<br>TITANOX<br>% of total pigment                                                | Chalking<br>began after<br>months | Checking<br>began after<br>months | Appearance                               |
|-----------------------------------------------------------------------------------------|-----------------------------------|-----------------------------------|------------------------------------------|
| 20% TITANOX-A MO (fast chalking anatase) .....                                          | 3                                 | 27                                | Excellent—clean white                    |
| 20% TITANOX-AA (semi-chalking anatase) .....                                            | 8                                 | 36                                | Good                                     |
| 20% TITANOX-RA (slower chalking rutile) .....                                           | 8                                 | —                                 | Fair as a result of slower<br>"clean-up" |
| 20% TITANOX-RA-50 (slow chalking rutile) .....                                          | 8                                 | —                                 | Poor as a result of slow<br>"clean-up"   |
| 10% TITANOX-A MO (fast chalking anatase) }<br>10% TITANOX-RA (slower chalking rutile) } | 3                                 | —                                 | Excellent—clean white                    |
| 15% TITANOX-A MO (fast chalking anatase) }<br>5% TITANOX-RA-50 (slow chalking rutile) } | 3                                 | —                                 | Excellent—clean white                    |

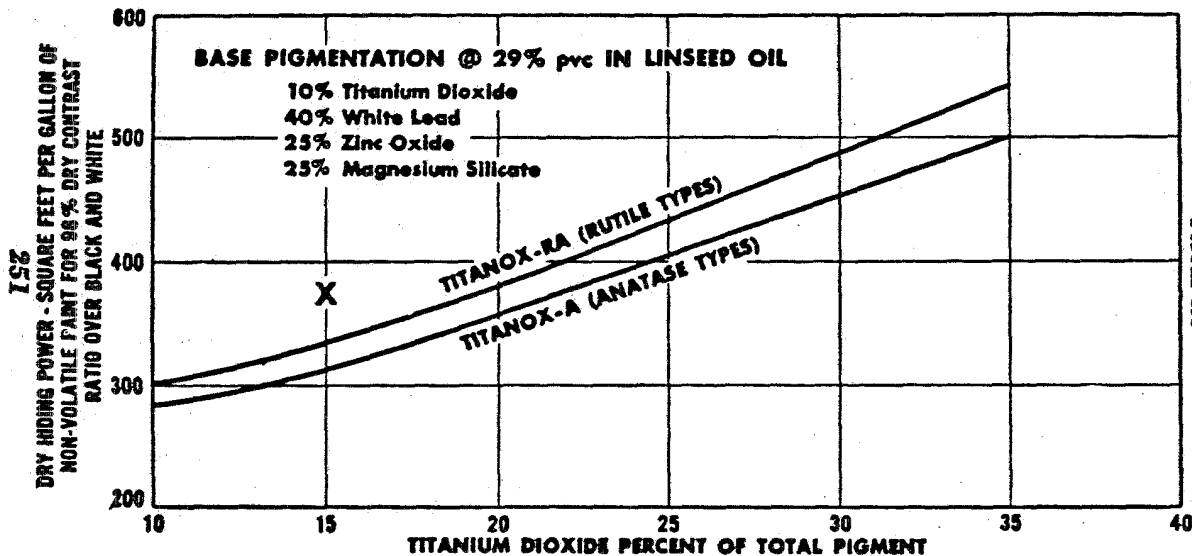


FIGURE IX

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case the high total titanium pigment content of today's paints yields high hiding even with the addition of the anatase chalking type. In formulas in which Titanox-A MO is the sole titanium pigment, in terms of hiding power, Titanox-RCHT may replace Titanox-A MO in the ratio of two pounds of the composite pigment to one of the oxide. The proportions of these pigments mentioned in Table VIII page 245 should be kept in mind where dirt collection is a factor.

#### Reduction of Reactive Pigment Content— "Fume-Proof" Paints

Rutile pigments especially Titanox-RCHT are particularly valuable in achieving high hiding where it is felt that the proportion of reactive pigment should be reduced to make room for the extra hiding of titanium pigment. In reducing white lead content a lead pigment having low specific gravity such as "ONCOR" basic silicate white lead 45X—100 pounds of which is equivalent to 161 pounds of basic lead sulfate or 169 pounds basic carbonate white lead—is usually preferred.

A classic example of the increase in hiding afforded by higher titanium dioxide content as a result of replacement of reactive pigments is depicted in Figure X.

The attainment of exceptionally high hiding plus increased durability is facilitated in this type of paint through the use of rutile type pigments. For example, in a "fume-proof" paint containing only zinc oxide as the reactive pigment, hiding power of 440 square feet per gallon (98% contrast ratio of dried film over black and white) was obtained with a combination of 2.13 lb. Titanox-RCHT plus 2.57 lb. Titanox-A MO per gallon of paint. The amount of anatase Titanox-A MO as the sole titanium pigment to yield this hiding was 3.7 pounds per gallon of paint.

Extensive exposures have revealed that high titanium dioxide content markedly improves the durability of "fume-proof" paints. A striking example is shown in Table X.

TABLE X

#### Effect of Titanium Dioxide Content on Durability "Fume-Proof" Paint

After Five Years Exposure, Vertical South,  
Savoyville, N. Y.

| Pigment              | Condition of Panel                                          |
|----------------------|-------------------------------------------------------------|
| 15% Titanium Dioxide | Evidence of erosion of film; checking and cracking visible. |
| 35% Zinc Oxide       |                                                             |
| 50% Extender         |                                                             |
| 30% Titanium Dioxide | No sign of erosion or checking and cracking                 |
| 35% Zinc Oxide       |                                                             |
| 35% Extender         |                                                             |

The use of rutile pigment as part of the titanium dioxide content at its high level in these paints not only increases hiding power but further delays checking and cracking.

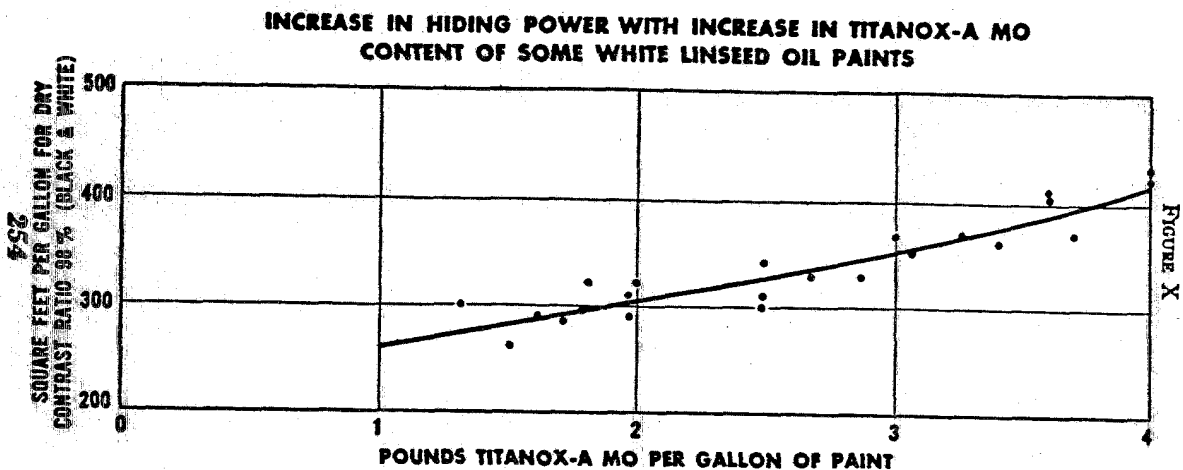
#### Titanium Pigment as Sole Pigment

The "fume-proof" white paint has been needed where industrial and other fumes would discolor a paint containing white lead. The poor durability of early lead free paints has been overcome through balanced pigmentation plus the use of bodied oil vehicles. But the current titanium-zinc paints still stain from weathered building hardware.

The objective in making titanium pigment the 100% white hiding component is a high hiding white house paint having lasting whiteness free from discoloration and staining associated with the reactive pigments plus good repaintability.

One of the first approaches to this end was to add titanium or other metallic soaps or compounds to be strongly adsorbed by the pigment to form a link with the vehicle. Another, prior to the advent of modern resins, was to add short oil varnishes particularly those compounded with tung oil.

In the soundly traditional linseed oil vehicles of white house paints it is possible to use titanium pigment alone. Such paints show extremely heavy dirt collection which cleans up after which the paint chalks and erodes leaving bare wood after a few years.



It was realized that to make titanium pigments the only white pigments in house paints, a vehicle had to be developed which would provide a pigment-vehicle system equivalent to that of the reactive pigments and linseed oil.

The following approach to the formulation of a strictly titanium pigmented paint proved successful:

1. Development of a combination of resins, oils and other film-formers which provided good workability, adhesion, hardness and durability.
  2. Pigmentation with the right combination of rutile and anatase Titanox pigments plus extender at suitable total pigment volume for:
    - (a) Whiteness and high hiding.
    - (b) Desirable rate of chalking and dirt removal.
    - (c) Freedom from film defects such as cracking after prolonged weathering.
    - (d) Proper body for application and for sufficient film thickness to promote long life and protection.
  3. Inclusion of mildew preventive or development of mildew-resistant vehicle.
- By necessity research on house paints is a slow process. The transfer to practice of any formula requires that it be thoroughly tested under the many conditions that this type of paint will encounter in service.
- Utilizing the three principles mentioned above, excellent results have been obtained on panel weathering tests and on houses by the following combination:
1. Vehicle—65% non-volatile consisting of long oil alkyd resin, chlorinated paraffin and linseed oil in the proportions respectively 35%, 25% and 40% by weight.
  2. Pigment—24% Titanox-A-168, 76% Titanox-RCHT at 33% pvc or 25% Titanox-A-168, 25% Titanox-RA-51, 50% Extender at 33% pvc.
  3. Mildew Preventive—Phenyl mercuric naphthenate, phenyl mercuric oleate.

Paints made with the foregoing combination have been tested for over ten years. The bright whiteness contributed by balanced titanium pigmentation is not marred by darkening from gases or by stains from rusting hardware. In addition, adhesion has been promoted through resistance to blistering. In greater detail, the combination is as follows:

#### ILLUSTRATIVE FORMULA WHITE HOUSE PAINT

Titanium Dioxide as sole Hiding Pigment

For approx. 100 gallons of Paint

|                                                  |      |         |
|--------------------------------------------------|------|---------|
| TITANOX-A-168 (anatase $\text{TiO}_2$ )          | 150  | Pounds  |
| TITANOX-RA-51 (rutile $\text{TiO}_2$ )           | 150  | "       |
| Magnesium Silicate                               | 320  | "       |
| Chlorinated paraffin resin (70% Cl) <sup>1</sup> | 96.5 | "       |
| Raw linseed oil (acid value 2-4)                 | 13.5 | Gallons |
| "C" bodied linseed oil (acid value 4-7)          | 8.0  | "       |
| Alkyd Solution (70% solids) <sup>2</sup>         | 25.5 | "       |
| Thinner <sup>3</sup> and driers                  | 21.0 | "       |
| Anti-skinning Agent                              | 0.2  | "       |
| Mildewicide (10% Hg) <sup>4</sup>                | 2.5  | "       |

<sup>1</sup> Chlorowax 70—Diamond Alkali Co. or equiv.

<sup>2</sup> Aroclaz 1248 (AIDIN) or equiv.

<sup>3</sup> Petroleum thinner 1, R.P. 350° to 375° F.

<sup>4</sup> Phenyl mercuric oleate or equivalent Hg organic.

#### Flat or Lustreless Exterior House Paints

Inasmuch as the conversion of an orthodox house paint to a flat, simply by increasing pvc, adding flatting extender, adjusting ratio of prime pigment to extender, and adjusting body and working qualities, will not give a durable paint, other approaches are used.

Outstanding among these is the selection of an alkyd that suitable for use in a flat paint, also helps to impart resistance to water, staining, after-yellowing, and penetration into porous surfaces. Such alkyds must be selected with the greatest care to make sure they do

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not contain modifiers that will ruin outdoor durability through promotion of brittleness and loss of adhesion. Exposure studies indicate that with a suitable alkyd, pigmentation should comprise "non-chalking" TITANOX-RA-NC for both whites and tints.

The high pvc of most flat wall paints should be lowered for exterior use. Indications are that 50% is about maximum.

For this type of paint, the TITANOX "C" pigments hold greatest promise, especially since they are not free chalking.

#### Exterior White Latex

Thus far, as contrasted to regular organic solvent exterior white house paints, latex counterparts require only a minor proportion of chalking anatase pigment, and in some cases none.

Thus, in butadiene-styrene latex white exterior paints, thus far, clean bright whiteness as a result of suitable rate of chalking-cleaning, has been obtained with "non-chalking" rutile TITANOX-RA-NC. Replacement of any proportion of this with chalking anatase is highly inadvisable inasmuch as early and heavy chalking might result.

While in polyvinyl acetate and especially in acrylic latices some rigorous exposure conditions might call for 100% "non-chalking" TITANOX-RA-NC or highly chalking resistant TITANOX-RA-50 or TITANOX-RA-51, usually bright whiteness initially, and as a result of suitable rate of chalking-cleaning, is secured through a proportion of anatase chalking pigment. About 10% of the titanium pigment as chalking type is indicated, such as TITANOX-A-MO, the remainder being "non-chalking" or highly chalking resistant.

Whiteness characteristics are also benefitted by the use of magnesium silicate extender, the whole pigmentation being at 40% pvc.

Here is an example of the proportioning of ingredients of this type of paint utilizing polyvinyl acetate and also acrylic latices:

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# ILLUSTRATIVE FORMULA

## EXTERIOR WHITE LATEX PAINT

### Polyvinyl Acetate Vehicle

#### For 100 gallons of Paint

|                                                |     |         |
|------------------------------------------------|-----|---------|
| TIRANOX-A-168 .....                            | 50  | Pounds  |
| TIRANOX-RA-NC .....                            | 200 | "       |
| Magnesium silicate .....                       | 115 | "       |
| Dispersing Agent .....                         | 1.5 | "       |
| Vinyl copolymer (55% solids) .....             | 36  | Gallons |
| Thickener (2% solids) .....                    | 18  | "       |
| Wetting, antifoam and mildewicide, Total ..... | 1.6 | "       |
| Anti-freeze .....                              | 3   | "       |
| Coalescing Agent .....                         | 1   | "       |
| Water .....                                    | 29  | "       |

## ILLUSTRATIVE FORMULA

### EXTERIOR WHITE LATEX PAINT

#### Acrylic Vehicle

#### For 100 gallons of Paint

|                                                 |      |         |
|-------------------------------------------------|------|---------|
| TIRANOX-A-168 .....                             | 25   | Pounds  |
| TIRANOX-RA-NC .....                             | 225  | "       |
| Magnesium silicate .....                        | 210  | "       |
| Acrylic Emulsion (46% solids) .....             | 55   | Gallons |
| Thickener (2% solids) .....                     | 18   | "       |
| Wetting, anti-foam and mildewicide, Total ..... | 3.25 | "       |
| Anti-freeze .....                               | 3    | "       |
| Coalescing Agent .....                          | 1    | "       |
| Water .....                                     | 4    | "       |
| Ammonium hydroxide (28% solution) .....         | 0.1  | "       |

## Characteristics

Brilliant or light tints, at high hiding power of the paint, account for the use of titanium pigments in tint base house paints. These effects naturally are derived from the brightening power and high opacity of titanium pigments. For a few years, fading due to chalking accompanied these benefits, but with the introduction of the first chalking resistant Tiranox pigment thirty-one years ago, high hiding tint bases were formulated to produce attractive colors initially and after weathering.

Of course, tinted house paints must not chalk to the point where strong white pigment will mask and thereby lighten the color. On the other hand, these paints must possess some self-cleaning stimulated by uniformly slow chalking which results in a gradual lightening of color after prolonged weathering, for unlike hard enameled surfaces, house paints are not subjected to cleaning and polishing.

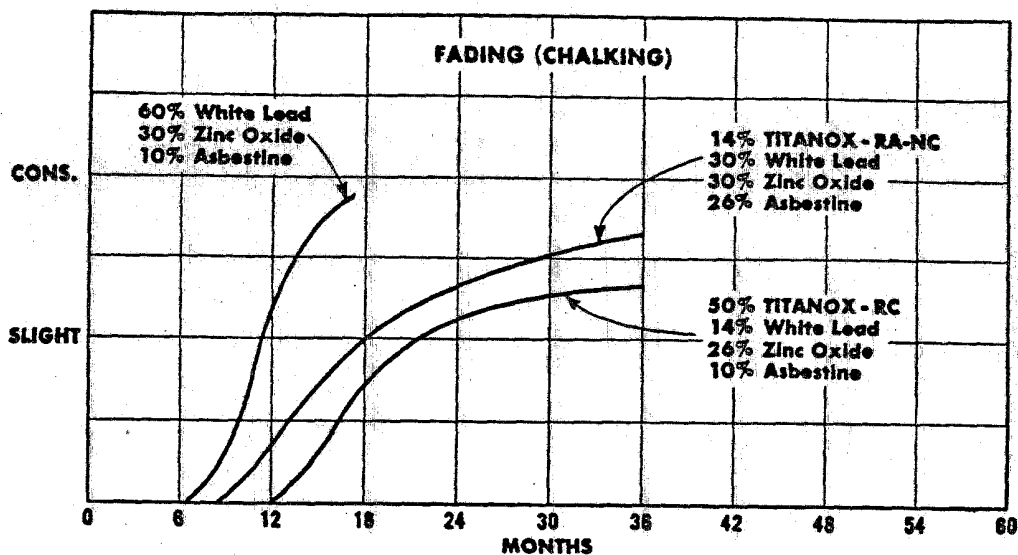
## Non-Chalking Pigment Applicable

The degree of chalking required in tint bases is not high enough to allow the use generally of chalking pigments such as TIRANOX-A-MO; -A-CG; or -A-168. When formulated according to the principles accepted for white paints (except that unusually high content of titanium pigment is not needed, since hiding power is increased by added tinting color through absorption) the "non-chalking" pigments TIRANOX-RC or TIRANOX-RA-NC produce highly acceptable tint bases.

Contrasted to an early pigmentation of white lead, zinc oxide and extender in common use before titanium pigments were established, an example of reduction in fading due to chalking of high hiding tint bases pigmented with TIRANOX-RC and TIRANOX-RA-NC is shown in Figure XI. Somewhat better performance is indicated from this chart for TIRANOX-RC in comparison with titanium dioxide plus extender and this is generally true where fibrous magnesium silicate or other high oil taking extender is used in appreciable proportion with TIRANOX-RA-NC.

## Tint Bases

Figure XI



The calcium sulphate integral with TITANOX-RC is highly adaptable to house paint tint bases because of low oil demand and uniformity in all properties. By selecting TITANOX-RC the amount of extender to be added is often greatly reduced. In addition, proper suspension, body and working qualities are readily attainable.

Inasmuch as relatively large amounts of extender are often needed, these should have low oil absorption or oil demand. Natural calcium carbonate and calcium sulphate in this class are generally preferred.

There is some evidence that better tint retention is secured with zinc oxide as the sole reactive pigment, the acicular type being preferred. Nevertheless, white lead is often included to promote durability.

The amount of reactive pigment, especially zinc oxide must be high enough to provide initial film hardness to resist collection of dirt and mildew and to assist clean-up after chalking has started. Between two and three pounds of zinc oxide per gallon of paint is the usual range, but if lower, a mildew preventive should be included.

Because titanium dioxide highly resistant to chalking-fading is often used in relatively low proportion to avoid too much white opacity for darker colors, total pigment volume concentration can be raised to advantage. A house paint tint base represents a strange balance of forces in that chalking although undesirable from the standpoint of lightening the color is needed for clean-up and must be uniform and slow. The tint base is actually a special case of a white house paint in which titanium pigment having high chalking resistance is diluted with extender to lower its tinting strength. But pvc can run higher in a tint base because of the higher chalking resistance and lower proportion of titanium pigment. Higher pvc is often needed to reduce gloss where a less glossy colored paint is desired.

It must be remembered that tint bases can be more durable than comparable white paints partially as a result of chalking resistant titanium pigments. This is particularly true of TITANOX-RC, for during many years of continuous testing, paints made with it are remarkably resistant to checking and cracking.

In general, in the same type of vehicle employed in white house paints, pigmentations at 33-45% pvc in tint bases range about as follows:

10-50% TIRANOX-RC  
or  
5-12% TIRANOX-RA-NC  
0-30% White Lead  
(preferably basic silicate-45X)  
20-40% Zinc Oxide (acicular)  
10-70% Extender

### Tint Bases — Titanium as Sole White Pigment

To make a house paint tint base with titanium as the only white pigment means simply transforming a white paint of this type, such as the combination on page 255, to a tint base. The combination of anatase and rutile titanium dioxide of the white paint is replaced by "non-chalking" TIRANOX-RA-NC.

Whereas the high hiding white paint contains 3.0 pounds titanium dioxide per gallon, the tint base contains a lesser amount depending upon depth of tint and hiding desired—for deeper tints 0.5-0.75 lb. may be suitable and for light or pastel tints as much as 2.0 pounds per gallon of paint.

### Latex Tint Base House Paints

Latex tint bases also exemplify the use of titanium pigment as sole white hiding pigment. Chalking type anatase pigment is excluded while "non-chalking" TIRANOX-RA-NC is first choice, although TIRANOX-RA-51 may also be used in some cases.

Factors that govern the performance of regular house paint tint bases are also operative in the latex types. But, of course, the type of latex is also a governing factor. Thus far, butadiene-styrene latex tint bases in our exposure programs have shown early and excessive fading-chalking followed by loss of appearance and protection.

Also, pigment volume concentration is maintained lower in latex tint base than in latex white, and is normally 30%.

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The formulator should guard against excessively high pigment volume concentration in latex tint base. Here is an example of the influence of pigment volume concentration on the fading (chalking) of a blue exterior emulsion paint:

| % PVC | Months of Exposure for start of chalking |
|-------|------------------------------------------|
| 30    | 30                                       |
| 55    | 11                                       |

Outstanding performance has characterized properly formulated latex tints.

As in regular tint bases, type of extender plays a part in some cases. With acrylic latex, low oil absorption type natural whiting apparently contributes to greater tint retention.

Here are some illustrative formulas for high hiding latex exterior tint bases.

### For 100 gallons of Paint

|                                         | Polyvinyl Acetate | Acrylic         |
|-----------------------------------------|-------------------|-----------------|
| TIRANOX-RA-NC                           | Pounds 200        | 200             |
| Magnesium Silicate                      | " 80              | —               |
| Natural Whiting                         | " —               | 140             |
| Dispersant <sup>1</sup>                 | " 1.5             | 1.5             |
| Acrylic Emulsion (46% solids)           | Gallons —         | 64.5            |
| Vinyl copolymer (55% solids)            | " 41              | —               |
| Thickener (2% solution)                 | " 18 <sup>2</sup> | 12 <sup>3</sup> |
| Wetting Agent <sup>4</sup>              | Gallon 1          | 0.9             |
| Antifoam Agent <sup>5</sup>             | " 0.3             | 0.4             |
| Preservative <sup>6</sup> (10% mercury) | " 0.4             | 0.4             |
| Anti-freeze                             | Gallons 37        | 3 <sup>6</sup>  |
| Coalescing Agent <sup>7</sup>           | Gallon 1          | 1               |
| Ammonium Hydroxide (28%)                | " —               | 0.1             |
| Water                                   | Gallons 26        | 6               |

- <sup>1</sup> Dispersing Agent—Potassium Tripolyphosphate.
- <sup>2</sup> Thickener—Methocel 4000 cps—Dow Chem. or equiv.
- <sup>3</sup> Thickener—WPA-4400—Union Carbide Chem. or equiv.
- <sup>4</sup> Wetting Agent—Surfynol TG—Air Reduction or equiv.
- <sup>5</sup> Antifoam Agent—Foamicide 581B—Colloids, Inc. or equiv.
- <sup>6</sup> Preservative—Super AD-IT Nudex Prod. Co. or equiv.
- <sup>7</sup> Freeze—Thaw Stabilizer—Propylene Glycol.
- <sup>8</sup> Freeze—Thaw Stabilizer—Ethylene Glycol.
- <sup>9</sup> Coalescing Agent—Carbital Acetate—Union Carbide Chem. Co. or equiv.

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## House Paint Primers

### Characteristics

Polymerized oil and high volatile content as major components of vehicle for house paints first made their appearance in the United States in the specially formulated first coat for two coat work on the exterior of houses. Experience with this type of paint—house paint primer—has been truly the stimulus to improved vehicles for house paints.

The need for bodied oil, of course, is dictated by the need for reduced penetration of the surface over which the primer is applied. As a result of this body, more thinner than had ordinarily been used in house paint vehicles was required essentially at the then higher pigment volume selected as a result of the need for sufficient hardness of film.

Essentially such primers consist of titanium pigment, white lead and extender, and a vehicle balanced for reduced penetration and hardness. Usually to assure sufficient hardness, through partially offsetting the plasticizing effect of white lead especially in the thick coats of primer usually employed, a small amount of a resin such as ester gum is included in the vehicle. Although originally designed for use over wood, these primers have found wide application as first coats on many different types of porous surfaces such as stucco, masonry, cement, Cinder block and particularly asbestos-cement shingles.

A combination on the following order is typical of house paint primers:

#### Pigment:

Total at about 40% pvc  
25-50% White Lead  
25-40% Rutile-calcium pigment or equivalent of titanium dioxide plus extender  
20-40% Extender

#### Vehicle: (Non-volatile)

55-60% raw linseed oil  
30-40% bodied oil  
5-8% resin  
Volatile plus drier—40-45%

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Because TITANOX-RC possesses such unusual durability its use in these primers is becoming more popular despite the fact that the paint is not a finish coat exposed to the weather. The reason for this is that after the top coat starts weathering away, the prime coat will maintain sound condition as a result of slow chalking and delay or prevention of checking and cracking.

*It must be understood, of course, that primers pigmented with rutile-calcium pigments TITANOX-RCHT, TITANOX-RCHTX, TITANOX-RC or TITANOX-C-50, are for use over wood or other non-metallic surfaces on which corrosion of any metallic substrate is not involved.*

"Non-chalking" rutile "pure" TITANOX-RA-NC may, of course, be used in place of TITANOX-RC to achieve substantially the same result. But appreciable extender must be added to the "pure" pigment with the result that regulation of body and suspension is not as easy as with the composite pigment. Where there is no interest in exceptional durability, TITANOX-RCHT may be used in place of the "non-chalking" pigments and at slightly lower cost.

Inasmuch as the primer must be spread at an optimum thickness to anchor to the surface and to hold up the top coat, TITANOX pigment content must not be so high as to give so much hiding as to encourage brushing out or applying the primer in too thin a coat. Thus, pigmentation is equivalent to about one pound TITANOX-A-MO or 0.8 pound TITANOX-RA-NC or 2.6 lb. TITANOX-RC per gallon of primer.

The vehicles comprise either linseed oil about Z-4 viscosity and acid value of about 6, or oils comprising combinations of tung or dehydrated castor with linseed cooked to yield desirable resistance to penetration. A proportion of heavy bodied blown linseed is often included to promote easy brushing. Resin may be incorporated as a cut (dispersion in mineral spirits) or a short oil length varnish. Recently because of the decline in varnish making among paint manufacturers, the all linseed type of vehicle is usually preferred. But in any case, the ability of the primer to seal and adhere to the surface depends upon the polymeric structure of the vehicle. The simple absorption or filter paper "ring test," page 186 has proven to be a valuable indicator of the penetrative qualities of the primer.

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## Alkyd Vehicles in Exterior House Paint Primers

As would be expected, alkyds because they can embody all properties needed—adhesion, structure, penetration resistance, durability—to name some, are an indispensable ingredient of many present day exterior house paint primers.

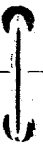
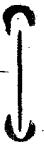
Here is an example of formulation of such a primer:

### For 100 gallons of Paint

|                                       |     |         |
|---------------------------------------|-----|---------|
| TIRANOX-RA-NC .....                   | 200 | Pounds  |
| Magnesium silicate .....              | 225 | "       |
| Flat alkyd solution (40% N.V.) .....  | 47  | Gallons |
| Alkyd solution (60% N.V.) .....       | 15  | "       |
| Thinner .....                         | 20  | "       |
| Driers plus anti-skinning Agent ..... | 1.5 | "       |
| Mildewicide (mercurial)* .....        | 1.3 | "       |

\* Paint containing a mercurial mildewicide should be packaged in lined cans.

Offered, as other formulas, only as a guide to experimental work and without guarantee of results.



## Enamels—Air Dry Exterior

As IR drying exterior enamels may be used for many purposes so that consequently a wide range of compositions may be presented. It is safe to say, though, that especially where the primary object is protection and decoration of an article or structure which is not subjected to direct physical contact such as foot traffic, vehicular traffic or impact from a machine part, insofar as titanium pigments are concerned, the problem involves meeting one or more of the following requirements:

- (1) Whiteness without excessive chalking.
- (2) Lasting color without excessive or non-uniform fading.

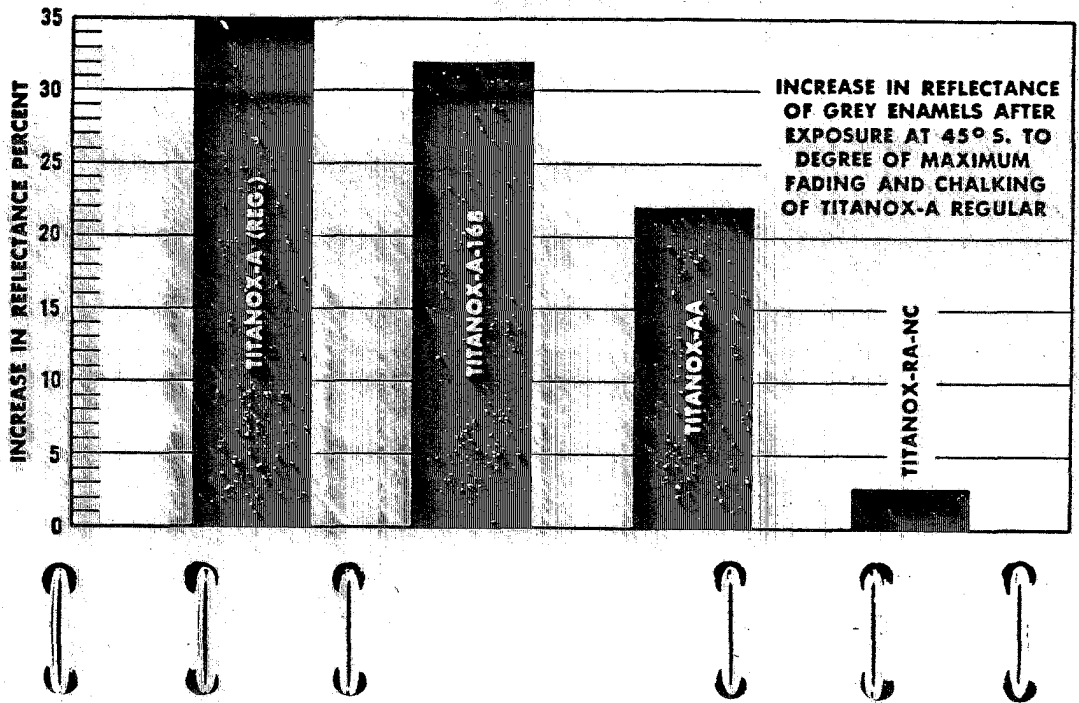
The selection of the type of TIRANOX to use is determined largely by the amount of hiding or brightness required and the pigment volume concentration as dictated by other requirements. In any event, usually "non-chalking" TIRANOX-RA-NC is the most logical choice.

The fading due to residual chalk on an enamel is, of course, objectionable and where vehicle is controlled, rules out appreciable amounts of chalking type titanium pigments for best results. An idea of a true quantitative difference between "non-chalking" titanium dioxide and others is depicted in Figure XII. Increase in reflectance is directly proportional to the degree of chalking and is the difference between reflectance of the enamel when placed on exposure and after exposure for the length of time required for chalking to occur.

The type of TIRANOX will have greater influence naturally in whites and light tints in which a larger proportion of white pigment is needed. In very dark tints requiring only small proportions of titanium pigment, use of "non-chalking" TIRANOX-RC or TIRANOX-RA-NC may not be necessary especially if the enamel need not have maximum durability.

TIRANOX-RA-NC need not be restricted to exterior enamels, for this pigment produces high gloss, whiteness, brightness and tint clarity in enamels that may be used indoors for many purposes. However, if the maximum in whiteness and tint clarity are needed for

FIGURE XII



interior enamels, and maximum chalking resistance is not needed. Titanox-RA-45 or Titanox-RA-51 may be selected. Choice depends also upon other uses of these pigments.

Generally, vehicle will have a greater influence upon chalking than will the type of titanium pigment, although for best results the most chalk-resistant pigment should be used where durability is a factor. An example of the influence of type of vehicle is presented in Figure XIII in which increase in reflectance of grey enamels after exposure is plotted for chalking and chalk-resistant pigments in a series of tests involving alkyd as one type and oleoresinous vehicles as another. This chart is not presented to show that alkyd vehicles are superior to oleoresinous types generally, but simply to indicate the role of vehicle in fading of tinted enamels.

The choice of vehicle is dictated largely by durability requirements. Of course, the vehicle must have pigment dispersive power to assure high degree of dispersion where gloss is a main requirement. While alkyds seem to be generally superior on straight weathering, oleoresinous varnishes may be selected to achieve other qualities (through pigmentation also) such as toughness, (resistance to wear when placed on floors for example), resistance to alkali and cleaning compounds, etc.

Although the Titanox "RA" pigments are used without extender in most high gloss enamels, extender may constitute a portion of the pigment in porch and deck and similar high lustre paints. As in house paint tint bases, calcium carbonate has often been preferred to promote tint retention and other properties. Extender content may include hard siliceous and fibrous extenders balanced with vehicle hardness and total pigment volume to contribute to wearing qualities under traffic and other properties including resistance to cracking.

Choice of extender is greatly simplified by using the already extended Titanox-RC.



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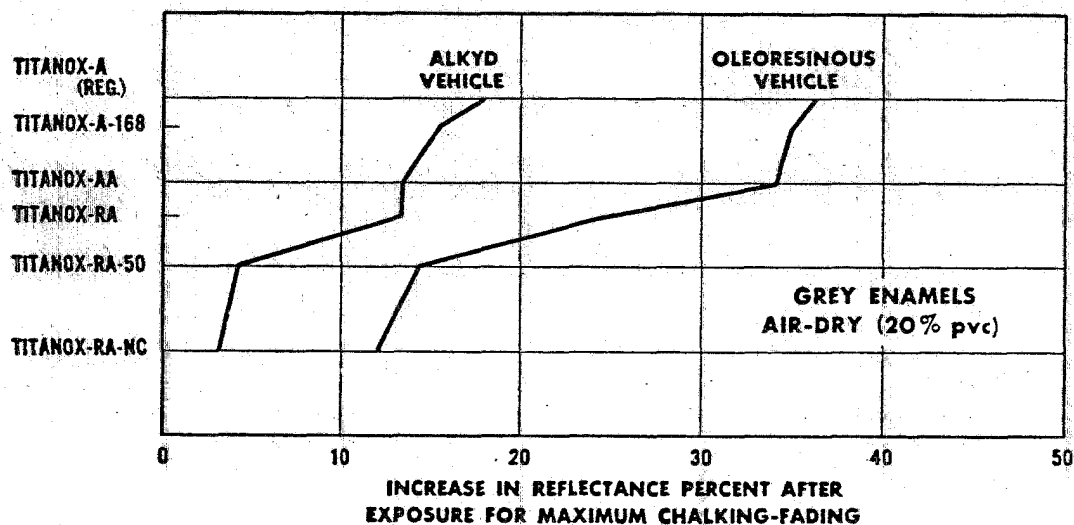
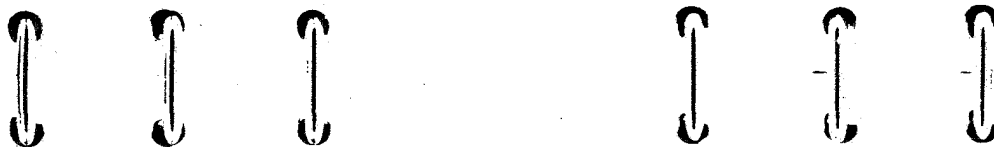


FIGURE XIII



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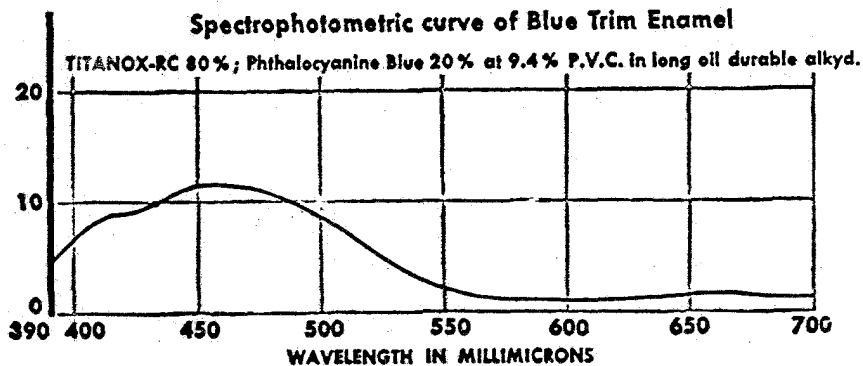


FIGURE XIV

An example of a popular shade of rather dark blue in a trim enamel pigmented with Titanox-RC is depicted in Figure XIV. The pigment here was 80% Titanox-RC, 20% phthalocyanine blue (72% color), the total at 9.4% pvc in a long oil alkylid. After ex-

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posure vertical south for three years at Sayville, N. Y. there was no chalking-fading nor any other defect visible in this enamel. This same type of enamel can, of course, be made with rutile "pure" titanium dioxide plus extender. The proportions are about: 32% TITANOX-RA-NC or TITANOX-RA-45 (or RA-51), 21% phthalocyanine blue (72% color) and 47% extender. But in this case, care must be taken to select a low oil absorption natural calcium carbonate as extender.

While generalizations cannot cover all cases, a guide to white bases suitable for tinted porch and deck enamels would comprise essentially the following:

TITANOX-RC at 2-3 lbs. per gallon.

Acicular zinc oxide about 0.5 lb. per gallon, pvc 15-20%.

Vehicles: Long oil alkyd such as Navy Spec. 52R13 Type I.

20-40 gal. oil length varnishes having suitable durability.

TITANOX-RA-NC or TITANOX-RA-50 at 1-1.5 lb. per gallon.

Acicular zinc oxide 0—about 0.5 lb. per gallon.

Extender 1-2 lbs. per gallon.

Same type vehicles as above.

## INDUSTRIAL PRODUCT FINISHES

The finish applied at the industrial plant to the industrial product must impart one or all of protection, identification and decoration. Because these finishes need one or more properties that ordinary air drying vehicles cannot provide, resinous or resin-like materials are their most important ingredient. Fast dry, hardness, toughness and many special qualities are provided by synthetic resins.

TABLE XI

### Some Resin Proportions in Vehicles of Industrial Product Finishes

| Type of Finish<br>Air Dry Enamels | % Alkyd | % Other Resin<br>and Type                  |
|-----------------------------------|---------|--------------------------------------------|
| general .....                     | 100     | —                                          |
| .....                             | 75-95   | 5-25 phenolic                              |
| faster dry .....                  | 80-95   | 5-20 vinyl                                 |
| resist. water, etc. ..            | 10-80   | 20-90 chlorinated rubber                   |
| increased durability.             | 75-95   | 5-25 silicone                              |
| Baking Enamels                    |         |                                            |
| general .....                     | 100     | —                                          |
| .....                             | 75-95   | 5-25 phenolic                              |
| appliance .....                   | 50-75   | 25-50 urea and/or melamine                 |
| alkali resist. ....               | 35-70   | { 5-30 epoxy<br>17-50 urea and/or melamine |
| automotive, etc. ...              | 65-85   | 15-35 urea and/or melamine                 |
| primers, etc. ....                | 70-95   | 5-30 urea and/or melamine                  |
| heat resistant .....              | 25-80   | 20-75 silicone                             |
| Lacquers                          |         |                                            |
| general .....                     | 30-70   | 30-70 nitrocellulose or other cellulosic   |

By and large, alkyds are a common constituent of the vehicles of most modern industrial product finishes. Of course, there are also finishes that do not contain alkyds. And alkyds are supplemented by other resins

and film-formers especially in baking enamels. Non-oxidizing alkyds have come to be a main constituent of cellulosic lacquers too. The general trend to alloyed in combination with other resins is illustrated by some general proportions of resins listed in Table XI.

Industrial product finishes being an important factor in the cost and merchantability of many articles have been first to reflect progress in finishing systems and coating ingredients. The white pigment that was not only adaptable to any vehicle but also gave high opacity at low pigmentation plus stability to heat, light, water, chemicals and other influences while eliminating thick and multi-coats was naturally rapidly adopted. This pigment was of course, titanium dioxide first Titanox-A then Titanox-A-168.

Early use of synthetic resin meant the phenolics for which Titanox-A-168 furnished better initial whiteness and less after-yellowing. As progress was made in vehicle systems that provide the optimum in bright whiteness, whiteness retention and other properties Titanox-A-168 was their natural white pigment. Indeed, modern appliance finishes came into existence with alkyd-amino resin combinations plus Titanox-A-168.

### Rutile Titanium Dioxide now Dominant

For some time the greater initial whiteness of this anatase pigment led some formulators to prefer it to the rutile type, Titanox-RA. But the greater brightening power of Titanox-RA (rutile) plus less after yellowing along with its recognized higher opacity are the main factors accounting for its ascendancy over the anatase pigment. A typical comparison of these pigments in these qualities is shown in Figures XV and XVI.

Where reflectance was a prime quality of the finish as in lighting fixtures, Titanox-RA was early preferred for its ability to produce highest reflectance. As shown in Figure XVII the superiority of this pigment over the anatase type is evident even at low film thickness. This superiority is primarily one of opacity because the measured reflectance of the film depends upon its hiding the background. Now, not only in reflector enamels but in most any type of coating rutile type pigment is first choice for effective coverage.

FIGURE XV

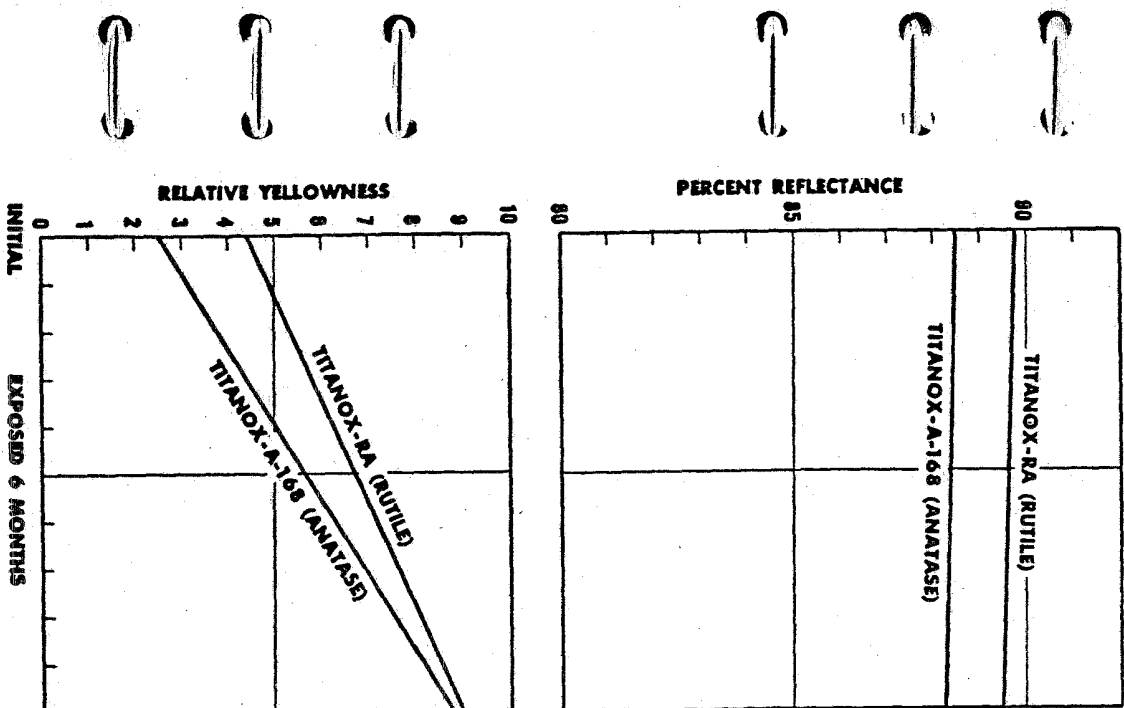


FIGURE XVI

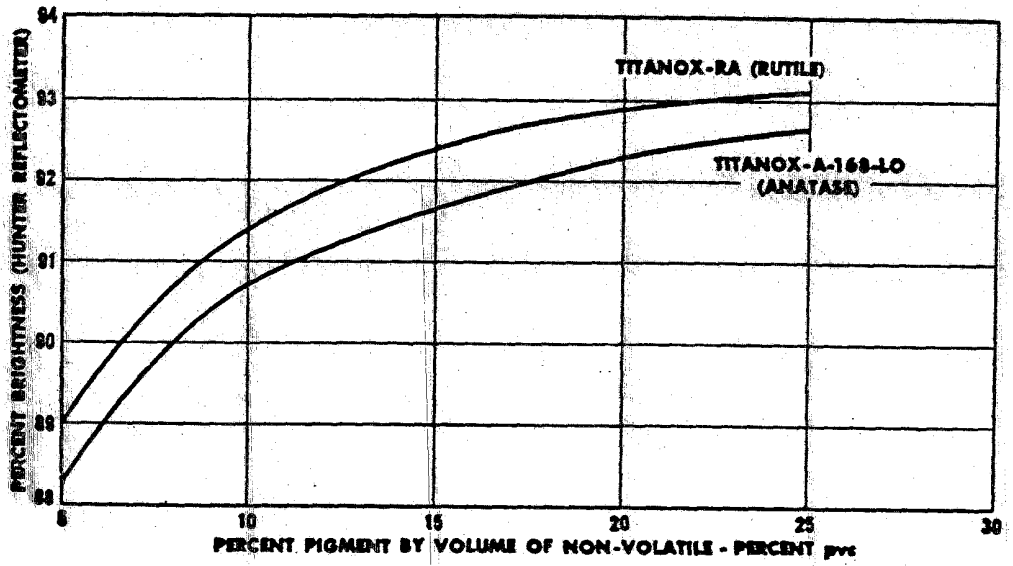
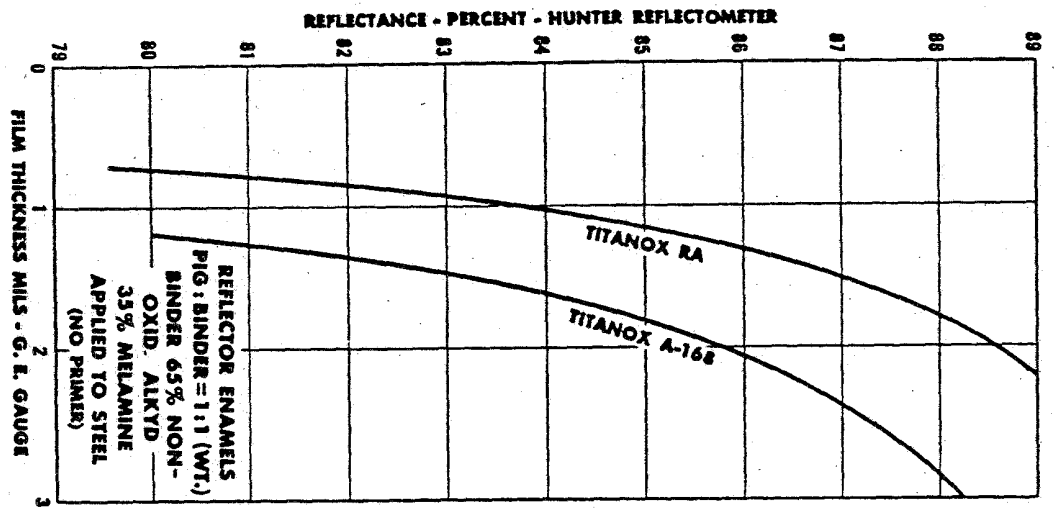


FIGURE XVII



As preference grew for rutile type pigment, other advantages were found in it. Outstanding among these is greater resistance to heat discoloration of some finishes. For example, in a typical comparison in an alkyd-amine baking enamel after being heated for 24 hours at 300° F., the enamel containing TITANOX-RA had yellowed much less:

Pigment to Binder Ratio 1:1 by weight

Vehicle solids: non-drying alkyd 70, melamine 30

| Pigment                 | After 24 hours at 300° F. |                          | Loss, % |
|-------------------------|---------------------------|--------------------------|---------|
|                         | Less in Gloss             | Yellowing* Brightness, % |         |
| TITANOX-A-168 (anatase) | 6                         | 2.8                      | 0.6     |
| TITANOX-RA (rutile)     | 5                         | 1.6                      | 0.5     |

\* Increase in relative yellowness — (% Amber—% Blue)

The less yellow tone of white coatings pigmented with anatase pigment has not been sufficiently beneficial to prevent its obsolescence. Largely this color difference between the two crystal types is evident only when toners are not employed. Experience with the rutile type pigment has led to skilful toning so that a wide range of different types of whiteness can be secured to meet various standards. Small amounts of blue and violet toners, other colors and also black are used to achieve the results. In the following group of enamels all pigmented with the same amount of TITANOX-RA (rutile titanium dioxide) in the same vehicle system different types of whiteness were secured through different toning of each enamel. Here color is expressed by Hunter reflectometer readings.

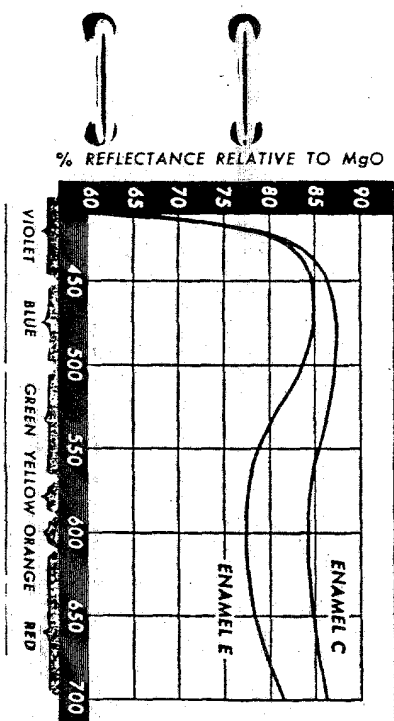
| Enamel (brilliance) | % Reflectance with filter |       | "TONE" Color Index* Amber-Blue X 100 |
|---------------------|---------------------------|-------|--------------------------------------|
|                     | Green                     | Amber |                                      |
| A                   | 86.1                      | 85.4  | 85.2                                 |
| B                   | 86.0                      | 85.9  | 86.0                                 |
| C                   | 87.3                      | 87.0  | 87.7                                 |
| D                   | 81.6                      | 81.2  | 82.7                                 |
| E                   | 80.0                      | 78.7  | 85.2                                 |

\* Relative yellowness—positive numbers usually obtained on creamy or yellowish whites, negative on bluish whites.

Greater insight into the color difference between enamels C and E is revealed in their spectrophotometric curves given in Figure XVIII. Both of these enamels are "blue-white" despite sharp decline in the deep blue and violet region (below 450 millimicrons wave length) . . . the characteristic absorption due to rutile in this end of the spectrum being balanced by toning. Enamel C, a clean white, is much brighter or higher in reflectance than enamel E which through heavier toning has been reduced in brightness. Higher hiding power accompanies reduction in brightness through toning so that maximum hiding per pound of titanium dioxide can be secured. Some average figures indicate that each 1% decrease in brightness yields about 50 square feet increase in coverage.

FIGURE XVIII

Example of Color of Enamels pigmented with TITANOX-RA plus toners



## Choice of the Type of Rutile TITANOX

Generally, TITANOX-RA-45 is the choice for coatings that must have low pigment volume concentration, such as 20% or below, or in which highest gloss is demanded. The exceptionally high tinting strength as revealed by maximum brightness of tints imparted by this pigment, permits minimum pigmentation as does also high hiding power in whites.

The multi-purpose TITANOX-RA-51 often yields suitable whiteness and sufficient tinting strength to qualify for use in finishes that may not require the unique properties of TITANOX-RA-45, especially if there is no problem to meet a particular specification. An example of difference in tinting strength between these pigments revealed this slight difference in brightness of a blue tint in enamels pigmented at 15% pvc:

|                     | Brightness |
|---------------------|------------|
| TITANOX-RA-51 ..... | 43.0       |
| TITANOX-RA-45 ..... | 43.9       |

In some white enamels, at higher pigment volume concentration, TITANOX-RA-51 has actually given higher hiding power:

|                     | Square Feet per U. S. Gal. of Enamel |     |     |     |  |
|---------------------|--------------------------------------|-----|-----|-----|--|
|                     | % Pigment volume concentration       |     |     |     |  |
|                     | 10                                   | 15  | 20  | 25  |  |
| TITANOX-RA-51 ..... | 235                                  | 350 | 430 | 500 |  |
| TITANOX-RA-45 ..... | 310                                  | 375 | 450 | 475 |  |

In some cases, TITANOX-RA-NC may be used in coatings that would ordinarily call for TITANOX-RA-45, provided the "non-chalking" feature of TITANOX-RA-NC would be operative in the finish, that is, whether with the particular vehicle system extra durability would be imparted by TITANOX-RA-NC. Also, the question of whiteness in the white enamel may be involved, but usually TITANOX-RA-51 and TITANOX-RA-NC are amenable to toning that also increases hiding.

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## Baking Enamels

Because such a large volume and variety of metal fabricated products are finished with baking enamels needing white pigment TITANOX pigments are of major importance to this class of finish. Many factors in the formulation of baking enamels can be related to industrial product finishes generally.

White baking enamels will carry TITANOX-RA or other type of TITANOX titanium dioxide at 15-25% pvc. Usually pigment content is expressed in terms of pigment to binder by weight and this is often 0.9-1.0 pigment to 1.0 binder or about 20-22% pvc.

Properties such as baking speed and temperature, adhesion, mar resistance, hardness, toughness, resistance to water, detergents, chemicals and household contaminants are largely dependent upon vehicle as are also consistency, flow and working qualities.

Most of these properties are resolved through combinations of urea and melamine resins with alkyds.

In general as the proportions of amino resins in admixture with alkyds is increased, film hardness is

TABLE XII  
Example of Effect of Alkyd, Urea and Melamine  
on Hardness of Baked Enamel\*

| Type of Alkyd                        | % Urea or Melamine (remainder Alkyd) |          | Sward Hardness |          |
|--------------------------------------|--------------------------------------|----------|----------------|----------|
|                                      | Urea                                 | Melamine | Urea           | Melamine |
| Non-oxidizing (coconut oil modif.)   | 10                                   | 6        | 10             | 10       |
|                                      | 20                                   | 12       | 17             | 17       |
|                                      | 30                                   | 15       | 26             | 26       |
|                                      | 40                                   | 19       | 29             | 29       |
| Oxidizing (soya oil modif.)          | 10                                   | 5        | 8              | 8        |
|                                      | 20                                   | 12       | 17             | 17       |
|                                      | 30                                   | 16       | 28             | 28       |
|                                      | 40                                   | 18       | 37             | 37       |
| Oxidizing (dehydrated castor modif.) | 10                                   | 9        | 14             | 14       |
|                                      | 20                                   | 15       | 22             | 22       |
|                                      | 30                                   | 18       | 35             | 35       |
|                                      | 40                                   | 21       | 40             | 40       |

\* Pigment to Binder 0.9 to 1.0.  
Pigment—TITANOX-RA.

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increased. At higher proportions melamine-formaldehyde yields a harder film than urea-formaldehyde. An illustration of this relationship is depicted in Table XII for baking enamels having a pigment to binder ratio of 0.9 to 1.0 the pigment being Tiranox-RA. This table is a general illustrative example of the relationship of Sward hardness to proportion of amino resin to alkyd.

For any specific resin, values may vary from those of this table which however is a useful guide.

The increased hardness imparted by higher proportions of melamine resin in general is accompanied by increased brittleness or loss of adhesion. Impact resistance can be taken as an indication of this behavior as shown in Table XIII. But note however that the type of alkyd whether non-oxidizing or oxidizing has a marked influence upon adhesion as indicated by impact. In general, oxidizing alkyds improve adhesion. The fact that high melamine content generally can harm adhesion means that steps must be taken to retain this property when high melamine content is desired. Increased melamine content can yield faster cure and improved durability.

TABLE XIII

Example of Effect of Alkyd, Urea and Melamine on Impact Resistance of Baked Enamel<sup>1</sup>

| Type of Alkyd                 | % Urea or Melamine (remainder Alkyd) | Impact Resistance (inch lbs. to disrupt film) |
|-------------------------------|--------------------------------------|-----------------------------------------------|
| Non-oxidizing (coconut)       | 10                                   | 15                                            |
|                               | 20                                   | 10                                            |
|                               | 30                                   | 7                                             |
| Oxidizing (soya)              | 10                                   | 35                                            |
|                               | 20                                   | 35                                            |
|                               | 30                                   | 31                                            |
| Oxidizing (dehydrated castor) | 10                                   | 35                                            |
|                               | 20                                   | 34                                            |
|                               | 30                                   | 30                                            |
|                               | 40                                   | 20                                            |

## Color or Whiteness

In general, alkyds have a stronger influence than any other component upon color and whiteness of many white baking enamels. Where alkyd is the main constituent without urea or melamine, initial whiteness and whiteness retention are degraded as oil length is increased. Zinc oxide when compatible may be used to supplement Tiranox-RA for reduction of after-yellowing.

Where whiteness and its retention is a prime requisite especially if heat resistance is also involved, naturally short oil alkyds and especially the non-oxidizing types modified with castor or coconut oils are selected.

In Table XIV the whiter color secured with non-oxidizing alkyd is indicated by the lower color index values.

TABLE XIV

Example of Effect of Alkyd, Urea and Melamine on Whiteness of Baked Enamel<sup>1</sup>

| Type of Alkyd                 | % Urea or Melamine (remainder Alkyd) | Brightness (Green) | Hunter Reflectometer | Color Index* |
|-------------------------------|--------------------------------------|--------------------|----------------------|--------------|
| Non-oxidizing (coconut)       | 10                                   | 91.3               | 91.8                 | 1.8          |
|                               | 20                                   | 91.4               | 91.5                 | 1.6          |
|                               | 30                                   | 91.8               | 91.2                 | 1.6          |
| Oxidizing (soya)              | 10                                   | 91.2               | 91.6                 | 5.2          |
|                               | 20                                   | 91.1               | 90.8                 | 4.7          |
|                               | 30                                   | 91.9               | 91.4                 | 4.9          |
| Oxidizing (dehydrated castor) | 10                                   | 91.6               | 91.2                 | 5.3          |
|                               | 20                                   | 91.4               | 91.0                 | 5.3          |
|                               | 30                                   | 91.6               | 90.5                 | 4.7          |
|                               | 40                                   | 91.7               | 90.6                 | 4.1          |

\* Pigment to Binder—0.9 to 1.0.

\* Relative yellowness — Green  
Amber-Blue  
x 100—The higher this figure the more yellowish the tone.

While alkyl-amino combinations tend to dominate white and light tinted enamels, acrylics have come forward rapidly because of outstanding color and color retention. These resins, because of water white initial color and resistance to discoloration, yield clean whiteness and sharp tints.

In general, in the selection of a vehicle system, attention is paid to initial color and as an indication of color retention, the change in color that occurs on overbaking. Using the color index or relative yellowness as defined in Table XIV, some different types of resins have exhibited color and color retention with rutile  $\text{TiO}_2$  pigments, as shown in the following table, which is presented for illustrative purposes only as indicative of results obtained with samples of vehicles in a particular study. Results in no way are to be interpreted as recommendation to use one type of vehicle in place of another.

COLOR AND COLOR RETENTION OF  
SOME VEHICLE SYSTEMS\*

| System                                       | Color Index                   |                       |
|----------------------------------------------|-------------------------------|-----------------------|
|                                              | Normal<br>Baking,<br>Standard | Overbaked<br>24 hours |
| Acrylic .....                                | 0.8                           | 0.9                   |
| Silicone resin .....                         | 5.2                           | 6.3                   |
| Acrylic-maleic .....                         | 2.7                           | 6.7                   |
| Epoxy-urea .....                             | 2.3                           | 6.7                   |
| Air dry silicone alkyd .....                 | 4.4                           | 32.8                  |
| Silicone alkyd polymer .....                 | 4.7                           | 9.8                   |
| Epoxy-alkyd-urea .....                       | 4.7                           | 14.9                  |
| Styrenated alkyd .....                       | 9.8                           | 21.9                  |
| Vinyl-acrylic .....                          | 1.9                           | 15.4                  |
| Oxidizing alkyd-urea .....                   | 8.8                           | 24.4                  |
| Epoxy-ester .....                            | 5.1                           | 24.9                  |
| Epoxy-polyamide .....                        | 7.3                           | 29.9                  |
| Polyurethane (oil mod.) .....                | 17.0                          | 39.1                  |
| Some Nitrocellulose<br>lacquer systems ..... | -1.6 to<br>0.4                | 37-44                 |

\* See also "Factors Influencing the Behavior of Titanium Pigments in Industrial Finishes," William Kamptner, *Official Digest*, April 1960.

## Gloss

The factors that determine gloss of coatings generally, are operative in industrial product finishes. A capacity for fine dispersion must of course characterize the pigment and this is true of all of the TIRANOX pigments used in these finishes, especially TIRANOX-RA-45.

But regardless of the innate ease of dispersion of the pigment, gloss is strongly affected by vehicle. In general, of course, in these systems the most pigment dispersive of the vehicle components should comprise the grinding vehicle.

Gloss is strongly influenced by variation in alkyd-urea-melamine combinations. With pigment maintained constant in all respects gloss can vary significantly as between type of alkyd whether oxidizing or non-oxidizing and proportion of urea and melamine resins.

Measurement of gloss at  $20^\circ$  picks up differences not determinable instrumentally say at  $60^\circ$  but discernible visually. Variation in  $20^\circ$  gloss with some vehicle compositions is depicted in Table XV.

TABLE XV  
Effect of Urea and Melamine Resins on Gloss  
of Non-oxidizing Alkyd Enamel

| %<br>Non-oxidizing<br>Alkyd | %<br>Urea | %<br>Melamine | %<br>Gloss |
|-----------------------------|-----------|---------------|------------|
| 90                          | 0         | 10            | 85         |
| 80                          | 0         | 20            | 82         |
| 70                          | 0         | 30            | 78         |
| 60                          | 0         | 40            | 75         |
| 50                          | 0         | 50            | 72         |
| 90                          | 10        | 0             | 80         |
| 80                          | 20        | 0             | 73         |
| 70                          | 30        | 0             | 68         |
| 60                          | 40        | 0             | 65         |
| 50                          | 50        | 0             | 63         |

### Proper Balance of Vehicle Components

The dependence of the properties of baking enamels upon proper balance of vehicle ingredients cannot be emphasized too much. As in all finishes no one property can be considered to be independent of others. Thus, maximum whiteness if secured through too much non-drying alkyd might give rise to poor adhesion which will also result from too much melamine for water and alkali resistance. Too much drying alkyd to enhance gloss can lead to poor color retention especially on exposure to heat. And, of course, solvent balance must be maintained too.

Special treatment may be necessary in order to secure the ultimate in some properties. For example, outstanding alkali resistance may indicate that the resin be cured longer than is required for development of maximum hardness.

The utilization of epoxy resins for their hardness and resistance to water and chemicals also exemplifies the importance of vehicle balance to secure the optimum in all properties.

Similarly, vinyl resins alone and in combination with others, such as acrylates, may impart flexibility otherwise difficult to obtain. Such flexible coatings are of course, demanded for coating sheet metal which will be fabricated into various articles through stamping and other operations.

Also straight silicones are modified with alkyds to improve adhesion, yet the straight silicone properly formulated may be preferred for total heat resistance.

### Baking Primers

Since white baking primers as compared with enamels may carry a larger amount of total pigment for higher pvc conducive to desired hardness, composite pigment or titanium dioxide plus extender, are usually employed. For wood—rutile calcium pigment Tiranox-RCCHT provides the desired hiding and other effects of prime pigment although this pigment is usually avoided in highly water resistant primers for metal. Titanium barium pigment, largely because of extreme water insolubility, was established in these primers, but with the discontinuance of this pigment, equivalent



combinations of titanium dioxide and barium sulfate replaced titanium barium pigment. In these replacements, care must be exercised in the selection of barium sulfate to assure high water insolubility where moisture resistance is most important.

Except for the water dispersible Tiranox-A-W/D any type of Tiranox titanium dioxide may be used in these primers. The water dispersible type is excluded when moisture resistance is a factor.

Because the primer provides only part of the hiding power of the system, anatase pigment such as Tiranox-A-108-LO is used at about one pound to the gallon of primer. A product of quite general application utilizes a medium soya alkyd so that the system may be baked to insure proper hardness.

Primers that need white hiding pigment and are used as base coats on steel or other metal that will be exposed to the weather, are best pigmented with Tiranox-RA-NC. This pigment is not, of course, an anti-corrosion or corrosion inhibiting pigment. It does, nevertheless, complement anti-corrosive pigments and contributes to durability of the primer as indicated by many observations of retarded rusting after prolonged exposure. In similar use, such durability is not associated with anatase titanium dioxide pigments so widely used in primers on metal surfaces used indoors.

### INDUSTRIAL PRODUCT FINISHES FOR EXTERIOR EXPOSURE

Through development of chalking resistance, the high tinting strength of titanium pigments has been made completely available for industrial product finishes having highest weather resistance.

Before the advent of "non-chalking" high hiding rutile titanium dioxide the anatase pigment Tiranox-A-24 represented the maximum resistance to chalking available in the Tiranox-A class. The rutile pigment Tiranox-RA-NC ("non-chalking") not only is more resistant to chalking (fading) but also higher in hiding power and tinting strength so important in achieving the highest hiding at a given degree of gloss and the highest brightening effect with minimum

amount of pigment. TITANOX-A-24 was of course discontinued in view of the superiority and value of the rutile pigments.

In some systems, TITANOX-RA-50 and pigments of similar resistance to chalking (TITANOX-RA-51; TITANOX-RA-45 and TITANOX-RA-46) may greatly retard fading-chalking as indicated in the example of Figure XIX which represents parallel alkyd-melamine enamels (17.5% of vehicle solids melamine) pigmented at 17.5% pvc. In some other systems, while these pigments retard fading-chalking and are superior to semi-chalking pigment TITANOX-RA they can be inferior to TITANOX-RA-NC which exhibits exceptionally high resistance to fading-chalking in some vehicles while, of course, maintaining its position as most chalk-resistant in all vehicles.

TITANOX-RA-NC is particularly outstanding in the newer acrylic enamels that exhibit exceptional gloss and durability. After exposure for 36 months in Florida, tinted thermosetting acrylics with TITANOX-RA-NC have shown no sign of fading-chalking, whereas the less chalk-resistant rutile  $\text{TiO}_2$ 's are chalking at ten months.

As is well recognized, progress in exterior finishes has paralleled not only that of titanium pigments but particularly progress in synthetic resins. Marked improvements in quality of finishes has resulted from the high alkyd content of lacquers and the transition from alkyds to alkyd-amine combinations of enamels.

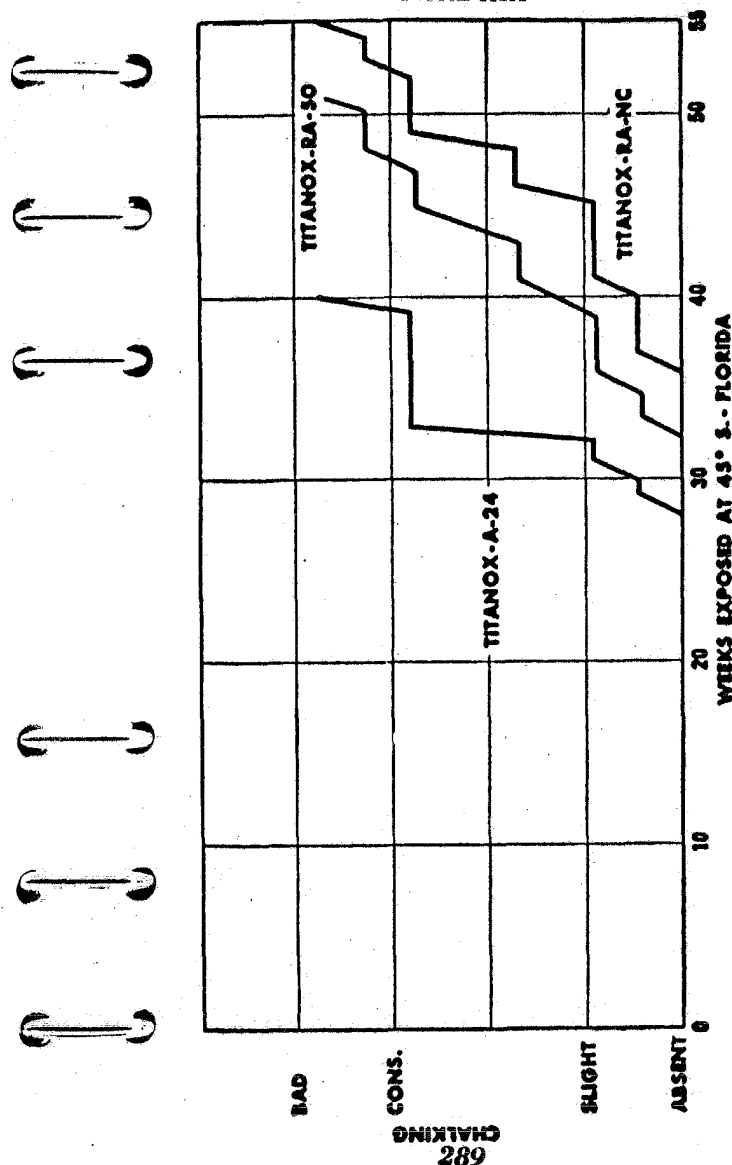
All of the factors that influence the properties of baking enamels also apply to these enamels that are to be exposed to the weather. Resins must be selected in relation to durability.

An additional factor in exterior baking enamels is the curing or baking schedule. No matter how chalk-resistant the white pigment or durable the resin the final film will lack durability if improperly baked.

#### Chalking Behavior Dependent Upon Binder

It is generally agreed however, that the type of binder is the most influential factor governing the chalking behavior of finishes. Binders may vary in durability not only from class to class but within a class itself, depending upon modification of the primary resin or combination of resins, as indicated

FIGURE XIX



in Table XVI which is presented as a guide to research. Results must be restricted to this particular study only, and are not to be construed as recommendations for the preference of one resin over another.

TABLE XVI

Example of:

Effect of Binder (vehicle solids) upon Chalking

Behavior of some Enamels

Simultaneous exposures of comparable enamels—  
exposure period terminated after 36 months

Pigment—Tiranox-RA-NC maintained constant—  
coated metal panels exposed 45° facing South.

| Type of Binder       | Start of chalking after exposure for months | Heavy chalking observed after exposure for months |
|----------------------|---------------------------------------------|---------------------------------------------------|
| Alkyd—silicane       | 13                                          | Beyond 36                                         |
| —melanline           | 5-21                                        | 13 to beyond 36                                   |
| —urea (bake)         | 10                                          | 16                                                |
| —styrenated          | 5                                           | 10                                                |
| —tall oil            | 3-4                                         | 10                                                |
| —water sol.          | 3-4                                         | 7-10                                              |
| Acrylic—unmodified   | 21                                          | Beyond 36                                         |
| —polyester           | 17                                          | Beyond 36                                         |
| —emulsion (bake)     | 13-16                                       | 27-36                                             |
| —vinyl               | 13-14                                       | 24-25                                             |
| —epoxy               | 10                                          | 13                                                |
| —copolymer           | 7                                           | 12                                                |
| Epoxy—acrylic        | 10                                          | 13                                                |
| —ester               | 3                                           | 6                                                 |
| —urea                | 3-4                                         | 4-5                                               |
| —polyamide           | 2                                           | 4                                                 |
| —phenolic            | 1                                           | 1                                                 |
| Polyurethane Systems | 1-2                                         | 7-9                                               |

## TRAFFIC PAINTS

In addition to industrial product finishes there are many types of coatings that contrasted to trade sales products are not marketed finally through retail outlets. Maintenance paints for industrial plants and institutions are among these as are also the wide variety of coatings made according to public and private specifications to be applied to all sorts of structures and articles. Public specifications for paints occur at all levels of our government—local, state and federal. A list of federal specifications for paints to which Tiranox pigments are applicable is given in Part VII.

One of the most interesting types of coating, in the class of miscellaneous paints, is traffic paint.

White paints for marking roads and highways must primarily be as visible as possible. Essentially because titanium pigments possess the power to whiten lasting, they are extensively employed in white traffic paints.

Generally the qualities needed in white traffic paint are:

1. Suitable applicability.
2. Fast dry—so that traffic will not be held up.
3. High visibility through high diffuse reflection.
4. Durability—not only to keep the paint on the road, but to maintain its visibility.

For a number of years, short oil varnishes or lacquer type binders to insure fast drying were highly pigmented with combinations of titanium pigments and flattening extenders such as fibrous talc, diatomaceous silica, etc., to secure high diffuse reflectance (flatness) and to contribute to fast drying. The content of total pigment by volume of solids of such paints ran about 60% pvc so in reality they were specialized types of flat paints usually characterized by lack of flexibility of the film. While many such paints were highly visible their life expectancy was short due to chip-ping from the surface and lack of resistance to the weather.

Much work has been done and is still in progress to improve all qualities of white traffic paints. First indication that pvc should be lowered came from the successful application of glass beads (for promotion



of night visibility through reflex reflection) wherein the amount of binder had to be increased in order to bind the beads to the paint.

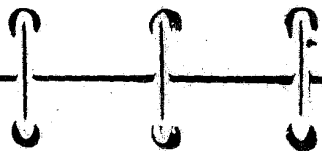
Recent studies reveal that through proper selection of vehicle fitted to a suitable combination of prime pigments and extender, pvc of 50-55% is optimum for most compositions.

Other than the use of sufficient titanium pigment to assure high hiding and consequent whiteness and brightness contributing to visibility, extenders must be chosen to impart flatness and visibility. Often, putty is added to the final paint to assure roughness of surface conducive to reflection of headlight beams at night. Of course, maximum night visibility is assured through glass beads. In formulating a paint for glass beads, pvc should be lowered to permit enough free binder to hold the beads.

### Alkyds and Newer Binders Replace Oleoresinous Varnishes and Cellulosics

Numerous tests since World War II indicate that alkyd vehicles are generally superior in durability to varnishes and this applies to beaded paints too. The extremely rapid set-up often specified for varnishes and lacquers was an early obstacle to the use of alkyd which set up more slowly. Bleeding from bituminous surfaces into the slower setting alkyd caused discoloration. But through the elimination of relatively slow evaporating mineral spirits ordinarily used with alkyds, resistance to bleeding was greatly improved to the point of not affecting visibility. Instead of mineral spirits, V. M. & P. naphtha is the solvent for the alkyd while fast-evaporating low-solvency thinner such as textile spirits or rubber solvent (initial boiling point 119°-150° F.) is the thinner for reduction to desired consistency.

With mounting demand for even shorter drying time than attainable with straight alkyds, other binders are being drawn into traffic paint formulation, for example, chlorinated rubber. When 10% to 20% of the vehicle solids consist of chlorinated rubber and the remainder



medium oil length alkyd, significant reduction of drying time is observed. For example, a paint having vehicle solids composed of 10% chlorinated rubber and 90% alkyd dried in twenty-five minutes. In contrast, paints containing all alkyd as vehicle solids dried in from forty-five to ninety minutes. In blending alkyds and chlorinated rubber, miscibility and choice of solvent must, of course, be considered.

Complete replacement of alkyd is being made by cyclized copolymers that involve polystyrene, and such a vehicle dries or sets very rapidly upon evaporation of solvent and thinner. Paints based upon this type of vehicle and relatively high in pigment volume will dry faster than combinations of alkyds and chlorinated rubber.

Of course, in all paints that dry by evaporation, close attention must be paid to selection of solvents and thinners for the proper balance dictated by the application conditions.

### TITANOX "C" Pigments Preferred

The rutile-calcium pigment Titanox-RCHT from the standpoint of effectiveness and economy is a logical choice for prime pigment. However, where a freer chalking type is preferred, anatase titanium dioxide such as Titanox-A-MO may be used. As in house paints a combination of these two pigments may fit the chalking conditions to be met. But generally, Titanox-RCHT as the sole white hiding pigment provides lasting visibility plus durability.

As in other white exterior finishes titanium-barium pigment was the first titanium pigment to be used in white traffic paints and for a number of years was prescribed in many specifications. Numerous exposure tests revealed that not only titanium dioxide plus extender but also Titanox-RCHT could replace titanium-barium pigment.

The coalesced rutile-calcium pigment Titanox-RCHT at the pigment volume concentration of white traffic paint produces more hiding power per dollar of pigment than titanium dioxide plus extender with the result that the cost of the paint is reduced while quality is maintained.



In place of magnesium silicate which has long been used in traffic paints, natural low oil absorption calcium carbonate has been found to yield excellent durability with Tiranox-RCHT in an alkyl vehicle.

Tiranox-C-50 (the 50%  $\text{TiO}_2$  rutile-calcium pigment) may replace Tiranox-RCHT depending upon the prime pigment-extender balance and pie required. Tiranox-C-50 (50%  $\text{TiO}_2$ ) naturally has correspondingly higher hiding power than the 30%  $\text{TiO}_2$  pigment and is also exceptionally easy to disperse.

Although the ultimate in pigment dispersion is not required in traffic paints there is a good deal of evidence to indicate that grinding should be to a fineness of at least 3 Hegman. Poor durability as indicated by flaking and scaling has often been associated with paints that have been poorly ground or not ground at all, such as to fineness (Hegman) 0.

If even greater ease of dispersion than characterizes Tiranox-RCHT is desired, Tiranox-RCHTX may be chosen. Also, where anatase titanium dioxide may be needed, and greater ease of dispersion than that of Tiranox-A-MO is desired, Tiranox-A-CG may be called upon.

Ease of dispersion also characterizes other Tiranox pigments that may be called upon for traffic paint or related use, such as Tiranox-RC the "non-chalking" "C" pigment and Tiranox-RA-NC the "non-chalking" rutile  $\text{TiO}_2$ , as well as the other Tiranox "RA" rutile  $\text{TiO}_2$  pigments.

## Yellow Traffic Paints

Yellow traffic paints ordinarily do not call for white hiding pigment, but evidence is being gathered on the beneficial effects that can be imparted to these paints through inclusion of Tiranox white pigments. Such paints should be no exception to tinted coatings in general that are improved in brightness and opacity and often in durability through pigmentation with the right amount of the right Tiranox white pigment. Our technical service department will be glad to discuss all aspects of the use of Tiranox white pigments in yellow traffic paints and, of course, in white traffic paints. Following are a few typical traffic paint formulas:

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## WHITE TRAFFIC PAINT

### Alkyl Vehicle

|                                                |      |         |
|------------------------------------------------|------|---------|
| Tiranox-RCHT .....                             | 439  | Pounds  |
| Natural calcium carbonate .....                | 234  | "       |
| Aluminum stearate <sup>3</sup> .....           | 3.3  | "       |
| Alkyl solution <sup>1</sup> (50% solids) ..... | 59.0 | Gallons |
| Textile spirits <sup>2</sup> .....             | 12.7 | "       |
| 24% lead drier .....                           | 0.9  | "       |
| 6% cobalt drier .....                          | 0.3  | "       |
| Anti-skinning agent .....                      | 0.1  | "       |

### WHITE TRAFFIC PAINT

#### Alkyl plus Chlorinated Rubber Vehicle

|                                                         |     |         |
|---------------------------------------------------------|-----|---------|
| Tiranox-C-50 .....                                      | 500 | Pounds  |
| Natural calcium carbonate .....                         | 210 | "       |
| Thixcin <sup>5</sup> .....                              | 3   | "       |
| Alkyl solution <sup>1</sup> (60% solids) .....          | 45  | Gallons |
| Chlorinated Rubber solution (20 cps) <sup>4</sup> ..... | 5   | "       |
| Toluol .....                                            | 22  | "       |
| Driers, anti-skinning agent and stabilizer .....        | 1.5 | "       |

<sup>1</sup> Medium oil length alkyl cut in V. M. & P. naphtha.

<sup>2</sup> Distillation range 140°-205° F., Amso or equiv.

<sup>3</sup> Metasap "V" grade or equivalent.

<sup>4</sup> Parlon-Hercules Powder Co.—50% solution in toluol.

<sup>5</sup> Thixcin, Baker Castor Oil Co.



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## PART VII

### TITANOX

and

### U. S. Govt. Specifications

for

### Paints and Titanium Pigments

LISTS of U. S. Government paint and pigment specifications relating to titanium pigments are presented in the following pages according to bureaus.

Only those specifications are listed which specify or require titanium pigments. In view of the large number of government paint specifications, some omissions may have been made, but it is believed the lists contain those specifications of current interest and activity.

For each bureau, the specifications are listed in numerical rather than alphabetical order, for example, TT-T-425 precedes TT-P-659.

The indexes will be revised as the need arises for additions and changes of specifications. We cannot, of course, guarantee that any specification listed is actually the issue in force.

The specifications are not fully described, but are simply designated by number and type of paint. In many cases, in addition to the type of TITANOX applicable, the approximate number of pounds of the applicable pigment to be used in each gallon of paint, is stated as a guide.

The listing of the type of TITANOX and approximate amount applicable to a paint specification does not mean necessarily that the requirements of the specification will be met. As generally recognized, paints made according to specifications must be examined and tested according to the full requirements of the specification.

Our technical service department is always willing to help solve problems in specification paints.

## FEDERAL SPECIFICATIONS

*In numerical order*

\*—Mandatory

*Spec. No.  
and Date*

*Type of Paint*

*TITANOX  
applicable and  
lb./gal. paint  
approximate ( )*

TT-P-18  
July 2, 1947

Alkyd-emulsion  
paste (exterior)

-A or -RA (2.0)

TT-P-0019a  
May 21, 1958

Acrylic emulsion  
(exterior)

opaque pigment  
-A-MO\*  
(max. 30%)  
plus -RA-NC\*  
(min. 70%)

TT-P-21  
June 30, 1941

Cement-water

-A

TT-P-22  
Aug. 30, 1943

Cold-water powder  
plus liquid (ex-  
terior)

-A

TT-P-23a  
Mar. 22, 1940

Cold water, protein  
(interior)

-A

TT-P-24a  
Nov. 22, 1955

Concrete and Ma-  
sonry (exterior)

white -A-MO\*  
(min. 30%)  
tint base -RA-NC\*  
(min. 15%)

TT-P-25a  
Jan. 11, 1951

Exterior Primer

-RA-NC (1.18)

TT-L-26  
Feb. 24, 1956

Lacquer; brushing  
gloss

-RA-45; -RA-NC

TT-P-0020b  
Aug. 24, 1961

Fire retardant flat  
(interior)

-RCHT

TT-P-29b  
Nov. 8, 1961

Latex base, flat (in-  
terior)

-RA-46; others

TT-P-30b  
Sept. 10, 1959

Alkyd flat  
(interior)

-C-50; others

TT-L-31b  
Sept. 19, 1961

Lacquer, gloss

-RA-NC

TT-P-0033  
Nov. 2, 1960

Paint, latex (ex-  
terior) masonry.

-RA-NC

| Spec. No.<br>and Date                                              | Type of Paint                                       | TITANOX<br>applicable and<br>lb./gal. paint<br>approximate ( ) | Spec. No.<br>and Date        | Type of Paint                                        | TITANOX<br>applicable and<br>lb./gal. paint<br>approximate ( ) |
|--------------------------------------------------------------------|-----------------------------------------------------|----------------------------------------------------------------|------------------------------|------------------------------------------------------|----------------------------------------------------------------|
| TT-P-34a<br>Mar. 19, 1958                                          | Fire retardant (ex-<br>terior) .....                | -RA-NC; others                                                 | TT-P-103<br>Mar. 21, 1951    | Exterior Oil Paint<br>Flame resistant<br>white ..... | -A-MO* and<br>-RCHT                                            |
| TT-P-47a<br>May 25, 1950                                           | Primer-Flat<br>(interior) .....                     | -RCHT (6.0)                                                    | TT-P-00115b<br>Apr. 20, 1962 | Traffic Paint .....                                  | -RCHT (3.2) or<br>-RA (1)                                      |
| TT-1-0050b<br>Apr. 4, 1961                                         | Lacquer, enamel<br>acrosol .....                    | -RA-NC                                                         | TT-P-442<br>Aug. 10, 1961    | Titanium Dioxide<br>(pigment)                        |                                                                |
| TT-P-51e<br>Mar. 13, 1962                                          | Flat (interior) ...                                 | -RCHT (5.5)                                                    | and Amend. 1                 | See page 39 of this<br>Handbook                      |                                                                |
| TT-1-0054a<br>Apr. 20, 1962                                        | Lacquer, spray<br>acid resistant ...                | -RA-45; others                                                 | TT-E-489c<br>Feb. 29, 1960   | Enamel (interior-<br>exterior) .....                 | -RA-NC (2.7)                                                   |
| TT-P-0055a<br>May 21, 1958                                         | Polyvinyl acetate<br>emulsion (exteri-<br>or) ..... | opaque pigment<br>-A (max. 10%<br>plus -RA-NC<br>(min. 90%))   | TT-E-491<br>May 7, 1946      | Enamel<br>white .....                                | -RA-NC (3.3)<br>-RA-NC (2.7)                                   |
| TT-P-56b<br>Feb. 23, 1954                                          | Wall Primer<br>(interior) .....                     | -RCHT (2.3)                                                    | TT-E-505a<br>Nov. 22, 1961   | Alkyd Enamel<br>odorless .....                       | -RA-45; others                                                 |
| TT-P-85b<br>Aug. 23, 1962                                          | Paint, reflectorized<br>(airport runway)            | -RCHT, -RC;<br>-RA-NC;<br>others                               | TT-E-506c<br>Mar. 26, 1954   | Enamel (interior).                                   | -RA (1.8);<br>-RCHT (1.4)                                      |
| TT-P-0087<br>Sept. 23, 1959<br>superseded in part<br>by TT-P-0085a | Paint, traffic<br>reflectorized ....                | -A (2.3)*                                                      | TT-E-506d<br>June 19, 1963   | Enamel (interior).                                   | -RANC (2.5)                                                    |
| TT-P-88a<br>May 20, 1945                                           | Resin-emulsion<br>paste (interior).                 | -A (2.1)                                                       | TT-E-508<br>May 7, 1946      | Semi-gloss<br>(interior) .....                       | -RCHT (5.7)                                                    |
| TT-P-91a<br>Apr. 10, 1950                                          | Rubber-base (for<br>concrete floors).               | -A; -RA;<br>-RA-NC (2.5<br>white base)                         | TT-E-509a<br>Sept. 21, 1960  | Enamel, odorless<br>semi-gloss (inte-<br>rior) ..... | -C-50; others                                                  |
| TT-P-95<br>July 3, 1953                                            | Swimming pool<br>rubber base ....                   | -RA-NC                                                         | TT-E-527a<br>June 1, 1961    | Enamel, lustreless.                                  | -RA-NC                                                         |
| TT-P-98<br>May 30, 1945                                            | Stencil Flat .....                                  | -RA (3.5)                                                      | TT-E-529a<br>Oct. 30, 1959   | Enamel, semi-gloss                                   | -RA-NC (2.3)                                                   |
| TT-P-0099a<br>May 21, 1958                                         | Styrene-butadiene<br>exterior emuls. .              | -RA-NC*<br>(85% min.)                                          | TT-E-543<br>Oct. 25, 1949    | Enamel undercoat<br>(interior) .....                 | -RCHT (6.0)                                                    |
| TT-P-102a<br>June 21, 1962                                         | Exterior Oil Paint<br>Class A-white ..              | -A-MO*                                                         | TT-E-545a<br>Nov. 30, 1959   | Enamel, odorless<br>(interior) .....                 | -RA-45; others                                                 |
|                                                                    | Class B-light<br>tints .....                        | -RA-NC*                                                        |                              |                                                      |                                                                |

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# MILITARY SPECIFICATIONS

## (JAN and MIL)

### In numerical order

\*—Mandatory

| Spec. No.<br>and Date      | Type of Paint                                          | TITANOX<br>applicable and<br>lb./gal. paint<br>approximate ( ) | Spec. No.<br>and Date         | Type of Paint<br>Equivalent Spec.                   | TITANOX<br>applicable and<br>lb./gal. paint<br>approximate ( ) |
|----------------------------|--------------------------------------------------------|----------------------------------------------------------------|-------------------------------|-----------------------------------------------------|----------------------------------------------------------------|
| TT-L-558b<br>June 12, 1957 | Stencel ink (for<br>metal, glass, etc.)                | -RA-NC; others                                                 | MIL-L-73A<br>June 4, 1956     | Lacquers (flat)<br>JAN-L-73;<br>52L14 and 3-162D    | -RA-NC; others                                                 |
| TT-L-559b<br>Dec. 20, 1945 | Stencel ink (for<br>wood, fibre, etc.)                 | -RA-NC; others                                                 | MIL-E-74B<br>Sept. 13, 1960   | Enamel (flat)<br>JAN-E-74a;<br>52E6; 3-67G          | -RA-NC; others                                                 |
| TT-P-645<br>Apr. 12, 1962  | Primer—zinc chro-<br>mate alkylid . . . .              | -RA-NC (0.75)                                                  | JAN-E-480<br>July 24, 1947    | Baked enamel<br>semi-gloss . . . .                  | -RA; -RA-46;<br>-RA-NC                                         |
| TT-P-659a<br>Dec. 30, 1958 | Primer-surfacer<br>(hospital furni-<br>ture) . . . . . | -RA-NC; others                                                 | JAN-P-630<br>July 23, 1948    | Camouflage (oil<br>type) . . . . .                  | -RA-NC                                                         |
|                            |                                                        |                                                                | MIL-P-699B<br>June 22, 1962   | Deck gray<br>JAN-P-699;<br>52P43a                   | -RA-NC* (0.36)<br>B, non-skid . . -RA-NC* (0.32)               |
|                            |                                                        |                                                                | JAN-P-700<br>Nov. 29, 1948    | Deck gray<br>(interior) . . . .                     | -RA-NC (0.75)                                                  |
|                            |                                                        |                                                                | MIL-E-1115A<br>Mar. 21, 1950  | White Enamel . . .                                  | -RA* (2.5)                                                     |
|                            |                                                        |                                                                | MIL-E-1264C<br>Dec. 7, 1960   | White, exterior . .                                 | -RA-NC* (2.5)                                                  |
|                            |                                                        |                                                                | MIL-E-1265C<br>Nov. 29, 1960  | Ocean gray<br>(exterior) . . . .                    | -RA-NC* (0.5)                                                  |
|                            |                                                        |                                                                | MIL-L-2638B<br>Sept. 28, 1955 | Vinyl lacquer<br>(gasoline and<br>water resistant). | -RA-50; others                                                 |
|                            |                                                        |                                                                | MIL-P-2852<br>Aug. 23, 1951   | Blue, striping . . .                                | -RCHT* (1.1)                                                   |
|                            |                                                        |                                                                | MIL-P-4812<br>May 21, 1954    | Bullet tipping . . .                                | -A or -RA                                                      |

Spec. No. and Date  
MIL-D-5550A  
Feb. 28, 1951

Type of Paint  
Liquor. Spec.  
Dope — flat (acetate-butyrate)  
White 601 and some tints

TITANOX applicable and lb./gal. paint approximate ( )

-RA-NC\*

AN-D-3

MIL-D-5551A  
Mar. 1, 1951

Dope — gloss (acetate-butyrate) ..

-RA-NC

MIL-D-5554A  
Jan. 26, 1953

Dope (nitrate) ... AN-TT-D-554

-RA-NC

MIL-D-5555  
Jan. 9, 1950

Dope; camouf. (nitrate) flat finish. AN-D-8

-RA-NC\*

MIL-E-5556B  
Oct. 16, 1961

Camouf. enamel AN-E-7

-RA-NC

MIL-E-5558A  
Oct. 1, 1951

Enamel, wrinkle finish, baked ....

-RA-NC

MIL-L-6805C  
May 14, 1959

Lacquer, Camouf. AN-L-21

-RA-NC

MIL-P-6884B  
Mar. 21, 1960

Temporary identification ...

-RA or -RA-50

MIL-L-7178A  
May 24, 1956

Lacquer, aircraft ...

-RA-NC\*

MIL-E-7729A  
July 1, 1955

Enamel, aircraft ...

-RA-NC\*

MIL-P-9886  
Aug. 23, 1960

Paint, reelectrized equip. marking .

MIL-E-10164  
Feb. 24, 1950

Enamel (for can closures) light gray

-RA-NC\* (3)

MIL-L-10182  
Mar. 9, 1950

Lacquer (automotive) .....

-RA-NC\*

MIL-E-10242  
Apr. 18, 1950

Stencil Enamel ... OQMC-152A

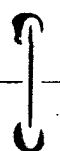
-RA-NC

MIL-L-10287A  
Aug. 19, 1953

Lacquer (ammonio identine) .....

-RA

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Spec. No. and Date  
MIL-E-10687B  
Feb. 18, 1959

Type of Paint  
Liquor. Spec.  
Flat finish for ammunition

TITANOX applicable and lb./gal. paint approximate ( )

-RA-NC\*

MIL-L-11195B  
Mar. 9, 1959

Lacquer, hot spray for ammunition .

-RA; -RA-NC

MIL-P-12742A  
Nov. 15, 1956

Primer (enamel) .

-RA-NC\*

MIL-P-13340a  
June 1, 1962

Camouflage (emulsifiable) .....

-RA-NC

MIL-L-13815A  
Jan. 26, 1960

Lacquer, blue-gray 331 .....

-RA-45; others

MIL-D-13983C  
Jan. 7, 1960

Lustreless paints (gasoline removable) .....

-RA-NC

MIL-E-15090B  
June 24, 1952

Enamel (equip. mach., etc.) light gray

52E4 (form. 111)

I-1 gloss .....

-RA-NC\* (22)

I-2 semi-gloss ..

-RCHT\* (40)

II-1 gloss .....

-RA-NC\* (18)

II-2 semi-gloss ..

-RA-NC\* (04)

III-1 bake .....

-RA-NC\* (22)

III-2 bake semi-gloss .....

-RA-NC\* (05)

Boot topping (wooden vessels)

-RA\* (0.15)

MIL-P-15128C  
Dec. 7, 1960

Navy blue (exterior) .....

-RA-NC (0.35)

MIL-E-15129C  
Dec. 19, 1960

Navy gray No. 7 (exterior) .....

-RA-NC (0.4)

MIL-E-15130C  
Dec. 7, 1960

Haze gray No. 27 (exterior) .....

-RA-NC (0.55)

MIL-P-15149  
May 15, 1950

Stencil Paint .....

-A; others

MIL-P-15150A  
May 16, 1951

Shop coat for steel (red) .....

-RA; -RA-NC (0.75)

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NLI 121408



| Spec. No.<br>and Date         | Type of Paint<br>figure, Spec.                      | Titanox<br>applicable and<br>lb./gal. paint<br>approximate ( ) | Spec. No.<br>and Date                     | Type of Paint<br>figure, Spec.                           | Titanox<br>applicable and<br>lb./gal. paint<br>approximate ( ) |
|-------------------------------|-----------------------------------------------------|----------------------------------------------------------------|-------------------------------------------|----------------------------------------------------------|----------------------------------------------------------------|
| MIL-P-15151A<br>June 27, 1951 | Shop coat for steel<br>(green) .....                | -RA* (0.75)                                                    | MIL-E-17138A<br>Sept. 25, 1952            | Medium blue<br>(gloss enamel) ..                         | -RA-NC* (0.8)                                                  |
| MIL-C-15159<br>May 15, 1950   | Canvas coating ...                                  | -RA-NC                                                         | MIL-E-17139A<br>Sept. 19, 1952            | Jade Green<br>(gloss enamel) ..                          | -RA-NC* (1.3)                                                  |
| MIL-E-15181C<br>Dec. 19, 1960 | Light gray .....                                    | -RA-NC* (0.8)                                                  | MIL-E-17140A<br>Sept. 25, 1952            | Marine Green<br>(semi-gloss<br>enamel) .....             | -RCHT* (2.20);<br>-RA-NC* (1.6)                                |
| MIL-P-15182A<br>Feb. 14, 1952 | Gray No. 46 (ex-<br>terior) .....                   | -RA-NC* (0.8)                                                  | MIL-E-17325A<br>May 22, 1957              | Rose-wood (semi-<br>gloss enamel) ..                     | -RCHT* (2.05);<br>-RA-NC* (1.7)                                |
| MIL-P-15183A<br>Jan. 24, 1952 | Gray No. 11 (ex-<br>terior) .....                   | -RA-NC* (0.5)                                                  | MIL-E-17326A<br>May 22, 1957              | Clipper Blue (semi-<br>gloss enamel) ..                  | -RCHT* (2.05);<br>-RA-NC* (1.7)                                |
| MIL-T-15195a<br>July 9, 1951  | Not a paint—<br>Titanium-calcium<br>(pigment) ..... | -RCHT                                                          | MIL-E-17327<br>(Ships)<br>Sept. 26, 1952  | Light gray (semi-<br>gloss enamel) ..                    | -RCHT* (2.3);<br>-RA-NC* (1.65)                                |
| MIL-E-15935B<br>Mar. 16, 1961 | Outside gray .....                                  | -RA-NC* (0.3)                                                  | MIL-E-17328<br>(Ships)<br>Oct. 13, 1952   | Cloud gray (semi-<br>gloss enamel) ..                    | -RCHT* (2.3);<br>-RA-NC* (1.65)                                |
| MIL-E-15936B<br>Apr. 24, 1961 | Outside gray .....                                  | -RA-NC* (0.3)                                                  | MIL-E-17329<br>(Ships)<br>Oct. 6, 1952    | Light blue (semi-<br>gloss enamel) ..                    | -RCHT* (2.1);<br>-RA-NC* (1.5)                                 |
| MIL-P-16188B<br>June 8, 1961  | Gray No. 17 (ex-<br>terior) .....                   | -RA-NC* (0.3)                                                  | MIL-E-17330<br>(Ships)<br>Oct. 10, 1952   | Sea-spray blue<br>(semi-gloss) ...                       | -RCHT* (2.3);<br>-RA-NC* (1.65)                                |
| MIL-P-16502B<br>Apr. 24, 1961 | Outside gray .....                                  | -RA-NC* (0.3)                                                  | MIL-E-17466A<br>(Ships)<br>May 22, 1957   | Sun-glow (semi-<br>gloss enamel) ..                      | -RCHT* (2.05);<br>-RA-NC* (1.7)                                |
| MIL-E-16663<br>Dec. 2, 1952   | Enamel, semi-gloss                                  | -RA-NC                                                         | MIL-P-17970C<br>(Ships)<br>Sept. 19, 1961 | White fire retard-<br>ant .....                          | -RCHT* (4.0)<br>-RA* (2.05)                                    |
| MIL-P-16738B<br>Mar. 28, 1961 | White (exterior) ..                                 | -RA-NC* (1.75)                                                 | MIL-P-17971C<br>(Ships)<br>Sept. 19, 1961 | Pastel green fire<br>retardant (semi-<br>gloss) .....    | -RCHT* (3.95);<br>-RA (2.05)                                   |
| MIL-E-17133A<br>Oct. 2, 1952  | Crean (gloss<br>enamel) .....                       | -RA-NC* (1.9)                                                  | MIL-P-17972C<br>(Ships)<br>Sept. 19, 1961 | Gray fire retardant<br>for equipment<br>(semi-gloss) ... | -RCHT* (3.78);<br>-RA* (2.05)                                  |
| MIL-E-17134A<br>Sept. 8, 1952 | Light gray (gloss<br>enamel) .....                  | -RA-NC* (1.5)                                                  |                                           |                                                          |                                                                |
| MIL-E-17136B<br>May 22, 1957  | Enamel, beach-sand<br>(semi-gloss) ...              | -RCHT* (2.05);<br>-RA* (1.7)                                   |                                           |                                                          |                                                                |

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NLI 121409

# NAVY DEPARTMENT

In numerical order

\*-Mandatory

Spec. No. and Date  
52E13 (ORD)  
Oct. 29, 1947

Type of Paint  
Semi-gloss (projectiles, rockets, etc.)

TITANOX applicable and lb./gal. paint approximate ( )

-RA-NC

## COAST GUARD

CGS-52P-5b  
Jan. 14, 1953

Exterior vinyl alkyl types .... -RA-NC (1.74)

| Spec. No. and Date                    | Type of Paint<br>Equiv. Spec.            | TITANOX applicable and lb./gal. paint approximate ( ) |
|---------------------------------------|------------------------------------------|-------------------------------------------------------|
| MIL-P-17973A (Ships)<br>May 22, 1952  | Green-gray fire retardant                | -RCH7* (2.05)<br>-RA* (1.7)                           |
| MIL-P-17974A (Ships)<br>May 22, 1957  | Yellow-gray fire retardant               | -RCH7* (2.05)<br>-RA* (1.7)                           |
| MIL-P-18210 (Ships)<br>Nov. 8, 1954   | Red, deck (interior)                     | -RA-NC* (0.4)                                         |
| MIL-P-18214A<br>Sept. 27, 1960        | Dark green, deck (interior)              | -RA-NC* (0.45)                                        |
| MIL-L-18389<br>May 14, 1957           | Lacquer                                  | -RA* (0.5)                                            |
| MIL-R-18708A<br>Oct. 11, 1956         | Rust arresting coating, gray, exterior   | -RA-NC* (1.7)                                         |
| MIL-L-19538A<br>July 19, 1960         | Lacquer, acrylic nitrocel., camoufl.     | -RA-NC                                                |
| MIL-E-19603B<br>Sept. 25, 1958        | Enamel, Baking                           | -RA-NC; others                                        |
| MIL-C-22325<br>Feb. 10, 1960          | Tinting Colors, (int. non-flaming) paint | -RCHT-X; C-50                                         |
| MIL-P-22808<br>Feb. 6, 1961           | Epoxy, hydraulic fluid resist            | -RA-NC; others                                        |
| MIL-C-27227<br>July 2, 1959           | Polyurethane coating; heat resist.       | -RA-NC (4.45)                                         |
| MIL-P-27316<br>Mar. 9, 1960           | Primer coat, epoxy                       | -RA-NC (2.41)                                         |
| MIL-C-52032<br>Feb. 17, 1960          | Gasoline container coating (interior)    | -RA; others                                           |
| MIL-L-52043A<br>Jan. 27, 1961         | Semi-gloss lacquer                       | -RA; others                                           |
| MIL-P-52108<br>Amend.<br>July 8, 1960 | Water emuls. stencil or oblit.           | -RA-NC;<br>RA-46; others                              |

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NLI 121410

# MARITIME ADMINISTRATION

## In numerical order

| *—Mandatory | Spec. No.<br>and Date        | Type of Paint                                              | TITANOX<br>applicable and<br>lb./gal. paint<br>approximate ( ) |
|-------------|------------------------------|------------------------------------------------------------|----------------------------------------------------------------|
|             | 52-MC-9<br>Nov. 23, 1942     | Not a paint—Rutile titanium dioxide, chalk resisting ..... | -RA-NC                                                         |
|             | 52-MC-19<br>Mar. 31, 1943    | Not a paint—Rutile TiO <sub>2</sub> pigment ..             | -RA                                                            |
|             | MAP-48<br>April 13, 1954     | Alkyd flat (interior) .....                                | -RA-NC (1.85)<br>-RCHT (2.80)                                  |
|             | 52-MC-103<br>May 8, 1946     | Striping Enamel—Blue-alkyd .....                           | -RA-NC* (0.77)                                                 |
|             | 52-MA-106a<br>Sept. 25, 1950 | Exterior Enamels<br>Semi-gloss (alkyd) .....               | -RA-NC* (2.2)                                                  |
|             | 52-MC-107a<br>June 10, 1960  | Interior Enamels—Gloss (alkyd) ..                          | -RA-NC* (2.2)                                                  |
|             | 52-MC-120<br>Mar. 27, 1950   | Interior Paints (flat) White base                          | -RCHT* (5.75)                                                  |
|             | 52-MA-121<br>Nov. 1, 1950    | Int.-ext. Enamel—pea green (alkyd)                         | -RA-NC* (0.85)                                                 |
|             | 52-MA-152a<br>Sept. 18, 1950 | Hull paint, light gray .....                               | -RA-NC* (0.85)                                                 |
|             | 52-MA-154b<br>May 15, 1952   | Deck gray .....                                            | -RA-NC* (0.75)                                                 |
|             | 52-MA-155<br>Sept. 25, 1950  | Interior gray enamel .....                                 | -RA-NC* (0.85)                                                 |
|             | 52-MA-156<br>May 4, 1960     | Reserve Fleet gray (exterior) .....                        | -RA-NC* (0.58)                                                 |
|             | 52-MA-210<br>Sept. 28, 1950  | Wood Primer, white and tints..                             | -RCHT* (3.73)                                                  |
|             | 52-MA-521a<br>June 13, 1957  | Not a paint—Rutile-calcium pigment .....                   | -RCHT                                                          |

# BUREAU OF RECLAMATION

Dept. of the Interior  
Commissioner's Office, Bldg. 53,  
Denver 2, Colorado

| Spec. No.<br>and Date                                      | Type of Paint | TITANOX<br>applicable and<br>lb./gal. paint<br>approximate ( ) |
|------------------------------------------------------------|---------------|----------------------------------------------------------------|
| Sealing compound<br>for curing<br>concrete<br>Aug. 1, 1960 | .....         | -RCHT (1.0)                                                    |

## TENNESSEE VALLEY AUTHORITY

Chief, Materials Branch  
Chattanooga, Tennessee

|                       |                                                                  |                |
|-----------------------|------------------------------------------------------------------|----------------|
| A-79<br>June 15, 1959 | Ready Mixed semi-gloss floor and interior enamel Tint Base ..... | -RCHTX; others |
| A-94<br>June 16, 1943 | Exterior semi-gloss enamel, tint .....                           | -RC; RA-NC     |

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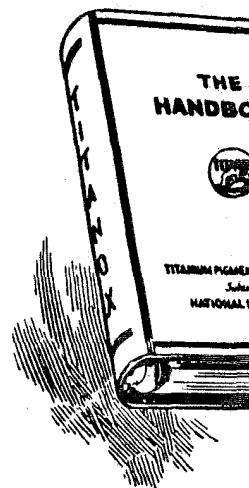
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of



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for new Page

A new leaf (page 41-1 and  
revision of page 42 to include  
of TITANOX-RA-47 rutile  
latex flat paints.

A new leaf (pages 63 and  
page 64 description of  
multi-purpose anatase ti

**TITANIUM PIGMENT C**

Subsidiary of National Lead  
111 Broadway, New York,  
Tel. 212 REctor 2-

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## TITANOX PIGMENTS

| Average Values                                                                     |                                 |         |                       |                      |                     |                    |                                    |                                                              |                                                    |
|------------------------------------------------------------------------------------|---------------------------------|---------|-----------------------|----------------------|---------------------|--------------------|------------------------------------|--------------------------------------------------------------|----------------------------------------------------|
|                                                                                    | %<br>TiO <sub>2</sub><br>(min.) | Sp. Gr. | 1 lb.<br>Bulk<br>Gal. | 1 lb.<br>Per<br>Gal. | Timing,<br>Strength | Opt.<br>Absorption | Relative<br>Chalking<br>Resistance | Principal Use                                                | Applicable to<br>Pigment Specifications            |
| <b>Rutile Titanium Dioxide</b>                                                     |                                 |         |                       |                      |                     |                    |                                    |                                                              |                                                    |
| TITANOX-RA                                                                         | 97                              | 4.2     | .0286                 | 34.99                | 1700                | 19                 | Medium                             | General utility; interior enamels; plastics,.....            | TT-P-442, Type II; ASTM D476-48, -II-1; 52MC-19    |
| TITANOX-RA-40 and RA-41                                                            | 98-97                           | 4.2     | .0286                 | 34.99                | 1600-1650           | 18                 | .....                              | Plastics and rubber (RA-40 mainly floor tile).               |                                                    |
| TITANOX-RA-42                                                                      | 92                              | 4.1     | .0293                 | 34.15                | 1700                | 32                 | .....                              | Paper                                                        |                                                    |
| TITANOX-RA-45                                                                      | 95                              | 4.1     | .0293                 | 34.15                | 1850                | 20                 | Medium                             | High gloss enamels, industrial and architectural.            |                                                    |
| TITANOX-RA-46 and RA-47                                                            | 93-91                           | 4.1     | .0293                 | 34.15                | 1675-1700           | 32                 | .....                              | Flat emulsion paints—RA-47 improved porosity                 |                                                    |
| TITANOX-RA-50                                                                      | 95                              | 4.1     | .0293                 | 34.15                | 1700                | 23                 | High                               | Multi-purpose                                                | TT-P-442, Grade B, Type III; ASTM D476-48, -II-11. |
| TITANOX-RA-51                                                                      | 93                              | 4.1     | .0293                 | 34.15                | 1850                | 26                 | High                               | All types of paints; multi-purpose.....                      | TT-P-442, Grade B, Type III                        |
| TITANOX-RA-NC                                                                      | 93                              | 4.1     | .0293                 | 34.15                | 1700                | 21                 | Highest                            | All types of exterior coatings and compositions              | TT-P-442, Grade A, Type III; ASTM D476-48; 52MC    |
| and-RA-NC IMPROVED                                                                 |                                 |         |                       |                      |                     |                    |                                    | RA-NC IMPROVED—higher gloss, greater tint clarity            |                                                    |
| <b>Rutile-calcium Pigment (50% TiO<sub>2</sub> (rutile); 50% CaSO<sub>4</sub>)</b> |                                 |         |                       |                      |                     |                    |                                    |                                                              |                                                    |
| TITANOX-G-50                                                                       | 49.0                            | 3.47    | .0345                 | 28.94                | 975                 | 20                 | Medium                             | Semi-gloss and flat paints; general utility                  |                                                    |
| <b>Rutile-calcium Pigment (30% TiO<sub>2</sub> (rutile); 70% CaSO<sub>4</sub>)</b> |                                 |         |                       |                      |                     |                    |                                    |                                                              |                                                    |
| TITANOX-RC                                                                         | 29.5                            | 3.25    | .0369                 | 27.07                | 600                 | 21                 | High                               | Exterior tinted paints.....                                  | ASTM D476-48                                       |
| TITANOX-RCHT                                                                       | 29.5                            | 3.25    | .0369                 | 27.07                | 600                 | 23                 | Medium                             | Interior paints (flats, semi-gloss, gloss); general utility  | ASTM D476-48; 52-MA-521a; MIL-T-15195A             |
| TITANOX-RCHTX                                                                      | 29.5                            | 3.25    | .0369                 | 27.07                | 600                 | 21                 | Medium                             | As RCHT but exceptional ease of dispersion...                | ASTM D476-48; 52-MA-521a; MIL-T-15195A             |
| <b>Anatase Titanium Dioxide</b>                                                    |                                 |         |                       |                      |                     |                    |                                    |                                                              |                                                    |
| TITANOX-A-MO and -A-LO                                                             | 98                              | 3.9     | .0308                 | 32.49                | 1250                | 25-21              | Low                                | White house paints; general utility; rubber....              | TT-P-442, Type I; ASTM D476-48, Type I             |
| TITANOX-A-168 (MO & LO)                                                            | 97                              | 3.8     | .0316                 | 31.65                | 1250                | 25-21              | Low                                | Plastics; inks; white house paints.....                      | ASTM D476-48, Type I                               |
| TITANOX-AA                                                                         | 96                              | 3.9     | .0308                 | 32.49                | 1250                | 22                 | Medium                             | Acetate rayon; white house paints.....                       | ASTM D476-48, Type I                               |
| TITANOX-A-CG                                                                       | 97                              | 3.8     | .0316                 | 31.65                | 1250                | 20                 | .....                              | Coatings for paper; white house paints.....                  | ASTM D476-48, Type I                               |
| TITANOX-A-MP                                                                       | 95                              | 3.8     | .0316                 | 31.65                | 1300                | 24                 | Low                                | Multi-purpose; paper filling and coating; white house paints |                                                    |
| TITANOX-A-WD                                                                       | 98                              | 3.9     | .0308                 | 32.49                | 1200                | ....               | .....                              | Paper filling                                                | ASTM D476-48, Type I                               |

<sup>1</sup> Timing Strength: Reynolds' constant volume method—0.5 grams of pigment plus 1.25 gm. ultramarine blue (6 parts by weight, 1 part ultramarine blue) plus 0.515 ml. refined linseed oil has limiting strength 1250. Although an exact general relationship cannot be shown, timing strength is generally indicative of relative hiding power.

<sup>2</sup> Opt. Absorption: Spectra method expressed as lb. oil per 100 lb. pigment—determined in relation to standard sample under controlled conditions.

<sup>3</sup> TT-P-442 is Federal Spec. for Titanium Dioxide dated August 10, 1961, superseding TT-T-425a dated December, 1951.

In addition to the pigments listed above, these highly specialized products are offered: Titanox-PL, rutile TiO<sub>2</sub> pigment for plastic laminating papers; Titanox-A-WG anatase TiO<sub>2</sub> for welding rod coatings; non-pigmentary or chemical grade titanium dioxides; Titanox-RA-10 rutile TiO<sub>2</sub> pigment.

TITANIUM PIGMENT CORPORATION, 111 Broadway, New York, N. Y. 10006

NLI 121423

# **TITANOX-RA-45**

NLI 121424

|                                                       |         |
|-------------------------------------------------------|---------|
| Minimum % TiO <sub>2</sub> .....                      | 95      |
| (Additive Al <sub>2</sub> O <sub>3</sub> principally) |         |
| Crystal Structure of TiO <sub>2</sub> .....           | Rutile  |
| Refractive Index (mean).....                          | 2.7     |
| Average Particle Size                                 |         |
| Mean Dia., micron.....                                | 0.2-0.3 |
| Specific Gravity.....                                 | 4.1     |
| Lb. per Solid Gal.....                                | 34.15   |
| 1 Lb. bulks Gal.....                                  | .0293   |
| Tinting Strength.....                                 | 1850    |
| Oil Absorption lb. oil/100 lb. pigment.....           | 19-22   |
| Relative Resistance to Chalking.....                  | High    |

TITANOX-RA-45 is rutile titanium dioxide pigment having maximum tinting strength, but otherwise most closely related in properties to TITANOX-RA-50. In most pigmented compositions, with few exceptions such as some flat latex paints, TITANOX-RA-45 exerts higher tinting strength and higher hiding power than the other TITANOX rutile titanium dioxide pigments. Higher brightness of cleaner whites, greater clarity of brighter tints plus higher gloss are associated with TITANOX-RA-45.

## **Uses**

TITANOX-RA-45 is particularly suitable for use in high gloss industrial product finishes and high gloss architectural finishes. But with few exceptions, TITANOX-RA-45 is applicable to the many uses of TITANOX-RA and of TITANOX-RA-50 which are discussed on pages 43 to 46.

Where brightness and opacity of a paint or other pigmented composition may be at a satisfactory level with ordinary rutile titanium dioxide pigment, a lesser amount of TITANOX-RA-45 will often give the desired hiding at resulting lower pigment cost. Outstanding exceptions are highly pigmented flat latex paints in which TITANOX-RA-51 or TITANOX-RA-46 give higher hiding.



**TITANOX-RA-46 and -RA-47** (rutile titanium dioxide pigments—primarily for use in flat emulsion paints)

**TITANOX-RA-42** (rutile titanium dioxide pigment—primarily for use in paper to achieve higher blue or TAPPI brightness)

These pigments have these average properties:

|                    |           |
|--------------------|-----------|
| Specific Gravity   | 4.1       |
| Lb. per Solid Gal. | 34.15     |
| 1 Lb. bulks Gal.   | .0293     |
| Tinting Strength   | 1700-1800 |
| Oil Absorption     | 32        |

Particle size distribution determinations indicate an average mean particle diameter of 0.2 micron for Titanox-RA-42 and Titanox-RA-47; 0.2-0.3 micron for Titanox-RA-46. Minimum %  $TiO_2$  is 93 in Titanox-RA-46, 92 in Titanox-RA-42, 91 in Titanox-RA-47.

#### Uses

**Water Emulsion Paints:** Titanox-RA-46 imparts high hiding and brightness of whites and tints at higher total pigment volumes (see pages 28, 29). Titanox-RA-47 shows even higher tinting strength while improving porosity and stain removal; it also has lower dispersant demand.

**Paper:** At higher levels of opacity, particularly in lightweight papers, these pigments have been found in some cases to impart opacity sufficiently higher than anatase to warrant use at equal or lower cost. Under the same conditions, Titanox-RA-42 yields also blue brightness comparable to anatase. Exceptionally high brightness (99% minimum) of Titanox-RA-42 itself contributes to high brightness in paper.

**Other Uses:** In high dry hiding organic solvent flat wall paints Titanox-RA-46 and -RA-47 may be called upon. These pigments should prove interesting wherever high oil absorption and resultant consistency effects of rutile titanium dioxide are desired.

Inasmuch as TITANOX-A-168 is a chalking type of pigment it is applicable to white exterior house paints. In other applications such as organic enamels, rub-ber, plastics, inks, leather—existing preference is the result of conditions which interfere with the adjust-ment of whiteness or color tone with TITANOX "RA" rutile pigments.

For all of the uses of TITANOX-A-168, the excep-tional ease of dispersion and high tinting strength of TITANOX-A-MP (see page 64) should be preferred.

### Uses

TITANOX-A-168 is anatase titanium dioxide pigment modified for minimum discoloration and after-yellow-ing of vehicles of organic coatings especially those based on synthetic resins. This pigment has been re-placed in many uses by higher hiding TITANOX "RA" pigments.

|                                                       |       |          |
|-------------------------------------------------------|-------|----------|
| Minimum % of $TiO_2$ (additive $Al_2O_3$ principally) | 97    | MO       |
| Crystal Structure of $TiO_2$                          | 97    | Medium   |
| Refractive Index (mean)                               | 2.55  | Oil abs. |
| Average particle size, mean dia., micron              | 0.3   | Low      |
| Specific Gravity                                      | 3.8   |          |
| Lb. per Solid Gal.                                    | 31.65 |          |
| 1 Lb. Bulks Gal.                                      | .0316 |          |
| Tinting Strength                                      | 1250  |          |
| Oil abs. lb. oil/100 lb. pigment                      | 24-26 |          |
| Relative resistance to chalking                       | low   |          |

Anatase Anatase

NLI 121426

TITANOX-A-168



## TITANOX-A-MP

Minimum %  $\text{TiO}_2$  ..... 95  
(additive  $\text{Al}_2\text{O}_3$  principally)

Crystal Structure of  $\text{TiO}_2$  ..... Anatase

Refractive Index (mean) ..... 2.55

Average particle size, mean dia, micron. 0.2

Specific Gravity ..... 3.8

Lb. per Solid Gal. .... 31.65

1 Lb. Bulks Gal. .... .0316

Tinting Strength ..... 1300

Oil Absorption lb. oil/100 lb. pigment. .... 23

Relative resistance to chalking. .... low

Titanox-A-MP is a multi-purpose (MP) anatase titanium dioxide pigment having the color retentive features of TITANOX-A-168, the exceptional ease of dispersion and freedom from coarse agglomerates of TITANOX-A-CG, plus maximum tinting strength available in anatase.

## Uses

TITANOX-A-MP applicable to all products that need anatase pigment should be preferred wherever its superior dispersibility or optical properties prove advantageous.

Outstanding is the use of this pigment in paper—in coatings TITANOX-A-MP is at least equal in all respects to the coating grade TITANOX-A-CG (page 66). As a beater or wet end addition, up to 15% less TITANOX-A-MP than conventional anatase filler pigments (even TITANOX-A-WD) may be found to give equal opacity and brightness especially at high opacity levels and in light weight stocks. In comparison with weaker anatase pigments, even less TITANOX-A-MP may suffice. The increased opacity available from TITANOX-A-MP has been found to narrow the difference between rutile and anatase, suggesting that where rutile may now be preferred as filler pigment that TITANOX-A-MP be tried.

# THE HANDBOOK

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