PAINT RESEARCHES

AND

THEIR PRACTICAL APPLICATION

BY

HENRY A. GARDNER

Director Scientific Section, Paint Manufacturers' Association of the U. S.; Assistant Director, The Institute of Industrial Research, Washington, D. C., etc., etc.

WASHINGTON, D. C.
PRESS OF JUDD & DETWEILER, INC.
1917

CHAPTER II.

THE WHITE-PIGMENT INDUSTRY.

Of the white pigments consumed in the paint-grinding trades, only a relatively small proportion is represented by those known as natural earth pigments which are prepared by crushing, grinding, and washing various minerals.* Such pigments will not be considered in this chapter, which bears wholly upon those pigments made by chemical or metallurgical processes from ores having a lead or zinc base, and referred to herein as opaque white pigments.

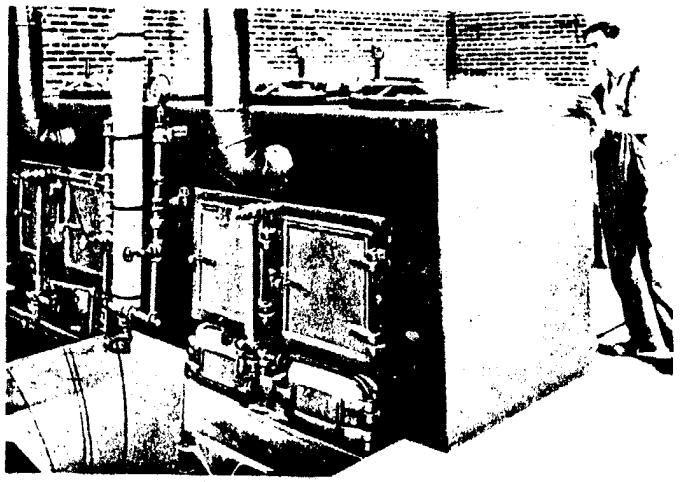


FIG. 2.

Lead melting-pots in white-lead factory.

Five years ago the opaque white pigments produced in the United States amounted to about 230,000 tons, valued at approximately $25,000,000. The writer's estimate for the year 1916 shows a production of approximately 370,000 tons, having a value of over $70,000,000. This tremendous growth of the industry is not to be

*For data on the natural earth pigments, see "Production of Mineral Paints in 1914," U. S. Geological Survey; also Consular Report 56, "Foreign Trade in Paints and Varnishes," U. S. Department of Commerce.

ascribed to any very marked increase in exports or to other conditions consequent upon the unsettled situation that prevails abroad and which might exert an expansive force on our trade thermometer. While, of course, such conditions would naturally increase the demands arising as a result of the growth of certain communities, it is the writer's opinion that the prevailing activity in the pigment world is largely due to the rapidly developing appreciation of the value of those products in which pigments are used. Let us now consider the five important white pigments produced in this country and their application in the paint industry where the largest amounts are used. Of these, the oldest will receive first consideration.

TABLE I.

An Estimate of the Production of the Opaque White Pigments in the United States.

		1911.‖		1916.	
		Quantity.	Value.	Quantity.	Value.§
		Tons.		*Tons.*	
Chemical process	Basic Carbonate-White Lead	132,612*	$17,393,241	100,000†	$28,800,000
	Lithopone	16,866	1,243,108	75,000	16,500,000
Fume process	Basic Sulphate-White Lead	80,611	7,343,762	139,000‡	28,150,000
	Zinc Oxide				
	Leaded Zinc Oxide				
Total		230,089	$25,980,111	374,000	$73,450,000

*Of this amount, 106,778 in oil, balance dry.

† Of this amount, 130,000 in oil, balance dry.

‡ Of this amount, Basic Sulphate-White Lead and Leaded Zinc constitute 43,000 tons, Zinc Oxides 96,000 tons.

§ White Lead Pigments and Leaded Zinc estimated at $175 per ton, American Process Zinc Oxide at $100, French Process Zinc Oxide at a higher price, and Lithopone at $220.

‖ 1911 figures from U. S. Geological Survey Bulletin, Production of Mineral Paints for 1914.

Basic Carbonate-White Lead.—The date of the first commercial production of corroded white lead in the United States has been recorded as 1807, and at the present time there are two large manufacturing organizations and several smaller individual corroders, the plants being well distributed throughout the country. The produc-

tion of the pigment in the various factories depends mainly upon the use of two distinct processes, which are described later on in the text.

There is probably no commercial pigment that has a pedigree quite as long as that held by corroded white lead, and its family history is indeed interesting. Many records of its use in ancient times have been found, and the following has been quoted in the excellent paper on White Lead by Klein:**

> "One of the earliest records of white lead is to be ascribed to Xenophon (430-355 B. C.), who in 'Aeconomicus'* records the use of 'cerussa' as a cosmetic. Church† states that a face powder or cosmetic, found in its original pottery box, of about B. C. 400, in the neighborhood, proved to be a mixture of white lead and whitening."

It is evident from this report that some of the modern paint mixers are not the only ones to understand the art of mixing earth pigments with lead, but whether it was done in those days for purposes of profit or to lessen the toxic effect of the pigment, is not known. Later on, however, in the fourteenth century, it is evident that certain pigments were looked upon with suspicion, as the following reference also from Klein will indicate:

> "Cennino Cennini‡ states that the ladies of Florence were prone to heighten their beauty by the application of white lead and other pigments, and in a homily warns ladies in general against the practice."

Since it is not intended in this chapter to deal with the toxic effect of pigments, those who desire further information on this subject may refer to the publications noted below.§ That the so-called ancients knew how to make real white lead is also shown by Klein in his quoted passage from Theophrastus (373-287 B. C.):‖

**"The Manufacture of White Lead." C. A. Klein, Chief Chemist, Brimsdown Lead Co., L't'd. Presented before the Paint and Varnish Society of London, December 4, 1913.

* Xenophon, quoted by Hofmann, "Das Blei."

† Church, "Chemistry of Paints and Painting," 127. 1901, Seeley, London.

‡ Cennini, "Treatise on Painting," etc., translated by Mrs. Merrifield. London, 1845, p. 51.

§ Bulletin 188, Department of Labor; also "The Toxic and Antiseptic Properties of Paints." H. A. Gardner, Bulletin 41, Scien. Sec., Paint M'f'rs' Ass'n of U. S.

‖ History of Stones, p. 223.

> "Lead is placed in earthen vessels over sharp vinegar, and after it has acquired some thickness of a sort of rust, which it commonly does in about 10 days, they open the vessels and scrape it off, as it were in a sort of foulness; they then place the lead over vinegar again, repeating over and over again the same method of scraping it till it has wholly dissolved. What has been scraped off they then beat to a powder, and boil for a long time, and what at last subsides to the bottom of the vessel is 'ceruse.'"

This old method undoubtedly produced a white lead carbonate, and it is interesting to note that the clay pot method is still in use today, but, of course, in a much more highly developed condition, and now known as the stack or Old Dutch process. Moreover, this process is responsible for a greater tonnage of product than all of the newer processes combined. This fact is indicated by Klein's figures (1914) on the lead production of the world, as quoted below:

TABLE 2.

Quantity of White Lead Produced by Principal Producing Countries.

Estimated Total Production, 275,000 Tons Annually.

	English tons, dry.
United States	120,000
England	55,000
Germany	30,500
France	22,000
Belgium	15,000
Russia	14,500
Italy	4,500
Holland	2,500
Spain	2,500
Canada	2,500

TABLE 3.

Approximate Quantities Produced by Various Processes.

Stack	180,000 tons
Chamber	45,000 "
Miscellaneous	50,000 "

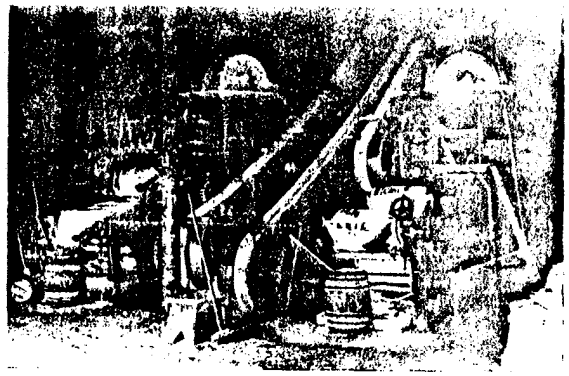
Comparison of these figures should be made with the figures given by the present writer in Table I.

It might be desirable to describe herein very briefly the various processes by which white lead is manufactured at the present time.

Courtesy A. S. Jennings and Messrs. Foster, Blackett, and Wilson

FIG. 3.

"Blue beds" of lead strips before corrosion at English factory.



Courtesy A. S. Jennings and Messrs. Foster, Blackett, and Wilson

FIG. 4.

Grinding white lead in oil at an English factory.

In the stack process, a series of units consisting of clay pots surrounded with tan bark and containing cupped acetic acid at the bottom, are filled with buckles or discs of metallic lead. The pots

are then covered with boards upon which are stacked subsequent layers of pots. Fermentation of the tan bark raises the temperature of the stack, facilitating the action of the acid upon the lead, forming the acetate which in the presence of the carbon dioxide evolved during the fermentation of the bark is transformed into the white basic carbonate. The process requires about three months' time, and when the stacks are finally stripped, the white lead is broken up, ground, washed, and prepared for the market. In the chamber process, which is used on the European continent quite widely, and especially in Germany, large brick corroding chambers

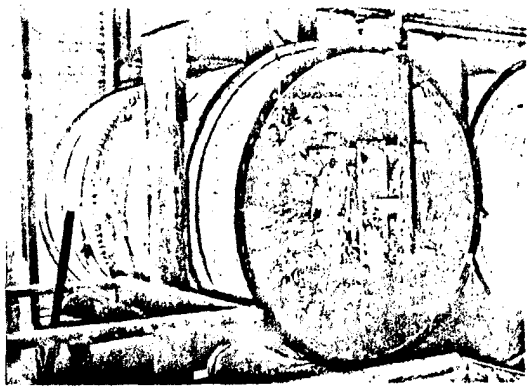
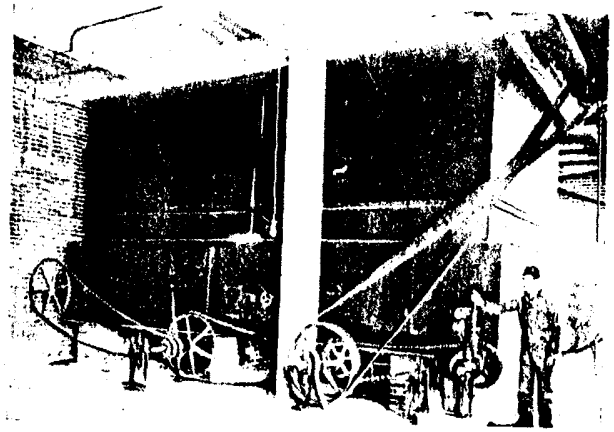


FIG. 5.

Revolving cylinders used in making quick process white lead

are used, in which strips of lead are hung from horizontal girders; a mixture of air, acetic acid, steam, and carbon dioxide being blown into the chambers through inlets in the floor. In less than two months' time the corrosion is complete, the dry white lead being removed and treated in the usual manner. In the Carter process, as used in the United States, metallic lead is granulated and placed in large revolving wooden drums; acetic acid and water being sprayed on the mass. Carbon dioxide gas is passed into the cylinders and agitation continued for a period of from six days to two weeks. The white lead produced is thoroughly levigated and then dried. In the Rowley or mild process, lead is melted and sprayed by means of air or steam to the form of a very fine metallic dust into a

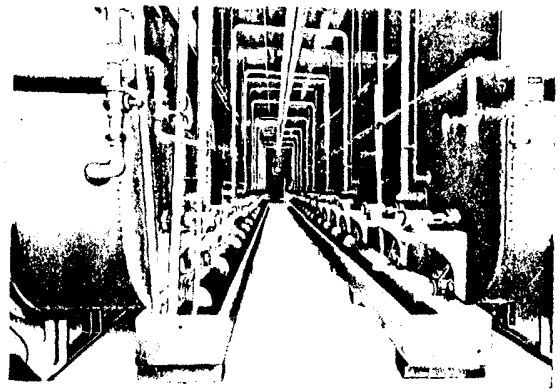
large iron chamber luted with water at the bottom. The mass is then agitated in the presence of air to produce the hydrate of lead,



Courtesy C. S. Neal

FIG. 6.

Steel chamber used in making mild process white lead.



Courtesy C. S. Neal

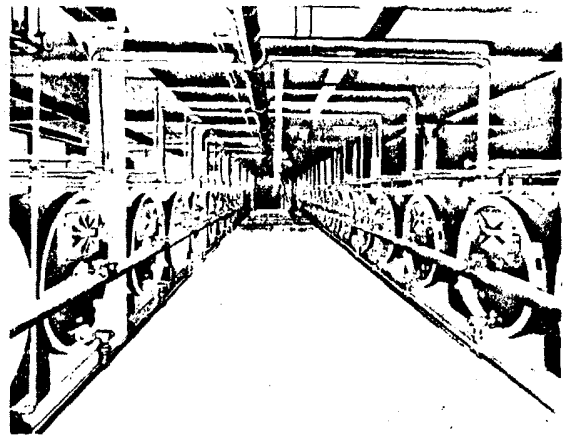
FIG. 7.

Agitation tanks for mild process lead.

and then placed in revolving cylinders and treated with carbon dioxide gas. Basic carbonate of lead is produced in two or three

days' time. Although only a small amount of white lead is made by this process, that produced is generally of a good grade. Other processes, including the electrolytic process, have been proposed and experimented with, but not with any great degree of success.

The enormous tonnage of corroded white lead produced and sold in the United States indicates the extent to which this valuable pigment is consumed in the form of paint. It is used as the base of the majority of white and tinted paints and generally in admix-



Courtesy C. S. Neal

FIG. 8.

Carbonating cylinders for mild process lead.

ture with a substantial percentage of zinc oxide or other pigments in which form the best results are obtained. For reports on the comparative wearing value of such paints, the reader is referred to the publications noted below.* While it is probable that a still greater quantity of corroded white lead would be in use today if other white pigments were not available, we must remember that even the enormous strides made in the use of the newer pigments have apparently only served to help fill the increased demand that

* Bulletins of the Scien. Sec., Paint M'f'rs' Ass'n of U. S.: No. 34, "Report of the 1912 Inspection of the Atlantic City Wooden Test Fence, Including the Repairing Tests and the New Tests"; No. 35, "Report of the 1912 Inspection of the Pittsburgh Test Fence," etc.; No. 36, "Report of Inspection of the Tennessee Test Fence."

of zinc containing certain percentages of lead ores in association. These ores are comparatively abundant, while lead-free ores are rare. As a consequence it follows that the only grades of American process oxides which promise an expansion adequate to a growing demand are those containing upwards of 10 per cent of basic lead sulphate. These leaded zincs are produced with approximately definite lead contents ranging from 10 to 35 per cent of the basic sulphate. Their color is not as a rule as good as that of the 'horsehead' oxides, but in other respects, considered as paint pigments, they are for many purposes generally regarded as superior. It may be said, in passing, that there is reason to believe that, since the color appears to depend somewhat upon the basicity of the lead sulphate contained, and since the lead oxide present in the basic sulphate appears to enhance the pigment value of the product, improvement of color may involve some sacrifice of pigment quality.

"In none of these leaded oxides is the color sufficiently 'bad' to have any practical importance, excepting in the manufacture of white and very light-tinted decorative paints; and by proper tinting and manipulation, even here the color can be made satisfactory. For all other uses, the difference is negligible in the finished product. From a manufacturing point of view there are several advantages in the use of leaded rather than a pure oxide. The percentage of oil required for grinding and the total volume of 'thinners' required to reduce to painting consistency is less in almost exact ratio to the percentage of lead content; the 'body' of the finished paint is decidedly superior; the durability of the paint would seem to be greater; the cost of the leaded zincs is lower.

"As to the durability of paint made from leaded zincs, the following excerpts from official reports will be sufficiently confirmatory:

"1910. Second Annual Report on Atlantic City Test Fence, Panel No. 39. Zinc lead white: chalking, 'considerable'; checking, 'very slight'; general condition, 'good'. This was the highest rating given to any single pigment paint.

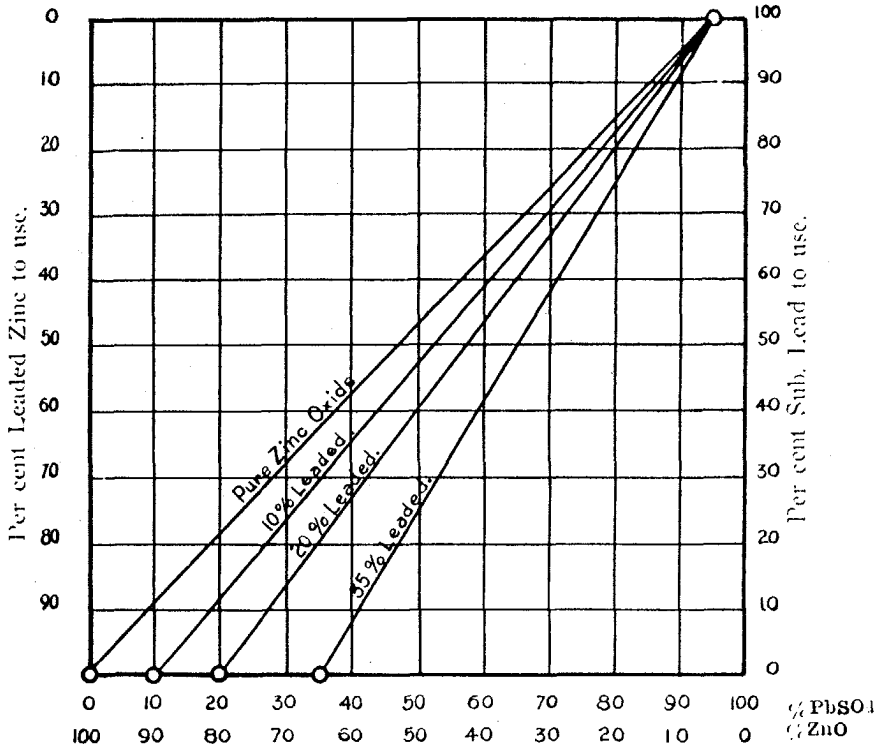
"1913. Report on Inspection of the Tennessee Test Fence. 'Zinc lead, a fume pigment consisting of equal parts of lead sulphate and zinc oxide, gave good results, presenting a surface that was quite free from defects. Leaded zinc * * * was not used as a straight pigment in the tests, but was applied in test No. 5 in combination with basic carbonate white lead (65 per cent leaded zinc, 35 per cent white lead). In such combination it gave good results.'

"1914. Report on Arlington Test Fence, Com. D-1, American Society for Testing Materials. 'Panel No. 107, zinc lead white, shows no checking and surface is very clean.' 'None of the paints composed of a single primary pigment are equal to paints made up of composite pigments, except zinc lead white, which is actually a composite pigment.'

"The following statistics may also prove interesting:

DIAGRAM I.

"Plot Shows Amounts Leaded Zinc and Sublimed Lead to Use for Desired Lead Content of Mix.



"The 35 per cent leaded oxide, when ground with 14 per cent of its weight of linseed oil yields a paste having the same consistency as ordinary white lead in oil. For use as a base for prepared paints the proportion of oil may conveniently be increased to about 22.5 per cent. Such a base may be reduced to good working consistency by the addition of a little less than

50 per cent of its weight of additional oil, thinners and dryer. If rosin in any form appears in the vehicle or the dryer, it should be completely neutralized to prevent reaction with the pigment. It is good practice to use about 10 per cent of turpentine in the vehicle of all leaded zinc paints. Contrary to the practice with basic-carbonate white lead, oils with very low acid number are preferable for leaded zinc paints.

"It is suggested that while objections to the color of these leaded zincs when used for white paint are largely sentimental, it may be greatly improved in practice, by the addition of a very small percentage of blue and also by grinding in refined oil rather than raw oil.

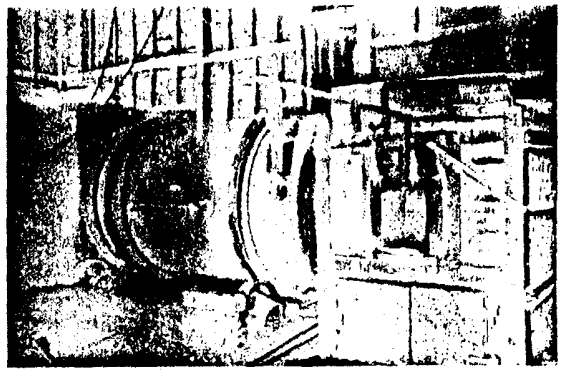
"It is to be noted that in States requiring the formula to be shown on the package, the lead content of all these oxides excepting the lowest (under 5 per cent) must be stated. In all cases where the lead sulphate is actually basic ($Pb3S_2O9$), this is properly given as 'Basic Lead Sulphate.' On the other hand if leaded oxide be used in which the lead content is practically all present as normal lead sulphate ($PbSO4$), the propriety of the designation may be subject to question.

"In practice it is often necessary or desirable to increase the basic lead sulphate content of the formula over that present in the leaded zinc available for use. Since Basic Lead Sulphate (or sublimed lead) as marketed contains about 5 per cent of zinc oxide, calculation of the required proportions of the two pigments required to yield the relative percentages is a rather complicated process.

"The chart (Diagram I) by J. E. Heckel will furnish the required information at a glance.

"The figures to the left indicate the percentages of leaded zinc and those to the right of sublimed lead required to produce the required percentages of ZnO and $PbO4$ indicated at the bottom of the chart. The four diagonal lines represent the several grades of oxide. To find any desired percentages shown in the bottom rows of figures, using any of the oxides shown, follow the perpendicular line to its intersection with the proper diagonal; the required percentages of that oxide and sublimed lead will then be found on the horizontal line to the left and right, respectively. E. g.—Desired percentages 50 each, using a 35 per cent leaded oxide. The 50-50 perpendicular intersects the 35 per cent diagonal at the horizontal line which indicates at the left, 76 per cent leaded zinc, and at the right, 24 per cent sublimed white lead. The desired percentages will, therefore, be obtained by using 76 pounds of the former to 24 pounds of the latter."

Lithopone.—This pigment was apparently first produced by Orr in 1874, and was at once developed in various forms in England and on the Continent. Its use in substantial amounts in America dates back about twenty years, when it was introduced to the oilcloth and linoleum trades to replace white lead, for making printing paints. Later its manufacture was undertaken in New Jersey and Pennsylvania on a comparatively modest scale. In 1914 there were six makers of this pigment in the United States, and the amount produced was relatively small (about 32,000 tons). At the end of 1916 there were nine factories in operation, four of which were making from 40 to 60 tons a day, the others averaging or contemplating a daily output of 15 to 20 tons. It is probable, however, that the total amount produced during 1916 was not over 75,000 tons. The indications are, however, that during the year 1917 there will be a production of substantially 100,000 tons. Among the factors contributing to the rise in price of this product during the last two years may be mentioned the stoppage of the import of German barytes, thus requiring the use of the American grade which could not previously be used, solely on account of the high freight rates to the points of pigment manufacture. The high prices of spelter and sulphuric acid, both of which are required in large amounts for lithopone manufacture, also greatly increased the cost of production.

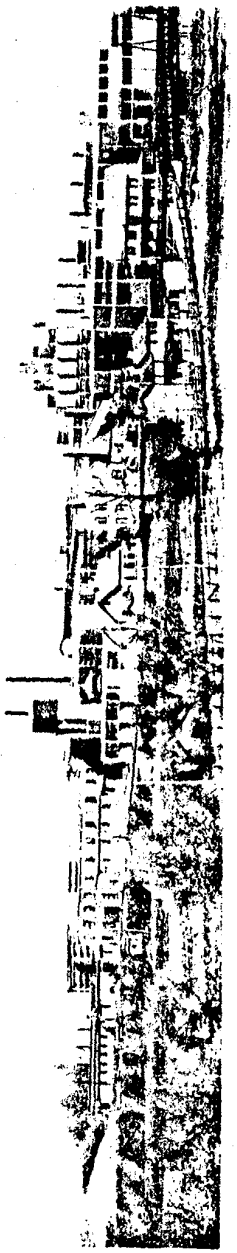


Courtesy H. V. Berg

FIG. 20.

Rotary furnace for roasting barytes and coal to produce barium sulfide.

While it is probable that the rapid growth in the production of



Courtesy H. V. Berg

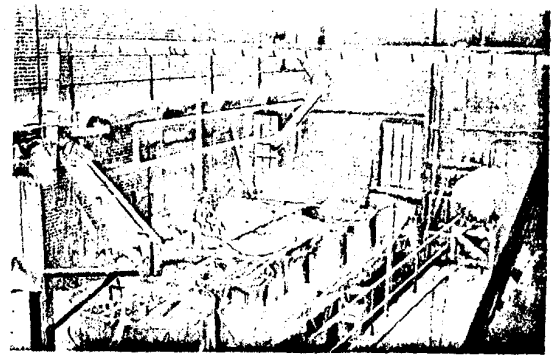
FIG. 21.
View of one large plant devoted solely to production of lithopone pigments.

Courtesy L. P. Nemzek

FIG. 23.
View of racks and drying ovens such as are used for

FIG. 22.
Filter presses used for extracting water from precipi-

lithopone in America should be attributed to a great extent to the modern desire for interior flat wall paints of the lithopone type, its use has also been increased by the demands for it in various industries. For instance, large amounts are used in the manufacture of linoleum, oilcloth and shadecloth, and, in fact, wherever a pigment of great whiteness and hiding power is required. The opacity of this pigment is commented upon, page 45, under Opaque Adsorption Pigments.



Courtesy H. V. Berg

FIG. 24.
Tanks for extracting barium sulphide used in lithopone production.

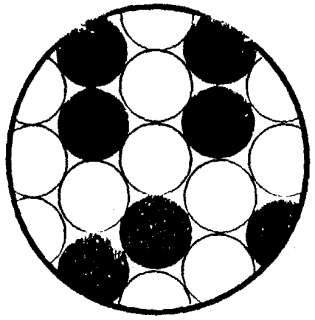


FIG. 25.
Diagrammatic view of mixture of transparent and opaque pigments.

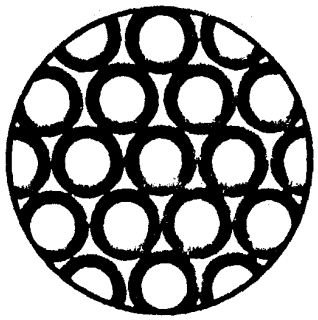


FIG. 26.
Diagrammatic view of precipitated pigment composed of transparent pigment coated with opaque pigment. Better hiding power is obtained from a precipitated pigment than from a mere mechanical mixture of the same pigments.

A number of American and foreign manufactured lithopones, used by the writer in exposure tests, were analyzed and the following results obtained, which show the composition of the average grade used in paints:

	Composition.		
No.	ZnS.	$BaSO_4$.	ZnO.
A	27.80	70.44	1.26
B	26.41	71.06	2.48
C	26.48	71.18	2.12
D	28.42	70.22	.70
E	27.10	71.18	1.20
F	27.97	71.02	.54
G	26.72	70.42	2.36
H	27.87	70.40	.82
I	27.90	70.30	.94
J	30.27	69.68	.22
K	29.09	70.10	1.30
L	26.94	72.36	.50
M	27.61	70.50	1.04
N	26.27	72.54	.76

While lithopone is very satisfactory for use in interior paints, it has not proved durable on exterior exposure. When exposed out-of-doors, it rapidly darkens and chalks away, leaving a rough film of little protective value. Tests of several years' duration have, however, shown that better results are obtained when lithopone is combined with certain other pigments. The formulas used in these tests are shown in Bulletins 34 and 35 of the Scientific Section, Paint Manufacturers' Association of the United States. When these paints are tinted, much better results are obtained than in white. For painting cement surfaces, certain mixtures containing lithopone as a component part of the paint pigment composition have also indicated good results.*

* Bulletin 53, Paint M'f'rs Ass'n of the U. S.

Chapter III.

PHYSICAL CHARACTERISTICS OF PIGMENTS AND PAINTS.

(*Colloidal Condition of Paints.*)

HIDING POWER OF PIGMENTS.

The opacity or hiding power (covering ability) of a paint pigment depends upon its fineness, refractive index, and oil absorption. These physical properties are responsible for the fact that a coat of white lead in oil hides a dark surface better than a coat of silica in oil.

Fineness.—Paint pigments, if produced in sufficiently large-size particles, would be more or less transparent like a lump of glass, since all such products allow the light to be transmitted in varying amounts. If any one of them, however, is broken down and powdered, the finely divided particles reflect the light in all directions and only a small amount of light is transmitted; the powdered substance thus appears opaque. Therefore, it may be stated that *the opacity of pigments increases with fineness of division.* With some pigments, however (produced by the fume process), there may be a point beyond which increasing fineness may result in a lowering of opacity.

Refraction.—The refractive index of a pigment determines the amount of light that will be transmitted by it—the higher the refractive index, the greater the reflection and consequent hiding power. A layer of white lead will reflect more light than a layer of finely ground silica, since the refractive index of the lead is higher than the refractive index of silica. When either of these pigments are ground in water, the same phenomenon holds true, but both are less opaque than in dry form because water has a higher refractive index than air. *As the refractive index of the vehicle approaches that of the pigment, opacity diminishes,* an optical condition being produced by the film around the particles, that allows the

passage of light, thus decreasing the reflection. When turpentine is used as a binding medium, the pigments show the same relative differences in hiding power, but both are less opaque than when in water, since turpentine is more highly refractive than water. When linseed oil is used as a medium, still less opacity is shown by the resulting paints, as linseed oil has a greater refractive index than turpentine. The resulting silica paint will now be practically transparent, since the refractive index of the medium is substantially the same as that of the pigment. The lead paint, however, will still be opaque, since white lead has a refractive index greater than that of the oil.

Oil Absorption.—Opacity increases inversely with the amount of oil absorbed by the pigment. This is shown by comparing the hiding power of lead and zinc whites. These pigments have substantially the same refractive index and theoretically should hide equally. As a matter of fact, however, a workable lead paint has greater hiding power, since it may be produced by grinding 70 parts of lead in 30 parts of oil, while a workable zinc paint will contain 50 parts of zinc and 50 parts of oil. More light will pass through a film of the zinc paint than through the lead paint, on account of the greater quantity of oil present in the former. This accounts for the difference in the hiding power of the two paints. The preponderance of oil in the zinc paint, however, accounts for the much greater durability of those paints which contain zinc oxide in combination with lead pigments, since abundance of oil is recognized as a necessity in exterior paints.

It is apparent from the above considerations that the hiding power of a white pigment is measurable by determining its physical characteristics. Various methods for determining fineness and oil absorption have been in use, but no method has apparently been adopted for determining the refractive index of pigments. It occurred to the writer that some application of the petrographic microscope might be made for this purpose. A series of pigments were therefore prepared and submitted to test, the readings being made by Dr. Frederick E. Wright, of the Carnegie Geophysical Laboratory of Washington. Small particles of the pigment under observation were

rubbed up with media of known refractive indices, covered with glass, and submitted to examination. Some of the readings are shown below:

Quartz silica	1.55	Basic carbonate—white lead	2.0
Barium sulphate	1.6	Basic sulphate—white lead	2.0
Zinc oxide	1.9+	Zinc sulphide	2.2 to 2.37

OPAQUE ADSORPTION PIGMENTS.

One of the most interesting pigments examined was lithopone. Difficulty was experienced in getting an exact reading, as it consists of a submicroscopic mixture of aggregated particles. It is possible that the average refractive index might be considered as being between 1.9 and 2.0. This pigment is prepared by the resulting interaction of chemically equivalent amounts of zinc sulphate and barium sulphide solutions. The precipitated pigment is calcined, quenched, washed and dried. It consists of approximately 70 per cent barium sulphate and 30 per cent zinc sulphide. When barium sulphate, which has a refractive index of 1.6, and zinc sulphide, which has a refractive index of 2.2 to 2.4, are *mixed* in the above named proportions, a pigment is produced which is deficient in hiding power. It is apparent, therefore, that the precipitation process of preparing these pigments produces some physical change which is of great importance. It is the writer's opinion that the effect is due to absorption of the zinc sulphide by the barium sulphate particles. Microscopial examination indicates that each particle of finely divided barium sulphate is coated over by adsorbed particles of opaque zinc sulphide. Experiments have been made with varying strengths of barium sulphate and zinc sulphide liquors in varying amounts, to determine whether it would be possible to produce even more opaque types of lithopone by increasing the amount of the zinc sulphide present. When lithopones are made containing as high as 50 per cent zinc sulphide, the hiding power has not been found substantially greater than that of lithopone, which contains from 28 per cent to 38 per cent of zinc sulphide. Below 28 per cent of zinc sulphide, the hiding power of the pigment decreases. It is, therefore, between the limits of 28 per cent and 38 per cent zinc sulphide that the greatest hiding powers are obtained, and the increased hiding power of lithopone containing 38

TABLE 4.—*Tests on Lithopone.*

Panel	Designation	Composition. ZnS	BaSO4	ZnO	TESTS ON DRY PIGMENT: Color	Darkening Test in Water Paste	TESTS IN OIL**: Bulk Wt. per gal. (pounds)	Consistency	Average Spreading Rate, One Coat	Darkening at end of 24 hrs. Exposure	Darkening at end of three Months Exposure
A	INT	27.80	70.44	1.26	Very white	Slight	16.3	Heavy	865	Slight	Considerable
B	13	26.41	71.06	2.48	Very white	None	15.3	Heavy	843	None	Considerable
C	14	26.48	71.18	2.12	White	None	16.3	Very heavy	655	None	Some
D	O.	28.42	70.22	.70	Very white	Very slight	16.6	Medium	700	None	Only at edge of panels
E	W. R.	27.10	71.18	1.20	Very white	Very slight	16.7	Thin	780	None	Only at edge of panels
F	D. G.	27.97	71.02	.54	Very white	None	16.7	Thin	745	None	Considerable
G	a	26.72	70.42	2.36	Off color	None	16.6	Heavy	960	Considerable	Considerable
H	b	27.87	70.40	.82	Very white	Badly darkened	16.8	Medium	755	None	Only at edge of panels
I	c	27.90	70.30	.94	Very white	Badly darkened	16.8	Medium	755	None	Only at edge of panels
J	R	30.27	69.68	.22	White	Badly darkened	17.1	Thin	980	Considerable	Considerable
K	G	29.09	70.10	1.30	Very white	Badly darkened	17.0	Medium	950	Considerable	Very dark
L	BN	26.94	72.36	.50	Very white	Badly darkened	17.0	Heavy	900	Considerable	Very dark
M	N	27.61	70.50	1.04	Very white	None	16.6	Heavy	885	None	Considerable
N	IMP	26.27	72.54	.76	Very white	None	16.4	Heavy	960	None	Some
O*		Lithopone 50, Zinc Oxide 50.							920	None	None
P*		Lithopone 40, Zinc Oxide 40, Whiting 20.							890	None	None
Q*		Lithopone 40 Sublimed White Lead 30, Corroded White Lead 30.							865	None	None

* Mixed paint prepared from M lithopone. Made in white and yellow.

** The paints were prepared containing 70 parts lithopone and 30 parts of pure raw linseed oil. For application to the panels, the paints were thinned to contain 60 parts pigment and 40 parts vehicle.

Frames ... Seve...

The ... gether ... gators ... some ... valuab... makers ... and a... propos... made ... painted ...

Chapter IX.

MARINE PAINTS.

One hundred tons of paint, costing approximately $25,000, represents the initial color requirements of a new battleship. The annual upkeep cost may even exceed this sum, since it is the custom to repaint different parts of a modern war vessel every three to six months. This would indicate an annual paint protection outlay of nearly a million dollars for our Navy. If to this sum we should add the cost of painting the thousands of lake boats, freighters, river steamers, and pleasure craft, a conception may be had of the importance of marine paints. While many different types of painting products are used on vessels, only those which find the most universal application will be discussed in the following paragraphs.

Primer Paints.—The priming coat of paint upon steel vessels is the most important of all, since protection from corrosion is governed by the effect of the initial coating applied to the steel. Many thousand tons of red-lead paint are annually used for this purpose. At the present time most red-lead paints that are used for naval vessels come in prepared form ready for brushing, one of the most satisfactory being composed of two parts of red lead and one part of silica, ground in linseed oil, drier, and mineral spirits. Such a paint, if well made, will remain in prepared form in a can for a long period of time without showing any tendency to harden, even though the red lead should contain up to 12% of litharge.

Bottom Paints.—Among the most important naval paints are those which are applied to protect the submerged parts of the hulls from corrosion or fouling by barnacles. The word "barnacle" is the popular name for that form of marine crustacea of the order *Cirripedia*, which consists of a clamlike body lodged in a shell that is often formed in a series of rings or plates. They become attached and adhere with great tenacity to rocks, pilings, and vessels. When removed from a ship's bottom, the clamlike body will be found separated

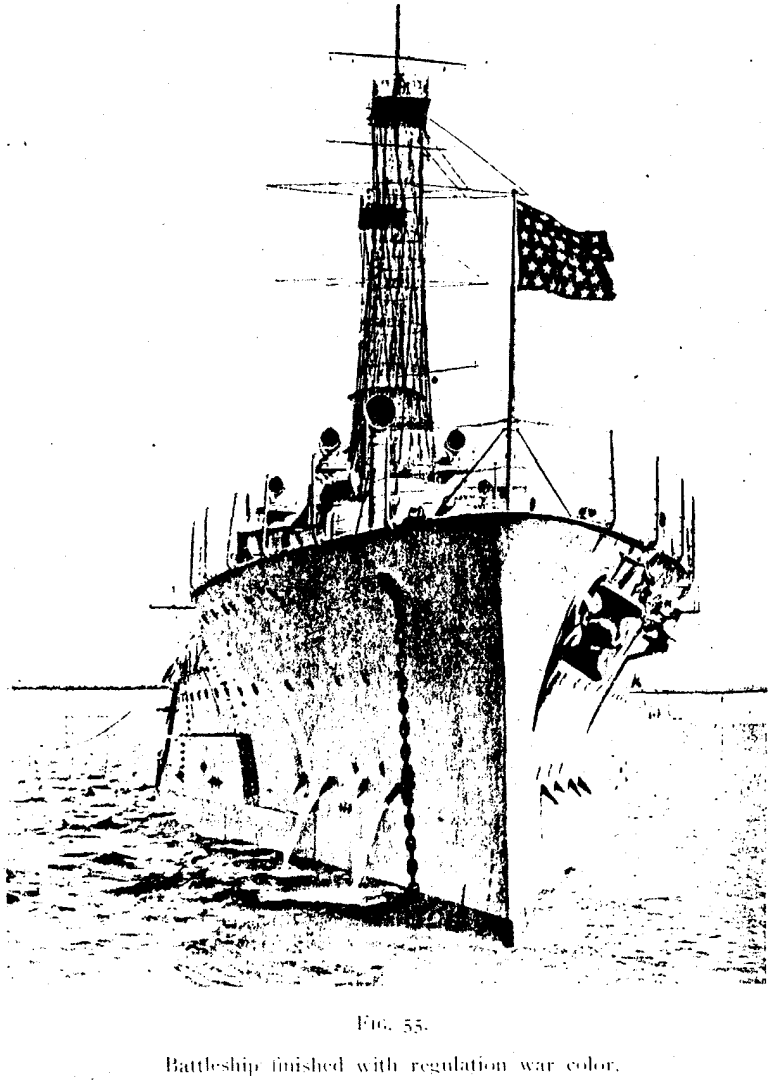


FIG. 55.

Battleship finished with regulation war color.

from the paint film only by a thin, semi-cal
which undoubtedly would allow the passage
pounds contained in the film. Without a
the speed of vessels would be greatly reta
up of a thick incrustation of barnacles and
During the building of steel ships it is the
above, to apply a coat of red lead for protect
during the construction period. Any rust
later on touched up and the whole unde
mediately afterward coated with what is
rosive marine paint. This is a light gray
made of metallic zinc, zinc oxide, alcohol
and turpentine. Drying occurs soon after t
A coat of red anti-fouling paint is then
composed of iron oxide, zinc oxide, mercu
shellac, pine tar, and turpentine. By the
drying paints two coats may be applied to
a day's time and the vessel made ready fo
water. This saving of time is a valuable
not embody the real reason for using qu
paints. It has been found that for under-
are better suited than oil paints, since the
and peel off in sheets. On the other hand,
not durable when exposed to the air. For
under burden, coated with shellac bottom pa
will present a large surface of the botton
Cracking and flaking of the hard film will

Examination of a new vessel after the
service will usually show that the shellac pa
fair service on account of the fact that it di
erly to the undercoating of red-lead-linseed
The entirely different characteristics of th
prevented amalgamation of the films. R
resorted to, with the usual ships'-bottom
good service is usually obtained from then o

The writer has often doubted the efficie
a constituent of such paints, and suggested
about two years ago, the water-white or an
late from turpentine known as pine oil.

point of over 200° C.; is miscible with alcohol-shellac solutions; has a high solvent action, and dries to a semi-resinous film possessing considerable elasticity. In tests which were conducted, paints made with the usual pigments ground with shellac dissolved in a mixture of 4 parts of alcohol and 1 part of pine oil have demonstrated their superiority over similar paints containing pine tar.

FIG. 56.

Upper view: Section of paint film removed from submerged plate test. The barnacle removed from film leaves white semi-calcareous membrane.

Lower view: Showing a barnacle attached to paint film removed from submerged test plate.

Toxic Constituents of Bottom Paints.—The efficiency of various toxic substances, such as mercury and copper, as constituents of ships'-bottom paints, have formed the basis of many practical tests that have been carried out on steel plates and in actual practice upon vessels. Mercuric chloride, when

ground in a paint, has been found high
but on account of its great solubility i
leached out of the film, which finally bec
oxide, on the other hand, being a solid

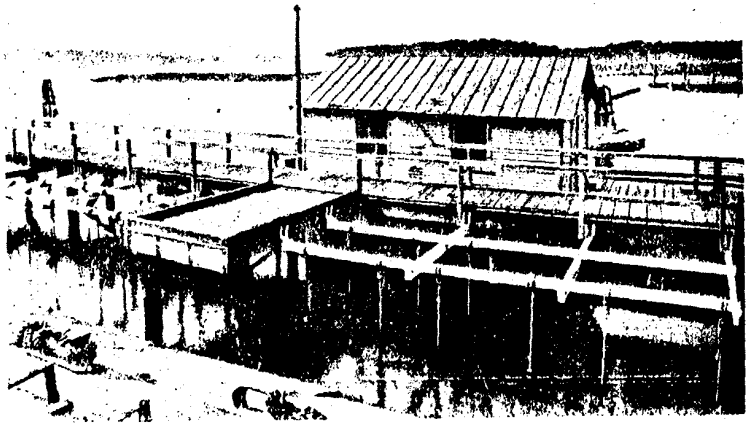
FIG. 57.

FOULING OF BOTTOM PA

View of painted steel plate after alternat
and air. Paint on left-hand side contains exc
fouled with barnacles. Paint on right does
is in excellent condition, considering time a

stantially insoluble in water, has been f
material to use for the toxic ingredient
the presence of salt water, and especia
other pigments which possibly are elec

mercuric oxide reacts and mercuric chloride in small quantities may be formed. This poisonous salt gradually becomes available as the film wears down during service, and sufficient amounts of the toxic salts are evolved to have a very poisonous effect upon attached barnacles. One objection, however, to the use of mercuric oxide has been its very high specific gravity, which causes it to subside in the containers in which the paints are stored. Unless such paints are thoroughly and carefully



Courtesy Navy Dept. Photo by N. E. Adamson, Jr.

FIG. 58.

Rack for suspending test plates painted with anti-fouling compositions. At ebb tide plates are exposed to air.

stirred before use, some parts of a ship upon which they might be used would be coated with films practically free of mercuric oxide, while other parts would be painted with portions in which the mercuric oxide would be in excess of the amount necessary for good results. In order to overcome this difficulty, the writer has suggested the use of various mercury soaps dissolved in turpentine or pine oil. When such soaps are added to a bottom paint, the mercury will be evenly distributed throughout the mass and the settling-out difficulty avoided.

Copper oxides have also been used with considerable success in anti-fouling paints, the red (cuprous) oxide being especially

toxic to marine animalculæ. It should be remembered, however, that red oxide of copper is electro-negative to iron, and if it should come in contact with the hull of the vessel at any point corrosion of the iron might be promoted. Copper soaps, soluble in turpentine products, might be used to advantage in connection with mercury soaps. Various salts of arsenic and lead have also been used in anti-fouling paints, but their toxicity is apparently much less than that shown by mercury and copper compounds. The writer is at present experimenting with copper cyanide, which appears to have highly toxic properties.

The function of zinc oxide or metallic zinc in bottom paints is one that has never received very much study. It is not thought that the zinc acts as a toxic substance, since it is weak in this character as compared to mercury or copper. It is apparent, however, that zinc pigments are best suited for the purpose, as practically all other types of pigments have been tried without marked success. It is well known that the value of zinc oxide in an exterior oil paint depends to some extent upon the hardness which it gives to a paint film. Since it has been found that bottom paints must produce a quick-drying, hard film, the efficiency of the pigment may depend on this characteristic. The function of the metallic zinc in the anti-corrosive paint may be of a like character, although it must be remembered that metallic zinc is electro-positive to iron, and when placed in contact with an iron surface protects the iron from corrosion, the zinc itself passing into solution.

Color Effects and Invisibility.—The present red color of bottom paints, while quite satisfactory for ships that present an almost constant water line, should be changed to a dark gray if used for colliers or other vessels that are sometimes high in the water when unloaded. Such vessels are of greater beam at many of those points where the red under-water shellac paint is applied, and a red color could easily be discerned from a hostile aëroplane at a great height, and would serve as a target during the dropping of bombs.

Attempts have been made by foreign navies during the present war to disguise the appearance of their ships by paint-

paints in the rural districts. In industrial communities, where the atmosphere is polluted with dust-laden smoke, such paints are an absolute necessity.

Prepared paints of the higher grade contain a substantial amount of zinc oxide mixed with white lead (corroded or sublimed). The inert pigments, such as silica, barytes,

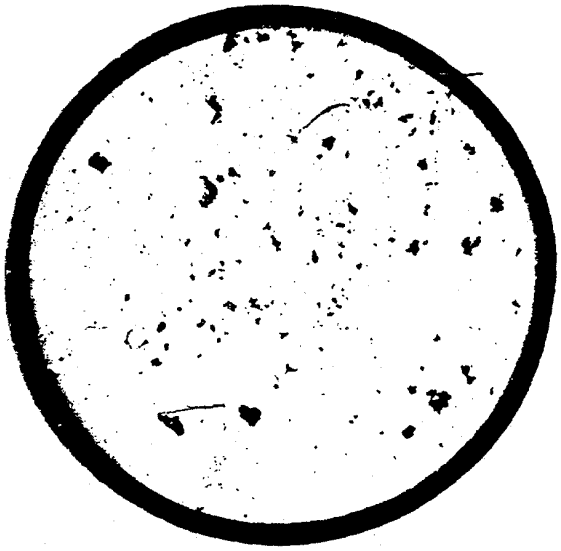


FIG. 62.

Microscopic view of lead paint which did not contain zinc oxide. Softness of paint has caused the retention of dust, plant pollen and insects, giving darkened appearance to paint.

asbestine, whiting, china clay, etc., are used in moderate percentages in some of these products.

Such paints afford the maximum wear and present the best appearance in any climate.

In the official report of the inspection committee of the American Society for Testing Materials, the following comments were made on the results of the above-described white-paint tests at Arlington.

A section of the tests illustrating the value of zinc oxide in preventing the darkening of paints. The first four paints contained zinc oxide. The last six did not.

Chapter XV.

THE TOXIC AND ANTISEPTIC PROPERTIES OF PAINTS.

Later experiments by the writer determined, in a more satisfactory manner, the composition of oil vapors. The tests were made in the "scrim" room of a large linoleum factory where thousands of yards of cotton scrim are suspended in the air and repeatedly coated with linseed oil. As soon as one coat becomes dry, another flowing coat is applied, and the process is repeated for several weeks until a semi-transparent rubber-like mass of oxidized oil, ¼ inch thick, is formed on either side of the scrim. In this room was placed an open tin can containing a pint of ordinary tap water. After exposure to the vapors in the room for a week, the can was removed to the writer's laboratory and the contents examined. The odor of the water was very strong and suggestive of acrolein. A considerable quantity of suspended and precipitated red oxide of iron was observed. As the water originally contained iron, it is probable that its precipitation was due to the carbon dioxide given off by the drying oil. Analysis of the water showed the presence of appreciable quantities of formic, acetic and butyric acids. Aldehydes were also found present.

A consideration of the previously cited laboratory tests in which the writer discovered the presence of carbon monoxide in the vapors from drying oils and paints, will no doubt be of interest to medical authorities. The results will probably throw considerable light upon cases of poisoning which have been attributed to lead absorption, but which were possibly due to the effect of carbon monoxide upon the red corpuscles of the patient. Symptoms such as sallow complexion, general lassitude, emaciation and incoördination, caused by the inhalation of carbon monoxide over long periods of time, might easily be mistaken for symptoms of lead poisoning. When

a painter, suffering badly from such symptoms, appears before a physician and informs him of the character of his work, the physician is very apt at first to diagnose the case as suspiciously like plumbism. Unless further examination be made, treatment for plumbism might be resorted to.

That great credence has been placed in the theory that white lead paint gives forth poisonous metallic vapors, is shown in the following citations from an article written by one of the most prominent medical men of the age:

> There is still considerable difference of opinion as to what takes place when men and animals who have breathed the emanations given from a surface freshly painted with white lead suffer in consequence. In my book, Diseases of Occupations,* I draw attention to the fact that during the preparation and mixing of paints, peculiar symptoms are occasionally complained of by the men, which are not altogether due to the white lead present, but to some peculiar condition of the linseed oil. Prof. Baly, of Liverpool, on spectroscopic examination of a beam of light passed through the emanations given off by a freshly lead-painted surface, was at first disposed to regard the harmful character of these exhalations as due to lead, but further experiments convinced him that, as similar emanations are given off by linseed oil mixed with manganese dioxide, they are due to unsaturated aldehydes, arising from hydrolysis of the linseed oil. These emanations are given off more readily from surfaces painted with white lead than where zinc white has been used. They vary with the percentage of linseed oil and they are given off in descending proportions according to whether white lead, sulphate of lead, or zinc white has been the compound added to the oil. Baly is therefore disposed to regard the aldehydes evolved from freshly painted surfaces as the harmful agent and not the lead. This, however, can only be partly true. That lead emanations are also given off is more than a probability, for only thus, among other reasons, can I explain the occurrence of severe colic, anæmia, a blue line on the gums, and the presence of a small quantity of lead in the urine of a previously healthy young medical man recently under my care, who became seriously ill through living and sleeping at home when all his rooms were being painted. Besides, the experiments of MM. Heim and Hebet show that lead is present in the vapor given off from painted surfaces, and that to this circumstance the plumbism of house and coach painters is due.
>
> (Excerpt from "Industrial Lead Poisoning and Some of the Problems it Raises," Sir Thos. Oliver, M. A., M. D., LL.D., D. Sc., F. R. C. P., Newcastle-upon-Tyne. Trans. XV. Internat. Congr. Hygiene and Demog., Vol. III, 896.)

At one time the present writer was disposed to place full confidence in the theory that lead paints evolve metallic vapors. His experiments have, however, afforded sufficient data to

* Diseases of Occupation. Methuen & Co., London.

dispose of such a theory. Lead is not a metal which forms easily volatile compounds. Arsenic and antimony are the only metals which afford vapors at ordinary temperatures, the hydrides of these metals being well known and of a very poisonous nature. Antimony is often present in pig lead, and it is quite possible that the lead used in corroding the pigment for Baly's tests contained traces of antimony. If so, it is possible that sufficient vapors were produced from this lead to account for the extremely delicate spectroscopic tests which were reported, providing the results obtained were really due to metallic vapors.

It is apparent that many other cases of lead poisoning have, without justice, been attributed to the vapors from white lead paints. The writer once heard of a case of lead poisoning, in which the patient (a woman) had contracted the disease while boiling out some old white lead paint pots which had been left by a painter. The patient, who was of an extraordinary robust nature, lost weight, became sallow in appearance, and developed a well-marked lead line on her gums. She, of course, attributed the poisoning to the breathing of lead fumes from the paint pots. It is probable, however, that she scraped the interior of the pots to clean them, and in so doing had collected considerable lead under her nails and in the pores of her skin. Possible failure to clean her hands properly before eating would account for the effects which followed. It is also possible that she possessed an idiosyncrasy to lead, which made the cutaneous absorption of a small quantity sufficient to cause poisoning.

A case of lead poisoning has been referred to by Klein* in citing a discussion of Baly's paper, where a young lady, the daughter of a physician, became seriously ill. A marked change was noted in her blood corpuscles. Her father had attended many lead workers and had observed a similar change in their blood when they became poisoned with lead. It was later ascertained that the young lady had occupied a room freshly painted with white lead. The father probably at-

* Behavior of Paints under the Conditions of Practice. Armstrong & Klein, J. S. C. I. No. 7, Vol. XXXII, April, 1913.

ventilated, but immediately afterward they may be closed for a day or so, in order to allow the fumes from the paint a thorough opportunity for asserting their antiseptic effect upon every portion of the walls, interior and contents of the room. Fumigation with burning sulphur or washing the old paint with liquid antiseptics are probably no more efficient from a sanitary consideration, and assuredly less productive of pleasing results from a decorative standpoint than the application of a fresh coat of paint to the walls and trim of a room. Flat wall paints made of non-poisonous lithopone and zinc pigments, on account of the ease with which they may be applied, their low cost and their ability to hide surfaces with few coats, make them especially fitted for this purpose.

Cause and Prevention of Toxic Effect of Pigments.

Much has been published regarding lead poisoning, and the subject has been discussed at length both here and abroad. There can be no doubt that painters have suffered to some extent from this disease, but recorded evidence shows that the majority of cases have occurred in factories where lead products are made. A historical review of the subject will show that the hand mixing of dry lead pigments is fraught with danger. It is apparent, however, that the painter who handles prepared-paint products does not come in contact with lead dust, and his trade is therefore a safe one, free from the dangers that attend the older methods and materials.

Eminent authorities have pointed out that the inhalation of dry dust containing metallic particles floating about, constitutes the most dangerous source of lead poisoning; respiratory absorption being readily accomplished under such conditions. This, of course, calls for the elimination of dust as far as possible in the painting trade. The dangers from cutaneous absorption or from gastro-intestinal absorption, which are in most cases caused through uncleanliness of hands or face, will, of course, be reduced when more cleanly and sanitary conditions are provided, and when the rules of hygiene are more strictly observed.

The susceptibility of certain persons to metallic poisons should make such persons exert extreme care in handling lead pigments, while the same precaution should not be neglected by those workmen who are supposed to exhibit a great degree of resistance or tolerance to metallic poisons. In the latter class, the resistance to lead may be due to its elimination from the system in sufficient quantity to equalize the amount daily absorbed. It has been observed by medical authorities that workers in lead, who are thus constituted, often feel that they are free from the effect of lead, whereas, as a matter of fact, their systems may contain a considerable amount of the metal, which upon the first provocation, induced possibly by over-indulgence in alcohol, may become active and cause fatal results.

Some danger from lead poisoning may attend the removal of old lead paints. Upon battleships it is customary to use for this purpose, wide steel chisels driven by compressed air. Piled up coatings ¼ inch in thickness are easily and rapidly removed by this method. There is formed during the operation, a considerable amount of dust containing a large percentage of white and red lead. The workers are, however, only allowed to carry on such work for short periods of time. During the interim, they are placed at less dangerous tasks. In this connection it may be of interest to cite the fact that red lead as a primer for steel ships is being replaced to a great extent by sublimed blue lead, which, on account of its less poisonous nature and highly rust inhibitive properties, is to be highly recommended for the purpose.

Differences of opinion have been expressed regarding the danger of removing paint from an old painted surface by means of a torch. This method is not used at the present time, to such an extent as formerly, on account of the efficiency of liquid removers. The old torch process, however, is more economical and therefore necessary in some instances The strong heat of the torch and the presence of dried oil and other organic substances will cause lead paints to be partially reduced as metallic lead. The temperature, however, is not as a rule sufficiently high to cause the formation

of metallic vapors of lead. If the paint is made of zinc oxide or lithopone (this is not always possible or practical) there is much less danger, for these pigments are not materially affected by the heat of a torch. Moreover, zinc vapors are not nearly as poisonous as lead vapors. The truth of this statement is shown by the following excerpts from articles relating to the toxicity of zinc compounds:

"Of 65 cases of zinc-poisoning collected by Witthause, 46 were in Great Britain and only 3 in the United States. All were caused by two salts, the sulphate and the chlorid. The sulphate was to blame in 25 cases, of which 8 were due to mistaking it for 'Epsom Salt.'"

Text-Book of Legal Medicine and Toxicology. Peterson & Haines, Vol. II, p. 443.

"The poisonous action of zinc oxide is so weak that it is almost doubtful whether it should be considered a poison. Dr. Marcett has given a pound (453.6 grams) during a month in divided doses without injury to a patient afflicted with epilepsy; and the workmen in zinc manufactories cover themselves from head to foot with the dust without very apparent bad effects. It is not, however, always inocuous, for Popoff has recorded it as the cause of headache, pain in the head, cramps in the calves of the legs, nausea, vomiting, and diarrhœa; and he also obtained zinc from the urine of those suffering in this manner.* Again, a pharmacy student filled a laboratory with oxide of zinc vapor, and suffered from well-marked and even serious poisonous symptoms, consisting of pain in the head, vomiting and a short fever."

Poisons: Their Effect and Detection. A. Winter Blyth, pp. 689 and 691.

"Brass founders' ague may be defined as an acute malaria-like syndrome of chill, fever (sometimes), and sweat, appearing a few hours after the inhalation for a few minutes or longer, of the vapors or fumes arising from molten brass or from the fumes of pure zinc alone† affecting only or mostly those unaccustomed to such exposure."

Excerpts from "Occupational Brass Poisoning: Brass Founders' Ague." Dr. Emery R. Hayhurst, Chicago, Ill. Trans. Internat. Cong. Hygiene and Demog., Vol. III, 706 and 707.

"In many cases large doses of the salt (zinc sulphate) have been administered for days without any symptom of toxic effects. In one instance 36 grains of salt were given three times a day for six weeks without the appearance of any symptoms of poisoning. All writers on toxicology, however, agree that in certain quantities zinc salts exercise a poisonous effect."

Page 33, "Zinc in Evaporated Apples," by Harvey Wiley. Bulletin No. 48, Division of Chemistry, U. S. Dept. of Agriculture, 1896.

* The so-called "zinc fever" has only been noticed in the founding of brass; it is always preceded by well marked shivering, the other symptoms being similar to those described.

† Lehmann, K. B.: Giess—oder Zinefieber, Arch. f. Hygiene, 1910, Bd. LXXII, s. 358-381.

A method* has been proposed for the removal of lead from the system by means of an electrical bath, the legs of the patient being partially immersed in a dilute electrolyte, which, on the passage of the proper amount of current, would remove the metallic poison from the system. Although such methods may prove of great value in the treatment of lead poisoning, it is much better for lead workers to use preventive measures which will guarantee their safety from lead.

It is pleasing to note that corroders are already alive to the value of preventive measures, and the factories of the country are all adopting safety appliances and devices which are of great merit for this purpose. The resident surgeon of a large white lead works states:

> "Dust is the curse of the lead industry, for its minute particles are surrounded by a layer of moisture which renders them more liable to absorption by the respiratory mucous membrane, so it is essential that dust in the various processes of manufacture be eliminated. Every effort has been made to accomplish this all-important factor. Our chasers are enclosed in heavy cast-iron dust-proof covers from which leads a flue with a powerful suction of air which carries all dust to one of the main organ-pipe dust collectors.
>
> "Dry sweeping is not allowed, and the rooms are gone over each day with a vacuum cleaner, which thoroughly cleans them without the creation of any poisonous dust to contaminate the atmosphere."†

The above citation indicates the great care which is exercised to prevent the absorption of lead dust in factories. Should we not exercise similar care in guarding against lead dust in our public buildings? Many tons of corroded white lead flatted with turpentine were at one time applied to the walls and ceilings of school rooms and hospitals. Gradual disintegration of such paint would result in the formation of dried particles of white lead dust. The presence of such dust in the atmosphere of a room is very dangerous to the health of the inmates. Fortunately the use of flatted white lead has been largely abandoned for wall and ceiling decoration, and its place has been taken by the more sanitary leadless flat wall paints.

*The Decorator, Nov. 22, 1913, Vol. XII, No. 138, p. 201.

†"Safety and Sanitation in the Manufacture of Paints." Dr. Francis D. Patterson. Paint and Varnish Record, Dec. 15, 1913.

It is evident from a consideration of the foregoing discussion that with the adoption of preventive measures, the installation of dust-retarding apparatus and the wider use of prepared paint products, lead poisoning will be done away with almost entirely.

The Relative Toxicity of Volatile Thinners

The Relative Toxicity of Volatile Thinners.—The toxic properties of certain volatile paint thinners has been discussed in a most excellent treatise which has recently appeared under the title: "The Hygiene of the Painters' Trade." This publication was issued as Bulletin 120 of the United States Department of Labor. A brief digest of this article is herewith presented:

> The painting trade is responsible for many cases of lead poisoning. The use of white lead, however, is necessary in the better types of exterior paints. For interior painting, white lead may be entirely replaced by the non-poisonous, leadless *paints (lithopone and zinc paints). Any type of paint, whether* made of lead, lithopone or zinc, may, if thinned with large quantities of benzine, cause sickness among painters, if such paints are used in rooms where there is no ventilation. The vapors from paint products containing benzol, wood alcohol, turpentine, etc., are very injurious, some investigators having reported fatal results attending the inhalation of such fumes. The danger from this source is apparently easier to avoid than the danger attending the use of white lead. Among the various pigments used in the manufacture of paint, corroded white lead (Dutch or Carter process) is the most poisonous on account of the greater solubility of lead carbonate in the gastric juice. Physiological experiments at the University of Chicago and practical tests at the Pullman Company shops indicate that the basic sulphate of lead (sublimed white lead) is less poisonous than basic carbonate of lead (corroded white lead). The dangers attending the use of red lead as a metal paint are becoming lessened on account of the displacement of red lead by other less poisonous pigments, such as iron oxides, chromatized pigments, etc. The rubbing, sanding or burning of old surfaces painted with white lead is the cause of much of the lead poisoning. Wet methods of sanding will, if adopted, prevent the formation of lead dust, and thus reduce the danger of lead poisoning. Painters who fail to cleanse their hands properly before eating, either on account of their ignorance of the principles of hygiene, or because of lack of time and facilities for such ablutions, are apt to become sufferers from lead poisoning. Much of the poisoning in the painters' trade will disappear when certain regulations are adopted, which will provide for more cleanly and sanitary conditions.

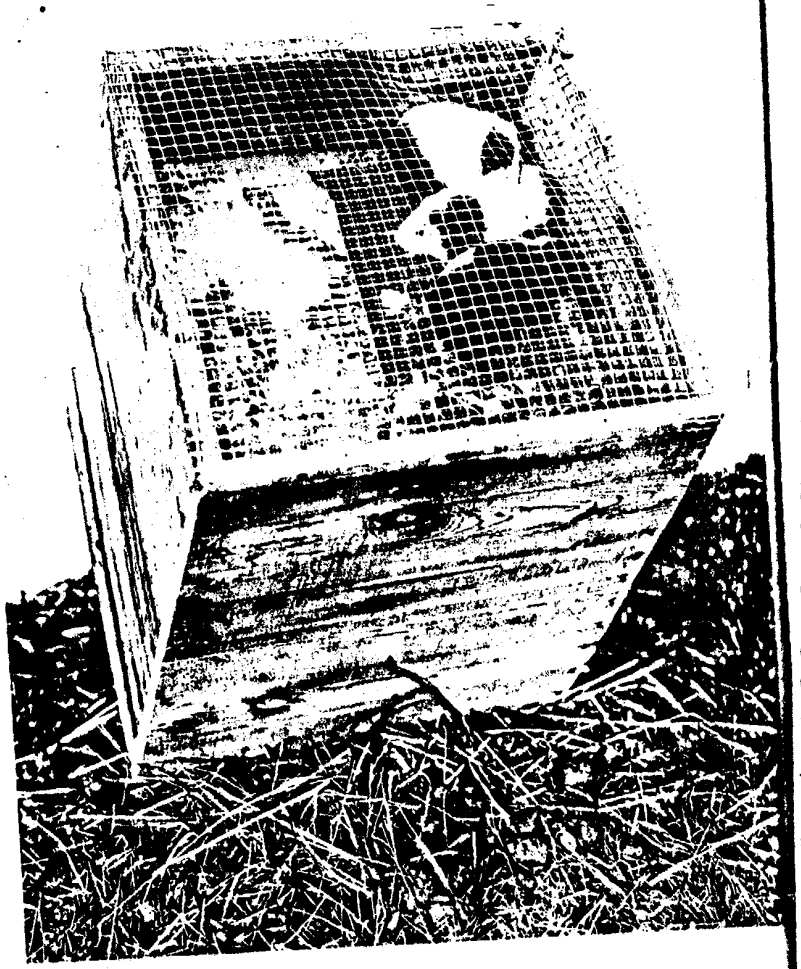


FIG. 112.

Box used for physiological test of effect of drying paint. Lower portion of box was painted on the inside. Guinea-pigs confined in upper portion immediately after application of paint and subjected to vapors from drying paint.

It is evident from the above able presentation of this subject that the thinners used in paints are in some cases quite as much to blame for the indisposition of painters as the pigments present.

The writer has for some time studied the character and physiological effect of various volatile thinners and the results of a recent series of tests are presented herewith. The tests were made by subjecting guinea pigs to the vapors of paint products, thinned with large percentages of volatile substances. The animals which were separately placed in specially designed boxes and kept under observation for a long period before subjecting them to the tests, were confined in the upper part of the boxes upon wire netting over a portion of which was placed perforated cardboard. Bedding, food and water were supplied, and the animals' weights recorded daily. The lower portion of the box was painted on the inside, the painted area averaging 16 sq. ft. and requiring for each coat about 6 ounces of paint. The paint used was white lead paste containing 10% of linseed oil, thinned in each instance with 40% of volatile thinner, such as turpentine, benzol, benzine and high-boiling point petroleum spirits.* One of the boxes was coated with shellac cut with wood alcohol (4 lbs. to the gallon). Another box was coated with shellac cut with denatured alcohol (4 lbs. to the gallon).

Subsequently, tests were made by exposing in the lower part of the boxes large open vessels containing a pint of the various thinners. The experiments were made with both ventilated and unventilated boxes. The results of the tests are shown in the following charts:

* Now referred to in paint specifications as "mineral spirits." It is a water-white petroleum distillate having a flash point (open cup) of approximately 100° F. and 98% will usually distill between 265° and 470° F.

TABLE 18.

Experiments Conducted in Well-ventilated Boxes.

Lower compartments painted with products containing 40% volatile liquids.

Pig No.	Volatile in Paint	Weight of Animal 1st day	Weight of Animal 3rd day	Condition of Animal at end of experiment
1	Wood Alcohol	Grams 302	Grams 312	Normal
2	Denatured Grain Alcohol	291	305	"
3	Turpentine	188	199	"
4	Benzol	278	289	"
5	Benzine 68°	230	239	"
6	High Boiling Point Petroleum Spirits*	235	240	"

TABLE 19.

Experiments Conducted in Partially Ventilated Boxes.

Lower compartments painted with products containing 40% volatile liquids.

Pig No.	Volatile in Paint	Weight of Animal 1st day	Weight of Animal 3rd day	Condition of Animal at end of experiment
1	Wood Alcohol	Grams 310	Grams 308	Rather Sluggish
2	Denatured Grain Alcohol	308	305	" "
3	Turpentine	200	190	" "
4	Benzol	281	252	Dead
5	Benzine	233	233	Rather sluggish
6	High Boiling Point Petroleum Spirits	240	242	Apparently normal

*Flash Point Open Cup 102° F., Boiling Point 320° F.

TABLE 20.

Experiments Conducted in Partially Ventil

Open pint cans of volatile liquids placed in low

Pig No.	Volatile	Weight 1st day	Weight 2nd day	Weight 3rd day	Weigh 4th da
1	Wood Alcohol	Grams 298	Grams 300	Grams 293	Gram 288
2	Turpentine	201	200	196	197
3	Benzol	254	255	250	241
4	Benzol containing 5% nitro-Benzol	302	300	290	285
5	High Boiling Point Petroleum Spirits	241	239	242	240

It is quite apparent from these tests th certain volatile liquids have considerable eff confined in quarters not properly ventilated weight is indicated in many instances. The least volatile (high-boiling point petroleum least dangerous, and this result would see opinion of many, that these spirits are mos thinners for interior wall paints.

Ordinary 62° benzine and 90° benzol, on great evaporative tendencies, proved quite presence of nitrobenzol is evidently harmful. discomfort, from the start of the test, to the to its fumes.

The results of Series No. 1 are interestin that when ventilation is supplied, the vapors tile compounds are not effective. Such vapor stances, and they expand rapidly throughou ventilated room, their effect being dissipated brief description is given herewith of the va used in the above-described tests.

Chapter XVI.

THE LIGHT-REFLECTING VALUES OF WHITE AND COLORED PAINTS.

In addition to toxic and antiseptic effects, interior paints should be considered from the standpoint of illumination and psychologic values. The attention of engineers is being constantly called to the relative value of different types of artificial illuminants for interior spaces. Very little thought, however, has been given to the light-reflecting power of the interior surfaces where such illuminants are used. That the surface constitutes quite as important a factor as the type of illuminant is indicated by the tests herein described, where the illumination of an interior space lighted with a tungsten lamp varied from 12 per cent. to 67 per cent. when different surface colors were used.

Athough considerable work has been done on the light-reflecting power of wall papers,* the constantly-decreasing tendency to use paper, on account of its insanitary properties, and the steadily increasing use of wall paints of the oil type, especially in hospitals† and public buildings, have necessitated a reconsideration of the problem, since different methods of determination would be required in many cases for two such different substances as paper and paint.

A search of the literature on illumination has produced one article which gives a series of carefully-made photometric measurements on the reflective value of paints. This is by Louis Bell,‡ who calls attention to the fact that traces of carbon in a paint (gray) or dust of a painted surface immensely decrease the illuminating value. He advocates the use of light-

*"Surface Brightness and a New Instrument for Its Measurement," Dow and Mackinney, *Illum. Eng.*, vol. 3, Nov., 1910, p. 655. "Apparatus for Measuring Light and Illumination," Dow and Mackinney, *Elec. World*, vol. 60, Aug. 17, 1912, p. 364.

†"The Sanitary Value of Wall Paints," H. A. Gardner, Bull. Scien. Sec. Paint Mfrs.' Assn. of U. S.

‡"Examination of the Coefficient of Different Tints in Its Relation to Indirect and Semi-indirect Lighting," Louis Bell, *Elec. World*, vol. 65, Jan., 1915, p. 211.