DEPARTMENT OF COMMERCE

CIRCULAR
OF THE
BUREAU OF STANDARDS

S. W. STRATTON, Director

No. 69

PAINT AND VARNISH

[1st Edition]
Issued November 17, 1917

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PAINT AND VARNISH

CONTENTS

I. INTRODUCTION

The paint and varnish industry is probably more highly developed in the United States than in any other country. While it may not be proper to class it as one of the great American industries, it is of practical importance to all householders, and its financial importance is much greater than is generally known. The value of the annual output of these products in the United States is about $125 000 000, while the value of the world's annual production of coal-tar dyes before the European war was about $100 000 000, of which Germany produced 70 per cent. Many look upon the coal-tar dye industry of Germany as one of the great industries; but the value of the products amounts to less than 60 per cent of that of the American paint and varnish industry.

The Bureau of Standards receives many requests for information in regard to paints and varnishes, not only from various branches of the Government which have such material tested by the Bureau, but also from private parties who are seeking information. This publication is intended to give in a general way, without unnecessary detail, such information as would be valuable to various people who desire information upon this subject. While the composition and methods of manufacture of paint may not in every case be essential, it is believed that a broad knowledge of these subjects will, in general, lead to a more intelligent selection and application of paints. On the other hand, little reference will be made in this Circular to methods of analysis, which would be useful only to persons engaged in the manufacture or testing of paints.

II. GENERAL NATURE OF PAINT AND VARNISH

A. CLASSIFICATION

In general, paint and varnish are applied to surfaces for decoration or protection, or both. The principal distinction between paint and varnish is that paint contains in suspension an appreciable amount of material, known as the pigment, which is substantially insoluble in the liquid portion, known as the vehicle. Varnish, on the other hand, consists of a liquid in which any resins or waxes present are mostly in solution. The liquid portion of a paint—that is, the vehicle—usually contains a number of subtances, which for convenience may be divided into two classes. Those which are volatile in a current of steam at atmospheric pressure constitute the "volatile thinner"; while the rest of the liquid portion is designated as the "nonvolatile vehicle." The definitions of most of the technical terms used in this Circular will be found in the glossary. (Chap. VII.)

B. DRYING OF PAINT AND VARNISH

The process which occurs when a film of paint or varnish dries depends primarily upon the nature of the vehicle. Water paints, such as whitewash and calcimine, and spirit varnishes, such as shellac in alcohol, dry by simple evaporation of the volatile liquid, this being water in the case of whitewash and calcimine, and alcohol in the case of shellac. The drying of oil paints and varnishes, however, is quite different and, in order to understand this, attention must be drawn to certain peculiarities of the so-called drying oils.

Suppose four plates of glass are coated, one with a thin film of water, another with gasoline, another with a heavy mineral oil, and another with linseed oil, and all four plates are exposed to the air for several days. The water and gasoline will evaporate and leave the plates dry and practically in the condition in which they were before applying the liquid. The plate covered with the heavy mineral oil will be found to be greasy and in practically the same condition as immediately after the oil was applied. The plate covered with linseed oil will also have a coating on it, but this coat will first become "tacky" and finally set to a hard varnish-like film. If this experiment is tried with other vegetable oils, it will be found that some of them—olive oil, for example—behave very much like mineral oils; that is, show only a very slight tendency toward the formation of a varnish-like coating. Other oils, such as those of corn and soya bean, will behave in a manner similar to linseed oil; that is, become a more or less tacky mass, with perhaps the final formation of a varnish-like material.

Oils which behave like linseed oil are called drying oils. It will be seen from this illustration, however, that the term "drying" as applied to such oils is not similar to the drying which takes place on the exposure of a material, wet with water, to dry air. The drying of a substance wet with water is simply the removal of the water by evaporation. The drying of a drying oil is caused by a change taking place in the liquid, which change is accompanied by an absorption of oxygen from the air. It is hastened by dry weather and sunlight, and is also accelerated by the presence of certain substances known as driers, which will be discussed later.

C. LIQUID RAW MATERIALS

Since many of the same liquid raw materials enter into varnishes and paint vehicles, it will be convenient to consider their composition and properties before passing to their applications in paint and varnish.

1. Water.—Water enters into the composition of paints and varnishes to only a very limited extent. As a vehicle in cold-water paints and calcimine it is of course essential, but these are of minor importance. A small amount of water is sometimes present in prepared oil paints, being added to prevent separation of pigment and vehicle. There seems to be no reason for objecting to this use of water, but if present in larger amounts, above about 1½ per cent, it would be classed as an adulterant.

2. Oils.—(*a*) LINSEED OIL.—Linseed oil is obtained from the seeds of the flax plant, *Linum usitatissimum*, a plant which is native to Central Asia, but is cultivated in many parts of the world for either the fiber, which forms linen, or the seed, from which the oil is obtained. When fiber is desired the plant is cut before the seed has ripened and therefore oil is not obtained in conjunction with the production of the fiber. The principal countries where it is grown in considerable quantities for oil production are Argentina, United States, Russia, India, and Canada. Linseed contains from 36 to 42 per cent of oil.

Preparation.—Linseed oil may be produced by cold pressing of the seed, which process produces a light-colored oil, used as a food in Eastern Europe and India. Practically no oil for painting is produced by cold pressing. The most common process is by grinding the seed and heating the resultant meal to about 71° C (160° F) or even as high as 82° C (180° F) and subjecting it to hydraulic pressure. The cake from the filter press contains from 5 to 7 per cent of oil and is used for cattle food. In a second process which is of commercial importance an Anderson expeller mill is used. In this process the meal is only slightly heated and is forced by a screw against a conical grating through which the oil passes. The residue comes out from the end of the expeller in the form of scales. The third commercial process is known as the extraction process. The ground seed is treated with a light petroleum distillate, which extracts the oil, leaving usually less than 4 per cent of oil in the residue. The light petroleum is recovered by distillation and used for extracting fresh meal. The oil produced from the same seed by the three processes has practically the same characteristics, but there is marked variation in oil from seed grown in different localities.

Foots.—Linseed oil as it comes from the press is cloudy and is generally filtered. Even when apparently clear a certain amount of sediment forms in the tanks on standing. This sediment is called "foots," and while its nature is not clearly known it is considered objectionable;[1] perfectly clear oil is preferred for most purposes.

Raw or unrefined oil on heating[2] above 177° C (350° F) frequently thickens and becomes filled with a cloud. This is apparently due to the presence of nonoleaginous matter, probably carbohydrates (mucilage) with phosphates of calcium and magnesium. This thickening in clots on heating is called the "break." This mucilaginous substance causing the break constitutes only a small fraction of 1 per cent of the oil; but oil which "breaks" is not suitable for some purposes, for example, varnish making. It is probable that this mucilaginous material that causes the "break" also forms at least a part of "foots" in many cases. Long storage tends to produce oil which will not break and is free from foots; but comparatively little oil is stored for a sufficient time to acquire the properties of well-settled and aged oil.

Refining.—The object of refining linseed oil is to remove all mucilaginous substances. Incidentally some of the coloring matter is removed and the oil becomes somewhat less viscous. The most common method of refining is by agitating the oil with about 1 per cent of strong sulphuric acid and after settling drawing off the acid and washing the oil with water. This process generally increases somewhat the free organic acid content of the oil.

Acid-refined oil is not generally used for varnish making for which purpose the oil is usually heated for a short time to a temperature of about 275° C (527° F) with or without small amounts of oxides of lead and manganese and then allowed to stand until the impurities settle out.

Another method of refining is by treating the oil with fuller's earth at a temperature of about 74° C (165° F) with subsequent filtration.[3] Refined oil is sometimes used in paint making, but

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[1] H. A. Gardner (J. Franklin Inst., June, 1915) states that linseed oil containing a large amount of foots does not dry properly and is apt to take up moisture from the air, forming an emulsion-like film which washes off.

[2] G. W. Thompson, "Industrial Chemistry," A. Rogers (1915), p. 586.

[3] For other methods of refining see "Linseed oil and other seed oils," W. D. Ennis (1909).

it is more commonly used for varnish manufacture, where it is necessary to have oil which will not break.

Properties.—Linseed oil is a fatty oil, that is, it contains in combination the radicles of fatty acids and glycerine. When decomposed by the action of alkali, glycerine is liberated and the fatty acid radicles unite with the alkali to form soap. Fatty oils are, in general, mixed glycerides of fatty acids. The nature of the acid radicles largely determines the characteristics of the different oils. The drying oils, of which linseed oil is the most important, are characterized by the presence of "unsaturated" fatty acid radicles containing at least two double bonds. These unsaturated bonds give the oil the property of absorbing oxygen from the air, thereby increasing in specific gravity, and finally, if exposed in thin films, becoming changed into a hard horny mass. The changes taking place in drying are not confined to the absorption of oxygen from the air. Though this may be the first change the drying is accompanied by very complex reactions, the nature of which is not understood. During the early period of drying the oil increases in weight, the maximum increase (15 to 20 per cent) being noted during the first 10 days; then it gradually decreases in weight and at the end of 180 days the film has about its original weight. However, the dry film has a much higher specific gravity and consequently occupies less space than the original oil. Even during the period when the film is gaining in weight, volatile products such as water, carbon dioxide, and organic acids are given off. The time of drying of raw linseed oil varies greatly, but with exposure out of doors in clear warm weather it generally is not less than two nor more than six days.

In color linseed oil varies from a pale straw yellow to a dark amber. The coloring matter is derived principally from the shells of the seed. Seed grown in a warm climate generally produces lighter colored oil than that grown in a cold climate. Under the influence of light, oil is somewhat bleached, and refining also lightens its color. It is very doubtful whether very pale oil has any practical advantage over oil of ordinary color, for oil on exposure to sunlight becomes pale, and when kept indoors darkens. Hence it appears that for exposure outdoors paints made with oil of ordinary color will soon bleach to be as light as those made with the palest oil. Also for exposure indoors all linseed oil in paint tends to turn yellow, so that while light (bleached) oil is usually preferred for interior work it is doubtful whether it has any real advantage over oil of ordinary color.

Testing.—To test the purity of linseed oil the chemist determines certain physical and chemical values by methods which are described in books on oil analysis. As has been mentioned before, seeds from different localities yield oils of somewhat different properties. Oil from North American seed has been most carefully studied by a committee of the American Society for Testing Materials.[4] This society has issued a specification for the purity of raw linseed oil from North American seed which is as follows:

	Maximum	Minimum
Specific gravity at $\frac{15.5^\circ\text{ C}}{15.5^\circ\text{ C}}$	0.936	0.932
Specific gravity at $\frac{25^\circ\text{ C}}{25^\circ\text{ C}}$	.931	.927
Acid number	6	....
Saponification number	195	189
Unsaponifiable matter, per cent	1.50	....
Refractive index at 25° C	1.4805	1.4790
Iodine number (Hanus)	....	180

While linseed oils from seed grown in other parts of the world have not been so carefully studied as that from North American seed it seems from the work of various observers that oil from Baltic seed has a slightly higher iodine number, oil from East Indian seed a slightly lower iodine number, and oil from South American seed a considerably lower iodine number, than that from North American seed.

Boiled Linseed Oil.—The term "boiled linseed oil" is strictly a misnomer, since linseed oil does not boil as water does, but when heated to a sufficiently high temperature undergoes decomposition. It was, however, long ago observed that if linseed oil is heated with oxides of lead and manganese to a temperature somewhat below its decomposition point, some of the metals go into solution and the oil dries more rapidly than raw oil. The method of heating all of the oil with metallic oxides is not now generally followed. In modern practice the manufacturer of boiled oil first makes a very concentrated boiled oil, that is, one containing a comparatively large percentage of lead and manganese, 15 to 20 times as much as is required in boiled oil. This material, known as crusher's drier, is mixed with raw linseed oil in the proportion of about 1 to 16 and the mixture heated to completely incorporate the crusher's drier in the oil. It is generally believed that better oil is produced if this heating is carried to a high temperature (above 170° C or 338° F) than if, as is frequently

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[4] A. S. T. M. Standards (1916), p. 497.

done, the oil is simply heated by steam coils. In some cases, instead of making the concentrated crusher's drier from linseed oil, it is made from rosin, whereby resinates of lead and manganese are formed. Boiled oils made from rosin are called resinate boiled oils, whereas those in which no rosin is used are called linoleate boiled oils. If properly made and without excessive amount of rosin, a resinate boiled oil is probably as good as a linoleate boiled oil. However, the fact that much boiled oil contains an excessive amount of rosin and is consequently of inferior quality has caused resinate boiled oils to be looked upon with suspicion. Another type of boiled oil is derisively called bunghole boiled oil. This is simply raw oil to which a drier, usually consisting of a solution of lead and manganese resinate or linoleate in turpentine or light mineral oil, has been added without heating.

The specifications of the American Society for Testing Materials [5] for purity of boiled linseed oil from North American seed prescribe the following limits:

	Maximum	Minimum		Maximum	Minimum
Specific gravity at $\frac{15.5^\circ C}{15.5^\circ C}$	0.945	0.937	Refractive index at 25° C	1.484	1.479
			Iodine number (Hanus)		178
Acid number	8		Ash, per cent	.7	.2
Saponification number	195	189	Manganese, per cent		.03
			Calcium, per cent	.3	
Unsaponifiable matter, per cent	1.5		Lead, per cent		.1

While raw and boiled linseed oil are the most important forms in which linseed oil is used in paint, in the preparation of varnish so-called bodied oils are used. For making bodied linseed oil, the oil which has been prepared so that it will not break either by long storage or by refining, is heated to a temperature of about 288° C (550° F), whereby some of the glycerine is driven off and the oil is to some extent polymerized;[6] both the specific gravity and the viscosity of the oil are materially increased by this treatment. The "bodying" of oil may also be accomplished by blowing air through it at a temperature of about 121° C (250° F). Blown oils are said to dry harder than oils bodied by heat alone.

Raw Versus Boiled Linseed Oil.—There seems to be no definite reason why boiled oil should be so largely used as it is. According to Hurst [7]

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[5] A. S. T. M. Standards (1916), p. 500.

[6] "Manual of Industrial Chemistry," A. Rogers (1915), p. 591.

[7] G. H. Hurst, Painters' Colours, Oils, and Varnishes (1906), p. 399.

> When exposed to the air in thin layers it (boiled linseed oil) dries much more rapidly than raw linseed oil, and leaves behind a hard lustrous coat; it is this property which makes boiled oil of so much use to the painter; yet it does not do to use boiled oil alone in the making of paints, because the coat which it leaves is too hard and rather liable to crack on exposure to the air; raw linseed oil is always added, as, by leaving a more elastic coat, it prevents this bad fault of boiled oil from showing itself.

While this may be true with the old-fashioned kettle-boiled oil which has been heated to a high temperature for a long time, it does not hold for boiled oil made by the present methods. This Bureau knows of no case in which boiled oil is used in paint, where equally satisfactory results could not be obtained by the use of raw oil and a suitable Japan drier.

(*b*) Tung Oil or Chinese Wood Oil.—This oil is imported from the Orient, being produced from the nuts of certain trees of the genus Aleurites, chiefly *Aleurites fordii*. This oil differs from linseed and other drying oils in that it dries to a film which is opaque and wax-like. It has a very characteristic odor and a very high specific gravity (not less than 0.939 at $\frac{15.5^\circ \text{C}}{15.5^\circ \text{C}}$). With time it changes to a white wax-like mass, especially on exposure to light. Tung oil commands a higher price than linseed oil, but is never used in the raw state, being always cooked either with resins or drying agents such as compounds of lead, manganese, or cobalt, and then thinned with turpentine or mineral spirits. By this process of cooking the oil becomes changed so that it dries with a glossy rather than a flat surface. Some tung oil varnishes are of excellent quality and treated tung oil is used in some ready-mixed or prepared paints.

According to specifications adopted by the American Society for Testing Materials[8] raw tung oil should conform to the following requirements:

	Maximum	Minimum		Maximum	Minimum
Specific gravity at $\frac{15.5^\circ \text{C}}{15.5^\circ \text{C}}$	0.943	0.939	Refractive index at 25° C	1.520	1.515
Acid number	6	....	Iodine number (Hübl, 18 hours)	....	165
Saponification number	195	190	Heating test (Brown method), minutes	12	....
Unsaponifiable matter, per cent	.75	....	Iodine jelly test, minutes	4	....

(*c*) Perilla Oil.—This oil, obtained from the seeds of several species of "perilla" grown in China, Japan, and India, is beginning

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[8] For details of testing under this specification see A. S. T. M. Standards (1916), pp. 503–507.

to appear in the American market. It has a specific gravity $\left(\frac{15.5^\circ \mathrm{C}}{15.5^\circ \mathrm{C}}\right)$ of 0.932 to 0.937, and an iodine number of 190 to 206. While it has the highest iodine number of any known oil and absorbs much oxygen, according to Lewkowitsch it has inferior drying properties, owing to its tendency to form drops when spread over a surface. Samples secured by the American Society for Testing Materials and by the Paint Manufacturers' Association of the United States did not show this tendency to form drops and would be considered superior to linseed oil.

(*d*) MENHADEN OIL.—Menhaden oil is obtained from fish (principally menhaden) in contrast to most drying oils, which are of vegetable origin. Samples of menhaden oil vary greatly, especially in iodine number. The specific gravity $\left(\frac{15.5^\circ \mathrm{C}}{15.5^\circ \mathrm{C}}\right)$ is from 0.926 to 0.937, while the iodine number ranges from 139 to 193. Lewkowitsch [9] states that when used as an adulterant in linseed oil it is deleterious. Toch [10] recommends it for use in smokestack paints and in zinc paints exposed at the seashore.

(*e*) SOYA-BEAN OIL.—Soya-bean oil is extracted from soya beans, grown extensively in Manchuria and Chosen (Korea). It has a specific gravity $\left(\frac{15.5^\circ \mathrm{C}}{15.5^\circ \mathrm{C}}\right)$ of 0.922 to 0.927, and an iodine number of 124 to 143. It dries slowly, forming a soft film. Owing to its cheapness, it is sometimes used to adulterate linseed oil. According to Gardner,[11] a small amount may be used in linseed oil without producing a bad effect. A private communication from G. B. Heckel states that this oil is in general use among paint manufacturers, linseed oil containing up to 25 per cent of soya-bean oil comparing favorably on exposure tests with pure linseed oil, and also that certain colors ground in soya-bean oil have proven more satisfactory than the same pigments in linseed oil.

3. Driers.—Certain metals when in solution in drying oils cause the drying to take place more rapidly. Mention has been made of this in discussing linseed oil. The metals most commonly used for this purpose are lead and manganese, though cobalt is sometimes employed. While certain pigments, such as red lead, act as driers, and while some driers are in paste form,

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[9] Chemical Technology and Analysis of Oils, Fats, and Waxes, fifth edition (1914), **2**, p. 415.

[10] Chemistry and Technology of Paints, second edition (1916), p. 206.

[11] Journal Franklin Institute, **171**, 57 (Jan., 1911).

most so-called driers are in liquid form, being known as driers, oil driers, Japan driers, or simply Japans.[12] They usually consist of solutions of lead or manganese salts of the acids of linseed oil or resins or mixtures of such salts in volatile solvents, such as turpentine or light petroleum oil. Upon incineration liquid driers usually yield from 5 to 8 per cent of ash, and in extreme cases from 0.5 to 15 per cent. The ash usually contains oxides of lead and manganese, and sometimes lime.

Strictly speaking, an "oil drier" should contain no varnish resin and when used alone should not dry to a hard film, whereas a "Japan drier" should contain such resin and when used alone should dry to a hard film having considerable coherence. This distinction is not, however, adhered to in the trade, and many manufacturers use the term so loosely that the name can not be taken as any indication of whether the material contains resin or not.

4. Volatile Thinners.—(*a*) TURPENTINE.—Turpentine is the most important of the volatile thinners used in paints and varnishes. It is produced by distilling the resin of pine trees, the important source in America being the resin of the long-leaf pine. Formerly all turpentine was made by distillation of the resin obtained from the trees, yielding the product known as gum spirits of turpentine. Another method now used to a considerable extent involves either steam distillation or destructive distillation of the wood containing the resin. This product, known as wood turpentine, has a very disagreeable odor unless carefully refined and is not so uniform a product as the "gum spirits." When properly refined, its disagreeable odor may be largely removed and its properties made to resemble those of "gum spirits."

For oil paints and most oil-resin varnishes turpentine is the most valuable thinner known. It has good solvent properties, evaporates in a satisfactory manner, and has excellent "flatting" properties. The following specifications have been adopted by the American Society for Testing Materials: [13]

STANDARD SPECIFICATIONS FOR TURPENTINE

General.—These specifications apply both to the turpentine that is distilled from pine oleoresins, and commonly known as gum turpentine or spirits turpentine and to the turpentine commonly known as wood turpentine that is obtained from resin-

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[12] The term "Japan drier" should not be confused with "grinding Japans," which are special kinds of hard-drying varnish used to grind fine colors to paste form for coach painting; or with "baking Japans," which are varnishes that after partial or complete drying are heated to a rather high temperature, thus partially fusing the coating.

[13] A. S. T. M. Standards (1916), p. 508.

ous wood, whether by extraction with volatile solvents or by steam or by destructive distillation.

The purchaser when ordering under these specifications may specify whether gum spirits or wood turpentine is desired.

The turpentine shall be clear and free from suspended matter and water.

Color.—The color shall be "Standard" [14] or better.

Specific gravity.—The specific gravity shall be not less than 0.862 nor more than 0.872 at 15.5° C.

Refractive index.—The refractive index at 15.5° C shall be not less than 1.468 nor more than 1.478.

Initial boiling point.—The initial boiling point shall be not less than 150° nor more than 160° C.

Distillation.—Ninety per cent of the turpentine shall distill below 170° C.

Polymerization.—The polymerization residue shall not exceed 2 per cent and its refractive index at 15.5° C shall not be less than 1.500.

If turpentine which conforms to the above specifications is used in paint or varnish, it is practically all volatilized during the drying process. However, storage of turpentine, especially in contact with air, results in the formation of nonvolatile matter of a resinous nature. It is probable that this material remains with the paint or varnish film on drying if the paint or varnish has been stored for a long time under conditions which are conducive to the formation of such nonvolatile matter.

(*b*) TURPENTINE SUBSTITUTES.—Substitutes for turpentine are usually prepared from suitable fractions of petroleum and vary greatly in specific gravity, flash point, solvent power, etc. The selection of such a substitute must be based on the requirements. It must be practically completely volatilized during the drying and must have suitable solvent power. That is, it must cause no precipitation of "gum" or polymerized oil in the paint or varnish. The use of those having a flash point which is close to that of turpentine naturally involves less fire risk than the use of the lighter fractions.

Petroleum Spirits (*Mineral Spirits*).—The substitutes that are prepared from petroleum having an asphaltic base (such as Texas petroleum) are believed to have better solvent powers than those prepared from petroleum having a paraffin base (such as Pennsylvania petroleum), but it must be remembered that different fractions from the same petroleum vary greatly in solvent power and there is little evidence to show what, if any, effect the nature of the crude petroleum has on the solvent power of the mineral spirits made from it.

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[14] The term "Standard" refers to the color recognized as standard by the Naval Stores Trade. Turpentine is of standard color when a depth of 50 mm in a perfectly flat, polished bottom tube approximately matches a No. 1 yellow Lovibond glass.

The variation in petroleum distillates that are used as paint and varnish thinners makes any definite statements regarding the differences between their "quality" and that of turpentine of doubtful value. If a petroleum distillate has the proper volatility and solvent power, the only marked difference in products containing it from those containing turpentine would be in flowing or spreading properties. Such differences are more important in varnish than in paint. The influence of the thinner on the drying process and on the nature of the dried film has never been satisfactorily determined.

Suitable specifications for petroleum spirits are those of the Navy Department,[15] the essential parts of which read as follows:

Quality.—The hydrocarbon distillate shall be properly prepared, unmixed with any other substance, and shall be pure, sweet, clear, water-white, and strictly neutral in reaction.

Appearance.—To be clear and free from suspended matter and water.

Color.—When sufficient quantity of the liquid is mixed with pure, dry basic lead carbonate to form a creamy paste and spread on a clean glass plate maintained at a temperature of 250° F for 2 hours, there shall be no perceptible darkening or change in the color of the white lead.

Distillation.—When 100 cc of the distillate are submitted to a continuous distillation, using an Engler flask and a condenser 22 inches long at an angle of 30° with the horizontal, and cooled with water, the first drop shall issue from the condenser at a temperature of not less than 265° F and 98½ per cent shall distill below 470° F.

Evaporation.—When 10 cc of the distillate are placed in a glass crystallizing dish 2½ inches in diameter on a steam bath maintained at a temperature of 212° F and evaporated, not more than $\frac{2}{10}$ per cent of residue shall remain after 2½ hours.

Flash point.—The flash test point will not be less than 85° F when determined by the closed Abel tester method, the test being made in the usual official manner. If an Abel tester is not available, when specifically authorized, flash point shall not be less than 100° F, as determined in an open tester filled within a quarter of an inch of its rim with a sample of the hydrocarbon distillate, which may be drawn at will from any one of the lot offered under the proposal. This tester thus filled will be floated on water contained in a metal receptacle. The temperature of the water will be gradually and steadily raised from its normal temperature of about 60° F by applying a gas or spirit flame under the receptacle. The temperature of the water is to be increased at the uniform rate of 2° F per minute. The taper flame should consist of a small bead of gas, the size of a pea, burning with a steady flame and held horizontally; it is to be used at every increase of 1° temperature, beginning at 90° F. It is to be drawn horizontally over the surface of the hydrocarbon distillate and on a level with the rim of the tester. The temperature will be determined by placing a thermometer in the hydrocarbon distillate contained in the tester so that the bulb will be wholly immersed in the liquid.

Basis of purchase.—To be purchased by the commercial gallon (231 cubic inches).

Solvent Naphtha (Coal-Tar Naphtha).—The distillate of light oil from coal tar, boiling principally between 130° C (266° F) and 160° C (320° F), is an excellent solvent and is quite extensively

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[15] Navy Department specifications, 52T3a, Aug. 1, 1916.

used, especially in bituminous paints and varnishes. It may therefore be considered as one of the turpentine substitutes. It is also an important ingredient in some paint removers. In many respects it is similar to benzol or benzene (not to be confused with benzine, a petroleum product) and toluol or toluene, which are definite compounds also derived from the light oil of coal tar, but of lower boiling points than the solvent naphtha. Benzene and toluene are sometimes used as volatile thinners, but to a less extent than the solvent naphtha. Solvent naphtha is sometimes called "160° benzol."

Other less important volatile thinners include grain, denatured and wood alcohol, which are used principally for shellac varnishes; amyl acetate and amyl alcohol, which are used in nitrocellulose lacquers; and carbon bisulphide, which is used in some bituminous varnishes.

III. VARNISH

A. CLASSIFICATION

In general, varnish may be defined as any liquid, not containing suspended matter (pigment), used for decoration or protection and capable of being spread in a thin homogeneous film which will dry to a hard coating. In the following pages no attempt will be made to go into great detail, particularly upon special varnishes, information concerning which can be found in numerous technical books.[16]

Most varnishes can be roughly classified into spirit varnishes and oil varnishes. The former contain only resin (or some other similar substance) and a volatile solvent, while the latter contain in addition a fixed or fatty oil. The latter are the more important and numerous, embracing such types as spar varnish, interior varnish, floor varnish, gear varnish, rubbing varnish, etc. In the factory a further classification of oil varnishes is based upon the relative amounts of gum and oil used; that is, on the number of gallons of oil per 100 pounds of "gum."[17] Some items in this classification may be open to criticism and for some types the lines of demarcation are not rigidly drawn, but it gives an idea of

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[16] For general information on varnish see the following: The Technology of Paint and Varnish, A. H. Sabin (1916); The Chemistry and Technology of Paint, M. Toch (1916); The Manufacture of Varnishes and Kindred Industries, A. Livache and J. G. McIntosh (1904–1911); German and American Varnish Making, M. Bottler and A. H. Sabin (1912); Handbuch der Lack- und Firnisindustrie, F. Seeligmann and E. Zieke (1914); A Varnish Catechism for Varnish Men, G. B. Heckel.

[17] In the varnish trade most of the resins, except rosin (colophony) and dammar are called "gums," although sometimes the same resin will be called a "gum" when it is an old fossilized (see p. 20) product, and called a resin when it is a fairly recent product.

the nature and use of different kinds of varnish. According to Scott[18]—

> the "short-oil" varnishes usually contain from 5 to 11 gallons of oil and include such material as furniture, rubbing and polishing varnishes, where a high degree of luster, hardness, and quick drying are more essential than great durability. The "medium-oil" varnishes, containing 12 to 24 gallons of oil, include the interior and architectural finishes, hard oil, cabinet, and floor varnishes. In this grade, luster, hardness, fullness, and a fair degree of durability are desired. The "long-oil" varnishes, designed for exterior use where durability is the main feature, usually contain from 25 to 50 gallons of oil per 100 pounds of gum. This class will include railway, carriage, and implement coach varnishes.

It is obvious that such varnishes as piano varnish would belong to the first class and gear and spar varnish to the third class. By blending different types, practically all degrees of hardness and elasticity can be obtained.

There are certain types of varnish which have a somewhat specialized and technical use, for instance, "flat" varnish, which gives a dull, lusterless coat; insulating varnish, chiefly used for insulating tape; dipping varnishes, in which articles are dipped and allowed to dry; grinding varnish, in which pigments are ground, etc. It is generally considered that the film obtained when a varnish is dried by baking—that is, by heating to a suitable temperature in an oven—is more durable than one dried at room temperature, and certain "baking varnishes," some of which contain no metallic driers and are entirely dependent on the baking process for acceleration of the drying, are made for this purpose. There are also the lithographic and patent-leather varnishes, the black asphaltum varnishes, black jacket enamels, and many kinds of lacquers.

B. RAW MATERIALS

1. Fatty Oils.—The two principal fatty oils that are used in the manufacture of varnish, namely, linseed oil and tung oil, have already been described (see pp. 8–13). The former when used for this purpose is practically always refined or treated in various ways, being then called "varnish oil," "borate oil,"[19] etc. Tung oil when heated at 250–300° C polymerizes with the formation of a jelly-like mass, and, since varnish makers wish to avoid such gelatination, to the oil they add rosin which has a solvent action on the jelly-like material. This is the common method

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[18] W. G. Scott, Drugs, Oils, and Paints, **31**, 249 (1915).

[19] Borate oil is a boiled oil which has been prepared by heating the oil with manganese borate.

for the treatment of tung oil, although gelatination can be prevented by other means.[20]

2. Volatile Thinners.—The chief volatile thinners, namely, turpentine and the lighter fractions of petroleum oil (mineral spirits), have already been described (see pp. 15–16). Many spirit varnishes, especially shellac varnish, contain either grain (ethyl) alcohol, wood (methyl) alcohol, or denatured alcohol. The latter is a mixture of grain alcohol with such meterials as wood alcohol, acetone, pyridine, benzine, etc.[21]

3. Metallic Driers.—Practically the same metallic compounds, namely, those of lead and manganese, are used in the preparation of varnish as are used in the manufacture of paint. These have already been described (see p. 14).

4. Resins.[22]—The trade nomenclature of the various resins used in the varnish industry is not definite in all cases, but the following classification will suffice: (*a*) Copals, which group includes the "fossil gums" such as Zanzibar, Kauri, Pontianak, Sierra Leone, etc.;[23] (*b*) dammar resin; (*c*) rosin (colophony); (*d*) lac, of which the most important is shellac; and (*e*) less important materials, such as prepared asphalt, synthetic resins, etc.

(*a*) COPALS.—Copals, which include the fossil gums, are formed by age and exposure to air, from the exudation of certain trees indigenous to New Zealand and various parts of the Tropics. The term "fossil gum" is supposed to designate the very old product which is dug from the earth, but some varieties of resin are found in all conditions, from the fresh resin to that which has lain deeply imbedded for a long period of time. The definite classification of all gums or resins into such groups as "fossil," "semifossil," and "recent" involves uncertainty. It is generally agreed that amber is a fossil resin. For varnish purposes the older the resin the more valuable it is. Zanzibar is considered the hardest and most valuable of the copals, while Kauri is the most used. The copals appear on the market in various grades, the classification being based on color, freedom from foreign matter, etc., and the different grades are classified according to size, as "bold," "nubs," "seeds," and "dust." The supply is limited and in time manufacturers will be

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[20] See E. E. Ware and C. L. Schumann, J. Ind. Eng. Chem., 7, 571–3 (1915); C. L. Schumann, J. Ind. Eng. Chem., 8, 5–14 (1916).

[21] For rules regarding the use and manufacture of denatured alcohol in the United States, see Regulations No. 30, revised, United States Office of Internal Revenue.

[22] For general information on resins see references given in footnote 16, p. 18, and the following: Analysis of Resins, Balsams, and Gum Resins, K. Dietrich (1901); Die Hartze und die Harzbehälter mit Einschluss der Milchsäfte, A. Tschirch (1906).

[23] Manila is usually called a "gum."

forced to find substitutes. The nitrocellulose esters and the condensation products of phenol and formaldehyde are the most promising of these. Many manufacturers at present will not use those gums which can not be always obtained, such as North Coast. Certain copals, such as Benguela, have already practically disappeared from the market.

(*b*) DAMMAR RESIN.—Dammar resin is formed from the exudation of certain trees. True dammars (in a botanical sense) are the products of certain species of *Dammara*, but the dammar of commerce is obtained from other genera. Kauri, which is classified as a copal and not a dammar, is obtained from *Dammara Australis*, while commercial Batavia dammar is obtained from the genus *Shorea*.[24] Dammar is generally classified according to the place from which it is shipped to the market, as Singapore dammar, Batavia dammar, etc. It is used chiefly for the preparation of spirit varnish.

(*c*) ROSIN.—Rosin is the residue left in the still after the distillation of turpentine (see page 15). It is graded according to color, the lighter-colored varities being the most valuable. When used as a varnish material, rosin is generally, but not always, hardened by the addition of lime. Resinates of the heavy metals such as zinc are also used to a limited extent. Treatment with zinc or calcium oxides not only hardens rosin but also lessens its acidity. In practice, however, the amount of such oxides added is not nearly sufficient to neutralize completely the rosin acid (abietic acid), the usual ratio of lime to rosin being only 1 to 20. The addition of too much oxide makes the product too hard and insoluble. The hardness of rosin is also greatly increased and the acidity decreased by prolonged heating. Rosin has generally been considered as an improper material to use for high-grade varnish since, when present in considerable amounts, it causes varnish films to be brittle, to turn white with water, and generally lowers the wearing qualities. Very fine varnishes are now made, however, which contain small amounts of rosin, and for interior use some of the tung oil-rosin varnishes, which contain considerable rosin, may be considered as high-grade products. Since manufacturers practically always regard their formulas as trade secrets, it is impossible to state whether the use of rosin in certain high-grade outside varnishes is practicable because of the small amount present or because of some preliminary treatment of the rosin.

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[24] The Manufacture of Varnishes and Kindred Industries, A. Livache and J. G. McIntosh (1904–1911), contains an abundance of valuable information regarding the botanical sources of the resins.

(*d*) Shellac.—Shellac is obtained from seed lac, which in turn is obtained from stick lac. The latter is resinous matter formed by the action of an insect on the twigs of trees indigenous to India and near-by places. This product is also the source of the lac dye, which was formerly much used. Shellac comes on the market as orange shellac or as bleached shellac, the latter being made by bleaching the orange shellac with such agents as chloride of lime. The chief adulterant of shellac is rosin.

C. METHODS OF MANUFACTURE

1. Oil Varnish.—(*a*) Without Resin.—Oil varnish containing no resin is made from "bodied" fatty oil, chiefly linseed oil. Driers and volatile thinners may or may not be added, according to the purpose for which the varnish is used. Such varnishes have a more or less limited and special use as lithographic [25] varnishes, patent-leather varnishes, etc.

(*b*) With Resin.—In the manufacture of oil varnish containing resin the following procedure is common, although naturally certain manufacturers have modifications of their own. The resin is heated in a kettle until it is completely melted and the fatty oil, which has been previously heated separately, is then added. The driers may be added separately or may have been previously incorporated with the oil. The mixture of oil and resin is heated until in the judgment of the varnish maker it is ready to be cooled and thinned. The details of the mixing and heating vary in different factories and are necessarily varied for different types of varnish, but heating must be continued until no separation of the constituents occurs on cooling. Generally "long-oil" varnishes are heated for a considerable time in order to increase the viscosity or "body." After thinning with a volatile thinner the varnish is filtered and stored. Some of the best grades of varnish are stored for a long time before marketing, in which case filtration may be omitted. Since the loss on heating the expensive copals is considerable, attempts have been made to incorporate the gum and oil without the application of so much heat, but such processes are not at present used to any great extent. Sometimes different varnishes are mixed and the blend marketed under a certain name.

It must be remembered that profound changes occur in both the oil and resin during manufacture. The oil is partially oxidized

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[25] For information regarding lithographic varnishes see the following: Analysis of Printing Inks, J. B. Tuttle and W. H. Smith, Bureau of Standards Tech. Paper No. 39 (1914); Bureau of Standards Circular No. 53 (1914); and The Chemistry and Technology of Printing Inks, N. Underwood and T. V. Sullivan (1915).

and polymerized, and the resins being actually decomposed with the formation of much volatile matter leave a material quite different in nature from the original raw resin. Also there is probably some chemical combination between the constituents of the oil and those of the resin. It is possible by variation of the details of mixing and heating to prepare from the same formula—that is, the same proportions and amounts of raw materials—varnishes that differ greatly in properties and quality.

FLATTING VARNISH.—"Flatting"[26] varnishes are designed to produce a "matt" or "flat" lusterless finish. They are special products of varied and often complex composition, generally containing some added wax or a small amount of pigment. Tung oil which has not been heated sufficiently to cause it to lose its property of drying flat is also used for this purpose.

2. Spirit Varnish.—(*a*) DAMMAR VARNISH.—Dammar varnish is prepared by treating dammar resin with turpentine or with light mineral oil, with or without the application of heat. It is generally believed that the varnish made by the "cold process" is the better. The usual proportions are 5 to 6 pounds of resin to 1 gallon of solvent. The resin is only partially dissolved so that commercial dammar varnishes always show more or less turbidity.

(*b*) SHELLAC VARNISH.—Shellac Varnish is made by treating about 5 pounds of shellac with 1 gallon of alcohol, forming a partial solution. This may be considered by some too thick for use, but of course any desired consistency can be obtained by the addition of more alcohol. A clear lacquer is obtained by decanting the clear supernatant solution from a thin shellac varnish. Similar spirit varnishes are also made from Manila, sandarac, mastic, and other resins.

(*c*) LACQUERS.—Lacquers are usually clear or nearly clear solutions. In fact, any thin spirit varnish, such as those mentioned above, containing shellac or other resins, can be considered a lacquer. Some lacquers are made by dissolving nitrocellulose, sometimes with the addition of resin, in such solvents as amyl acetate, wood alcohol, acetone, or mixtures of these and other liquids. Lacquers are frequently colored by the addition of soluble coloring matter.

(*d*) ASPHALTUM VARNISH.—Asphaltum varnish and other similar products are, in some cases, oil varnishes containing in place of part or all of the resin a prepared asphalt or pitch, and in other

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[26] See German and American Varnish Making, Bottler and Sabin; A Varnish Catechism for Varnish Men, Heckel.

cases spirit varnishes made by dissolving coal-tar pitch in coal-tar naphtha (see p. 17).

(*e*) Insulating Varnishes.—All resins, bitumens, and oils have rather good insulating properties, so that any varnish made of the usual materials, which dries with a reasonably impervious film can be considered as an insulating varnish. Special varnishes of the air drying or baking types, however, are often made to meet particular requirements for special kinds of work such as extreme hardness of film, and resistance to heat, oil, or water.

(*f*) Flatting Spirit Varnishes.—Flatting spirit varnishes contain such materials as shellac, glycerin, and galipot, with various solvents.

D. TESTING OF VARNISHES

1. Properties Required.—Before considering the various practical and laboratory methods of testing varnish, it is desirable to discuss the properties required in a varnish, which naturally depend upon the use to which it is to be put. Since varnishes for outside use must be elastic and waterproof, a better and more expensive varnish is usually required than for inside use, although some of the very finest and most expensive varnishes are made for interior use on pianos and very costly furniture. Outside varnishes are "long-oil" varnishes and generally dry more slowly than varnishes for use indoors. For general inside use it is not so essential that the film should be elastic. Good grade interior varnish should not turn permanently white with water and the very best grades do not turn white even while wet. In varnish manufacture hardness, which is usually obtained by addition of resins, is produced at the expense of elasticity and vice versa. The necessary properties of a varnish may be classified under "flowing and drying properties," "appearance," and "durability." The first two of these can be readily ascertained from careful consideration of the requirements, although for some work expert judgment is needed. For instance, it is generally required that piano varnish have a beautiful high lustre and that floor varnish should dry hard in, at most, three days. Color requirements are dependent upon the nature of the surface to be varnished. When it is desired to retain the light color of certain woods or of white or tinted color coats, a light-colored varnish is essential. Further discussion of the required properties will be given in the following paragraphs on testing.

2. Practical Testing.—Considering the testing of varnish, it may be said that for fine or special work varnishes must be tried out by skilled workmen, who know what qualities, such as elasticity, hardness, luster, etc., are essential in each particular case. However, for general use certain testing, which can be performed by anyone, will be of value in ascertaining the properties of a sample. For this the following procedure may be used:

Note whether or not the sample has the desired color, clearness, and flowing properties. Apply a coat of the varnish to a metal or wood panel, which has been painted a dull black. Drop black in oil, thinned with turpentine and dryer, gives a good under coat.[27] Note the time required for the film to dry hard; that is, when the finger pressed firmly against the surface leaves no impression. Let the coat dry for two days more, and then rub with steel wool or with powdered pumice and water. Note whether or not the sample has good rubbing properties; that is, whether or not a smooth, dull surface, suitable for the application of a second coat, is obtained. Note whether or not the rubbed surface "sweats"; that is, glossy patches form on the panel after 24 hours. Apply a second coat of the varnish and let the film dry for three days after it has become hard. At this point the relative luster of different samples can be noted. Let a stream of cold water run over the varnished surface over night, and in the morning note whether the film is unaffected, dulled, or whitened. Then let a stream from a vessel of boiling water flow over the varnish for 15 minutes and note the effect on the film. Any other desired tests, such as the application of soap and water or of household ammonia, can be made.

In addition to the panel test, flow some of the sample on a clean glass plate, and allow it to drain and dry in a vertical position. Note the time required for the film to dry "free from tackiness" (the point at which the film no longer feels sticky when touched lightly with the finger), and to dry hard. After 5 days, run the point of a knife blade through the film at the top of the plate and note whether it is elastic; that is, comes off as a ribbon from a clean cut, or "dusts"—breaking into small pieces.

Other special tests[28] may be made if they are of value, such as the final drying of a film in a box, wherein a gas jet is burning to ascertain if under such conditions a smooth lustrous coat is obtained. In service or practical tests a varnish may show undesirable characteristics which are known by the terms of the work-

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[27] The expert varnish tester will not be satisfied with as simple a method of preparing the panel, but will prepare a surface exactly like the surface on which the varnish is to be used; this will naturally vary greatly, depending upon nature and grade of work to be done.

[28] See W. G. Scott, Drugs, Oils, and Paints, 31, pp. 249–252 (December, 1915), and pp. 288–289 (January, 1916).

man's vernacular. These names generally explain themselves, though for convenience some are defined in the glossary.

As mentioned above, a varnish which does not give an elastic film is unsuitable for outside use, and naturally the better the waterproof qualities the better the varnish, other things being equal. For some inside work a very hard film, although it dusts, is more suitable than a softer, elastic film. The purchaser must decide whether it is best to insist on certain properties which may necessitate paying higher prices.

The practical testing of dammar varnish and shellac varnish is limited to ascertaining that a sample has the proper color and consistency, and that it gives a smooth film. The practical testing of lacquers, aside from such special requirements as may be necessary, is limited to ascertaining that a sample has satisfactory color, consistency, and drying properties, and that it does not dull a polished metal surface. For testing black varnishes they should be applied to a metal panel, and the time of drying and the nature of the film noted. If in subsequent use the varnished surface is to withstand high temperatures, a baking test should be made to ascertain whether the film retains its gloss, elasticity, and adhesive properties at the necessary temperature. Insulating varnishes should be tested principally to ascertain their adhesive properties and resistance to oil and water. Whether or not the dielectric strength should be determined depends upon the conditions of use.

Special requirements, such as resistance to acids and alkalies, will demand, in addition to the above tests, certain special tests.

The most satisfactory and reliable information regarding varnish is naturally obtained by actual use, but such information can be collected only after several months. It should be borne in mind, however, that while service tests give useful information regarding certain brands, which are of uniform quality, one must assume or actually prove that such brands remain uniform in composition and properties. In service tests of outside varnishes it has generally been found that a difference in climatic conditions causes a greater variation in the length of service of any brand of good quality varnish than is obtained with different brands under the same climatic conditions.

3. Specifications and Analysis.—There are three general types of varnish specifications: (*a*) Those that state that samples must be equal to a standard sample or brand; (*b*) those that require only certain physical properties, and certain results from practical tests; and (*c*) those which, among other requirements, state that a sample must be made from or be free from certain materials. Considering the first class, it may be said that the conclusions from comparative examinations of a standard and a submitted sample should be based mainly on the results of service tests and practical tests, such as are outlined on pages 24–26. Practical tests are also the main basis of a report on samples submitted under a specification of the second class. Specifications of the third class necessarily involve chemical tests or analyses.

In estimating the value of specifications for varnish, one must consider separately the following groups: (*a*) Spirit varnishes, such as shellac varnish and dammar varnish; (*b*) commercial oil varnish containing resin, such as spar and interior varnish; and (*c*) special varnishes for specific purposes.

Specifications for *shellac varnish* and *dammar varnish* which require certain amounts of resin and solvent and freedom from adulterants are very satisfactory, since present methods of analysis are adequate and the nature of the material desired is known. Wood alcohol alone is very seldom used as the solvent in shellac varnish because of its disagreeable odor and the danger of poisoning from fumes during varnishing. The odor from the denatured alcohol which is used in shellac varnish is not objectionable, and the only advantage in specifying that pure grain alcohol be used is that it is less poisonous than wood alcohol. The advantage of specifying pure turpentine for a dammar varnish is doubtful, since the petroleum substitutes have ample solvent power for this purpose and it has never been established that the nature of solvent (provided it has the requisite volatility) has any marked influence on the nature of the resinous film, though it is claimed that a pure turpentine dammar, especially if properly aged, generally works smoother and dries faster than one made with turpentine substitute.

A typical specification for *dammar varnish* is the following (Navy Department, 52V2a, 1914):

> *Composition 1.*—To consist exclusively of a solution of pure dammar resin in petroleum spirits (turpentine substitute) and to be absolutely free from all foreign matter. To contain not less than 55 per cent nor more than 60 per cent by volume of petroleum spirits.

Specifications for *shellac varnish* usually specify the nature of the solvent and the absence of rosin.[29]

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[29] For methods of analysis of shellac varnish see: Bur. of Chemistry Bull. 109, revised (1910)—reprinted 1916 by Bureau of Standards; G. W. Knight and C. T. Lincoln, J. Ind. Eng. Chem. 7, pp. 837–43 (1915). For methods of analysis of dry shellac see: Proc. Amer. Soc. for Testing Materials, Pt. I, pp. 522–8 (1916).

There are but few specifications for *nitrocellulose lacquers*, but the composition of a sample can be fairly well ascertained by analysis.[30]

The value of specifications of any sort for oil varnishes, such as commercial spar varnishes, interior varnishes, floor varnishes, etc., is doubtful, particularly of specifications that call for certain composition. If the purchaser is not required to follow certain legal regulations in the acceptance of bids, the best method to follow is that mentioned on page 26; that is, the actual service tests of certain brands, with such inspection as is necessary to establish that the manufacturers of accepted brands are maintaining the quality of their products. Specifications requiring composition have the following disadvantages: (*a*) Present methods of analysis [31] are not adequate to determine the actual composition of a sample or the formula used in its preparation. For instance, the identification and determination of the various gums, when two or more have been used, is practically impossible, as is also the quantitative separation of linseed oil and tung oil. It must also be borne in mind that the relative amounts of the constituents in a finished varnish are not the same as those of the raw materials prescribed in the formula, so that, even if we assume that the results of a varnish analysis are correct, the calculation of the formula from such results is subject to serious uncertainty. (*b*) Methods of varnish manufacture are constantly changing, so that, while a given specification for a varnish may prohibit the selection of a sample of very poor quality, it is very likely to exclude also satisfactory products.

When *black asphaltum varnish* is analyzed under such a specification as the following (Navy Department 52V1*a* 1913), the only difficulty lies in the detection of water-gas tar pitch:

> 1. Black asphaltum varnish must be made exclusively from pure, high-grade asphaltum of the very best quality, pure linseed oil, petroleum spirits * * * and lead manganese driers * * *.

Much research is needed at the present time to improve methods of analysis and tests, and to ascertain the effects of variation in composition and methods of manufacture upon the durability.

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[30] For methods of analysis see: H. Wolff. Farben-Ztg., **16**, pp. 205–6 (1911); F. H. Zimmer, Kunststoffe, **3**, pp. 323–5 (1913).

[31] For information regarding the analysis of varnish see the following: The Chemical Technology and Analysis of Oils, Fats, and Waxes, J. Lewkowitsch, 5th edition, Vol. III, pp. 144–168 (1915); The Analysis of Paint and Varnish Products, C. D. Holley (1912); Analysis of Paints and Painting Materials, H. A. Gardner and J. A. Schaeffer (1911); Some Technical Methods of Testing Miscellaneous Supplies, P. H. Walker, Bureau of Chemistry, Bulletin **109**, revised (1910), reprinted 1916 by Bur. Standards; Determination of Oil and Resin in Varnish, E. W. Boughton, Bur. of Standards, Tech. Paper No. **65** (1916); R. Darner North Dakota Experiment Station, Paint Bulletin, **1**, No. 6, (1915); P. C. McIlhiney, Proc. Amer. Soc. for Test. Mat., **8**, 596 (1908).

IV. PAINT PIGMENTS

A. GENERAL PRINCIPLES

In general, the *pigment* of a paint includes all the insoluble or suspended matter present in a paint. The various pigments in use may be roughly divided into (*a*) body pigments, that is, those which constitute the bulk of the pigment present and give to the paint film its characteristic properties; (*b*) color pigments, which are used primarily to produce a decorative effect; and (*c*) extenders, that is, substances which have few, if any, of the properties required for body pigments but which on account of their cheapness are added to paints, in many cases without harmful effect. There is no sharp distinction between these classes, since many colored pigments serve to give both body and color to a paint. Many substances that may be classed as extenders were formerly considered solely as adulterants; while now it is recognized that, in some cases at least, the use of certain extenders may improve the quality of a paint.[32]

The properties required of a pigment to produce a satisfactory paint film are not clearly understood or defined. In general, it may be assumed that the greatest covering power and opacity are furnished by pigments of which the particles are very fine and have high refractive indices.

For convenience of reference, the various pigments will be grouped according to their colors, rather than according to their specific uses.

B. WHITE PIGMENTS

1. Body Pigments.—(*a*) BASIC CARBONATE WHITE LEAD.[33]—Basic carbonate white lead is the most important white paint pigment. In composition it is regarded as consisting of two equivalents of lead carbonate and one of lead hydroxide and may be given the chemical formula of $2PbCO_3.Pb(OH)_2$, from which composition the commercial product should not vary widely even though made by different processes.

Old Dutch Process.—In the method of manufacture known as the "old Dutch process" metallic lead in the form of perforated disks, called buckles, about 6 inches in diameter, is put into special pots in the bottom of each of which is a well containing dilute acetic acid. These pots are stacked tier upon tier in large rooms, each tier being covered with boards and a layer of tan bark, and al-

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[32] See discussion of zinc oxide, p. 32.

[33] Also known as white lead, corroded lead, corroded white lead, carbonate of lead, basic lead carbonate, hydrate of lead, hydrocarbonate of lead, lead carbonate, carbonate white lead or lead.

lowed to stand 100 to 120 days. The fermentation of the tan bark generates heat enough to vaporize the acetic acid, and also produces carbon dioxide (CO_2). These products corrode the lead plates forming a white flaky substance, which is crushed, screened, ground in water, and either dried to form dry white lead or is ground in oil without drying, forming what is known as pulp mixed white lead.

Carter Process.—In the Carter process the melted lead is converted into a granular dust by means of a blast of superheated steam, and in this form is treated with dilute acetic acid and carbon dioxide in slowly rotating wooden cylinders for several days until the corrosion is complete, after which the process is the same as in the old Dutch process.

Mild Process.—Basic carbonate white lead is made in this process by reducing the molten metal to the finest possible state of subdivision by means of a blast of superheated steam, and this finely divided lead, partly hydrated and oxidized by this process, is agitated in cylinders containing water, through which air is passed until the lead is completely changed to lead hydroxide. This is treated in other cylinders with carbon dioxide, which forms the basic carbonate.

Precipitation Process.—In this process lead is dissolved in acetic acid in the presence of air, producing a solution of the basic acetate. From this solution the basic carbonate is precipitated by means of carbon dioxide.

Electrolytic Process.—In the electrolytic method a solution of sodium nitrate is electrolyzed, using lead anodes. The lead, which passes into solution as lead nitrate, is precipitated as hydroxide by the caustic soda formed at the cathode; and is then converted into basic carbonate by the action of carbon dioxide or sodium bicarbonate.

Properties of Basic Carbonate White Lead.—Old Dutch process basic carbonate white lead is composed of both fine particles and coarse ones. Though not so white as zinc oxide, it is very dense and opaque, has very great hiding power, and works very smoothly under the brush when ground in oil as paint, but does not spread over quite so much surface as do some pigments. Carter process basic carbonate white lead is usually whiter, finer, and more uniform in the size of the particles than that made by the Dutch process, but is less dense and opaque. White lead produced by precipitation is finer even than Carter process lead, but its opacity or obscuring power is lower. Mild process lead is extremely fine and uniform and very white if properly made. Much discussion of the relative merits of these different white leads as paint pigments has been carried on, and each has its strong points. All show in time a tendency to chalk and all are blackened by compounds containing sulphur. The old Dutch process probably furnishes three times as much white lead at the present time as all other processes combined. The specifications of the General Supply Committee for white lead, dry, furnished to departments of the United States Government require that it shall—

> contain not less than 98 per cent hydrated carbonate of lead; must be of the best quality, finely ground, free from all impurities, and must not be deficient in specific gravity;[34] must contain not more than 0.5 per cent of moisture nor more than one-tenth of 1 per cent of matter insoluble in nitric acid; must be equal in whiteness to the whitest pure lead on the market.

Basic carbonate white lead is practically the only white pigment which is used unmixed with other pigments in oil paints. The advocates of this material claim that it is a complete pigment and that anything added to it except for tinting makes it less valuable. They further claim that—

> pure white-lead paint is the only paint of established reputation known to be always reliable and satisfactory, which in its preparation and application permits the exercise of the painter's intelligence in adapting it exactly to all requirements.

A white-lead linseed-oil paint spreads and hides well and dries to a somewhat soft film, which does not generally decay by cracking, but chalks—that is, becomes powdery on the surface—a condition generally satisfactory for repainting. Owing to the soft nature of the surface, such paints frequently show a greater tendency to take up dirt than harder paint films.

(*b*) BASIC SULPHATE WHITE LEAD.[35]—Basic sulphate white lead is made by heating a mixture of powdered anthracite coal and lead sulphide ore to a high temperature in the presence of air. In this process, by carefully regulating the temperature and the amount of air, the lead sulphide is vaporized and sublimed as a basic lead sulphate. The resulting white fumes are carried by a current of air to the "bag room" and collected in large bags, the air and gases escaping through the meshes of the fabric. The ores used in making basic sulphate white lead always contain some zinc. The pigment varies somewhat in composition, but usually contains about 15 per cent of lead oxide and about 5 per cent of zinc oxide, the remainder being lead sulphate. The

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[34] This should range from about 6.4 to 6.8.

[35] Frequently sold under the trade name sublimed white lead, also sometimes called basic sulphate of lead, sublimed lead, basic lead sulphate, sulphate of lead, or white lead.

pigment, however, does not appear to be a simple mixture of these three ingredients, and, while its constitution is doubtful, it is possible that it consists of a mixture of basic lead sulphate ($Pb_3S_2O_9$), lead sulphate, and zinc oxide. Its prominent feature is its fineness of grain. It is not usually so white as Dutch process lead, but it resists better the discoloring action of hydrogen sulphide or other gases often found in the air, especially near cities. Its hiding power is only a little less than that of basic carbonate white lead.

(*c*) ZINC OXIDE.[36]—"French process" zinc oxide is made by heating metallic zinc in a current of air and collecting the oxide thus formed in long chambers. The finest particles are carried farthest before deposition and the product is graded accordingly into "white seal," "green seal," and "red seal." The "white seal" zinc oxide is the finest and whitest, being very light—150 pounds to the barrel, as against 300 pounds for the other grades. It is used extensively in high-grade enamel paints. "American process" zinc oxide is made by heating in a furnace a mixture of zinc ore and anthracite coal, as in the manufacture of basic sulphate white lead. The product is very similar to French process zinc oxide, but is not generally so white and may contain small amounts of lead compounds.

Zinc oxide is used alone as a pigment in the best grades of white-enamel paints, but in America, at least, it is used in oil paints practically always mixed with other pigments. The following is a discussion of the merits of zinc oxide as an oil paint pigment by experts of the largest manufacturers of this product:[37]

> Zinc oxide is the best individual white pigment known. In whiteness, hiding power, permanence, durability, inertness to oil and protective power it takes front rank. When exposed to air containing sulphur compounds which would darken or blacken white lead, it remains white, as the sulphide of zinc is as white as the oxide. It does not chalk or crumble and it does not become transparent.
>
> Then if this is the case why not use zinc oxide alone in our paint? Why all the other constituents?
>
> The answer is that zinc oxide when used alone has certain economic drawbacks which vanish entirely when it is used in a properly compounded mixed paint.
>
> In the first place, owing to its excessive fineness, zinc oxide forms a perfect blend with the oil, and in consequence spreads out under the brush to an exceedingly thin layer. Hence, in order to get the thickness of paint coating necessary to cover and protect properly, more coats of paint are required than, say, with white lead. Now, when we mix white lead and one or more of the three pigments, asbestine, silex, or barium sulphate, with the zinc oxide, we stop this tendency to excessive spreading. These pigments are, comparatively speaking, coarse-grained. They have what painters call "tooth." They take hold of the surface of the wood and cling there

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[36] Also known as oxide of zinc, zinc white, white zinc, and zinc.

[37] Painting Specifications, New Jersey Zinc Co., 55 Wall Street, New York.

and prevent the paint from spreading out too thin, and the necessary covering can be got with fewer coats of paint.

Secondly, a paint consisting of zinc oxide and linseed oil only, dries with a hard, smooth surface. The advantages of this we shall deal with later. The disadvantage is that when, in the course of years, the oil becomes dry and decomposed (as happens sooner or later with all paints) the paint coat cracks and peels off in patches. This makes it impossible to do a good job of repainting unless the old paint is burnt off or otherwise removed. Now, white lead does not do this. When a white-lead paint coat fails, it does so by crumbling to powder or as painters say, "chalking." The surface of a chalking paint gives an even surface for repainting.

Now, when we make up a paint composed of zinc oxide, white lead, and inert pigments, we get the advantages proper to each of the pigments. The zinc oxide imparts whiteness, durability, and permanence of color; the inerts and white lead enable the painter to get a good covering layer of paint for each coat he applies, and the white lead insures that a good surface for repainting shall be present when in course of time the paint has perished.

And zinc oxide does one thing more. If we paint two boards, one with zinc oxide and one with white lead, and expose them to a dusty atmosphere, the white-lead board will accumulate dust much faster than the zinc-oxide board. The smooth, even surface of the latter makes it very difficult for the particles of dirt to adhere, whilst the comparatively rough surface of the former holds them. This is particularly well shown when a wet sponge is passed over the boards. The zinc board will show up clean and white after this treatment, whilst the lead board will remain dirty. A board painted with a mixed paint behaves in this respect like a board painted with straight zinc oxide. The zinc oxide, owing to its excessively fine state of division, blends so thoroughly with the oil that it enters the glossy surface which the oil forms over the paint, so that the surface of the paint coat has the same dirt—and we may say also wet—repelling power that a straight zinc-oxide paint possesses, and at the same time the mixture is free from the tendency to crack and peel and gives a good surface for repainting. The effect of this property on the protective value of the paint is obvious.

The Navy Department specifications[38] for white zinc are as follows:

1. *American process.*—The dry pigment must contain at least 98 per cent by weight of oxide of zinc, not more than two-tenths per cent by weight of sulphur in any form, and be of the best quality known as "XX."

2. The pigment must be of the best quality, finely ground in at least 14½ per cent by weight of pure raw linseed oil, in accordance with the latest specifications for the same issued by the Navy Department. Oil only to a medium stiff paste, which will break up readily in thinning, and must be free from grit, adulterants, and all impurities.

3. *French process.*—The dry pigment must contain at least 99 per cent by weight of oxide of zinc and not more than one-tenth per cent by weight of sulphur in any form, and be of maximum whiteness as compared with the standard sample.

4. The pigment must be of the best quality, finely ground in at least 15½ per cent by weight of pure raw linseed oil, in accordance with the latest specifications for the same issued by the Navy Department. Oil only to a medium stiff paste, which will break up readily in thinning, and must be free from grit, adulterants, and all impurities.

5. The whiteness and fineness must be equal to the standard sample. Any indication of bluing will be sufficient cause for rejection.

6. The requisition will state specifically which process is desired.

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[38] Navy Department specifications, 52Z1, Apr. 10, 1912.

(*d*) LEADED ZINC.—Leaded zinc is made by a method similar to that for producing American process zinc oxide, using, however, bituminous coal and carbonate-sulphide zinc ores that may contain lead in any proportion up to an amount equal to that of the zinc present. Producers control the composition of the ore used by mixing ores of different per cent of lead content, thus obtaining uniform products containing fairly definite amounts of basic lead sulphate as, for example, under 5 per cent, approximately 10 per cent, 20 per cent, and 35 per cent. These mixtures have properties similar to zinc oxide and basic sulphate white lead, being very fine grained and of fair hiding power but not so white as American process zinc oxide.

(*e*) LITHOPONE[39].—Lithopone is usually made by adding, under proper conditions, a solution of barium sulphide to an equivalent solution of zinc sulphate. The resulting precipitate of barium sulphate and zinc sulphide is filtered off, calcined at low red heat, plunged into cold water (which treatment gives density or body to the product), ground, dried, and powdered. The best grades contain nearly 30 per cent zinc sulphide, a little zinc oxide, and the remainder barium sulphate. Lower grades differ chiefly in having ground barytes added. Well-made lithopone is white in color, fine in texture, and almost or altogether equal to white lead in body and opacity.

Lithopones vary widely in their behavior on exposure to bright light; some darken while others retain their color. This darkening is apparently caused by reduction of the zinc sulphide forming metallic zinc.[40] Paints made of it rapidly decay on exposure outdoors; but it is much used for inside work, especially in "flat" wall paints and, to a certain extent, in enamels for furniture. Owing to the unstable condition of the zinc sulphide, it would seem that it should not be used with basic carbonate white lead; however, the two pigments are sometimes successfully used together.

(*f*) SLAKED LIME.—Strictly speaking, slaked lime, or calcium hydroxide, which is produced by the action of water on quicklime, or calcium oxide, is a paint pigment. Its use is, however, confined to water paints, particularly whitewash.

2. Extenders.—(*a*) BARIUM SULPHATE.—The most important extender is barium sulphate, known as blanc fixe when obtained

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[39] This material is also known under various names, some copyrighted, such as "lithophone," "ponolith," "Orr's white," "Beckton white," "Griffith's white," etc.

[40] See A Study of Lithopone, by W. J. O'Brien, J. Phys. Chem. **19**, pp. 113-144 (1915), for an account of this peculiar phenomenon.

by precipitation, and as barytes when obtained by grinding the mineral baryte or heavy spar. Its chief characteristic is extreme chemical stability. It does not react with any material used in paint making and is not affected by any gases or vapors found in the air. It is practically colorless when mixed in oil and hence has little hiding power, but is useful for diluting highly colored pigments without modifying the tone.

The ground mineral is crystalline and coarse in structure, and settles out from the vehicle in the paint, but the precipitated form is much finer and stays up better. It is much used as the base upon which colors are precipitated to form "lakes." (See page 41.)

(*b*) SILICA (SILEX).—Another extender in common use is silicon dioxide, which occurs in two distinct forms. One obtained by crushing and grinding quartz rock, chert, flint, sand, etc., is composed of very fine sharp particles, and is inert and white, but without hiding power. It is valuable as the base in paste wood fillers and to give "tooth" to paints; that is, power to take hold and adhere to wood surfaces. The second form, known as diatomaceous earth or kieselguhr, is a natural deposit of skeletons of microscopic organisms called diatoms. It has less "tooth" than the ground quartz.

(*c*) MAGNESIUM SILICATE.—Magnesium silicate is a white pigment of low specific gravity and more or less fibrous structure, obtained by grinding waste asbestos and known by the copyrighted name of "Asbestine," is largely used to mix with other pigments to prevent them settling out of the paint when it stands in the container. Other magnesium silicates, for example soapstone, are also ground and used to some extent in paints; these, however, are inferior to the ground asbestos in that they do not so effectually prevent settling out of the pigment from the paint.

(*d*) KAOLIN OR CHINA CLAY.—Kaolin is hydrated aluminum silicate and is used largely in the so-called dipping paints to prevent them from settling in the tanks. It is also used as the inert base upon which colors, especially para reds, are precipitated as lakes. (See page 41.)

(*e*) GYPSUM (TERRA ALBA).—Gypsum is hydrated calcium sulphate. When heated to about 180–190° C, part of the water is driven off, leaving plaster of Paris, which, as is well known, can absorb water and thereby set. If the heating is carried somewhat above 200° C, all the water of the gypsum is removed, forming "dead burnt" calcium sulphate, which does not again readily take up water. This is used as an extender in Venetian red.

(*f*) CALCIUM CARBONATE.—*Natural Chalk.*—Natural chalk is ground and levigated, and graded according to fineness and whiteness into "Paris white," "gilders' whiting," and commercial "whiting." The first two are very fine and bulky, and are used in paints to aid in suspension of the pigment and to neutralize acidity; the last is used in calcimine and putty.

Marble Dust.—Marble dust is crystalline in character and gives "tooth" to paint, but settles out too readily to make its use desirable, except in priming. It is sometimes added to putty to make it work "short." Ground limestone is similar to marble dust, but likely to be less pure.

Precipitated Chalk.—Precipitated chalk, also called "alba whiting," is very white and extremely bulky and may be used instead of Paris white or gilders' whiting.

C. BLACK PIGMENTS

(*a*) LAMPBLACK.—Lampblack is soot produced by the incomplete combustion of oils, fats, resins, or resinous woods and is more or less nearly pure carbon. It is a grayish black in color, very bulky, remarkably permanent, and has great color strength. When mixed with white it produces a fine blue gray and is used largely for this purpose. It is also used as a solid color, though it is not so bright a black as some others.

(*b*) GAS BLACK OR CARBON BLACK.—Gas black is closely related to lampblack, being made in a similar manner from natural gas. It is far blacker looking than lampblack, and for this reason is used as a solid or body color and in printing inks. With white it gives a brownish or smoky tone to the gray that is not desirable. Both lampblack and gas black when burnt should leave not more than a small fraction of 1 per cent of residue.

(*c*) BONE BLACK.—Bone black is made by heating bones in a retort from which the air is excluded. The resulting bone charcoal, which is ground fine, contains 10 to 20 per cent of carbon, to which it owes its fine black color. The rest is largely calcium phosphate. Because of the large amount of ash its color strength may be not more than one-eighth as great as that of lampblack, and the gray it gives with white is not so pure. It is used as body color, especially for carriage painting, and is known as coach black. "Ivory black," as the name implies, should be made from ivory chips and cuttings, and is hence a high-grade bone black. The term "Drop black" is sometimes used for the same material, but in other cases it refers to a charcoal black sometimes known as Frankfurt black, though this meaning is apparently now obsolete in America. Any distinction between coach, ivory, and drop black is to-day largely traditional. All kinds of bone black may contain Prussian blue, which is added to modify the color. A much stronger color can be made from bone black by removing the mineral matter with hydrochloric acid.

(*d*) CHARCOAL BLACK.—Charcoal black is produced in the same way as bone black, but is of vegetable origin. Some of the best sources are peach and plum pits, cocoanut shells, cork waste, and grapevine cuttings. The latter grade is called blue black or vine black and is used by artists in water colors.

(*e*) GRAPHITE. (BLACK LEAD OR PLUMBAGO).—Graphite is a form of carbon which is found as a natural mineral in many parts of the world. That used in paint sometimes contains as much as 85 per cent graphite, the remainder being siliceous material. To this is sometimes added silica or other pigments, so that the graphite content of the pigment in a graphite paint may be no more than 40 per cent. Graphite is extremely permanent, but its dull grayish-black color renders it undesirable for anything but inconspicuous surfaces. It is used largely in paints for iron roofs and other iron surfaces. "Brown graphite," "green graphite," and "red graphite" paints are graphite paints with some other coloring matter added. "Acheson graphite" is an artificial graphite of extremely fine texture that is used sometimes in paints.

(*f*) MISCELLANEOUS BLACK PIGMENTS.—Black mineral substances, such as coal, shale, etc., are ground and sold under a variety of names, such as "mineral black," "keystone filler," or "iron filler." Their use is generally confined to paints applied as fillers for rough surfaces.

D. RED PIGMENTS AND LAKES

(*a*) INDIAN RED.—Indian red was formerly obtained as a natural hematite iron ore, but is now largely produced artificially by roasting ferrous sulphate (green vitriol), which yields colcothar or rouge, of colors from bright scarlet to purplish red, depending on the heat treatment. Indian red is of a dark purplish color and should contain at least 95 per cent of ferric oxide. It affords pure tints with white, for which purpose it is much used. It is very permanent, not being affected by light or by other pigments with which it is mixed. As a body color it is very opaque and may be extended by the addition of large proportions of inert material, and yet cover very well. "Turkey red" is a name given to iron oxides of bright red color.

(*b*) Tuscan Red.—Tuscan red is Indian red enriched by an alizarin lake (see Lakes, p. 41) which gives it a beautifully subdued crimson tone. Because of the great strength of the color it is usually reduced by mixing it with barytes, whiting, or gypsum. Tuscan reds are very permanent and will stand heating to 150-175° C (300-350° F) without change. They are extensively used to withstand vigorous exposure; that is, for painting passenger cars, steam pipes, radiators, implements, and machinery. Cheaper dyes of inferior quality instead of alizarin and other bases than Indian red are sometimes used, but these colors soon fade and such products are worthless for the special uses for which Tuscan red is adapted.

(*c*) Venetian Red.—While Venetian red formerly consisted of natural earths which possessed a reddish color due to oxide of iron, it is now produced almost exclusively by artificial means. The better grades are made by heating ferrous sulphate as in the production of Indian red. This calcined product is then mixed with gypsum, which has been found most suitable, or in inferior grades, with barytes or whiting. A solution of ferrous sulphate may be treated with lime water and the precipitate calcined; or ferrous sulphate and oyster shells may be used, thus giving an intimate mixture of ferric oxide and dead burnt calcium sulphate. Good Venetian red can be used for any kind of painting in oil or for "distemper"; it has excellent body and, if free from whiting, has great permanency, and can be mixed with any other pigment safely. Its color is always the characteristic brick red. It is used very widely when an inexpensive and reliable pigment is needed. Some cheap calcined earth reds that are not much more than clay with enough iron to color them are sold as Venetian reds. They should not be confounded with high-grade Venetian reds. Their use, except in cases where reduction of cost is the only object, is likely to lead to dissappointment.

(*d*) Red Lead.—Red lead is a brilliant scarlet red pigment. It is not used as a color or for tinting, but for its protective action. It is made by heating metallic lead or sandy white lead in a properly constructed furnace, first producing lead monoxide, which by further heat treatment is converted to red lead. If pure, its chemical formula is Pb_3O_4, and it may be regarded as 1 part of lead peroxide (PbO_2) and 2 parts lead monoxide (PbO). As ordinarily obtained on the market it contains from about 70 to 99 per cent (usually over 85 per cent) of Pb_3O_4, the remainder of unadulterated samples being lead monoxide unchanged in the process of manufacture.

Such red lead is a good drier of itself, and when mixed with oil will solidify to a hard mass within a short time. It is necessary therefore that the paint be mixed not more than 24 hours before use. To overcome the difficulty of mixing the dry pigment with oil, the red lead is sometimes ground to paste form in nondrying oil, but this practice is not to be recommended. It is also ground mixed with other pigments such as silica, but when so mixed should not be sold as pure red lead. On account of the great specific gravity of red lead the paint made from it is very heavy and flows on stiffly, has a tendency to sag, and is not likely to cover as much surface as white lead. When properly prepared and applied it forms a very tough, adherent coating, and in spite of its drawbacks and rather high price it is the most satisfactory paint in use as a priming coat for the protection of iron and steel. It is also used in wagon painting as a primer for the running gears as it will stand knocks and friction that would remove any other paint. It is blackened by hydrogen sulphide or other sulphur compounds, and has a tendency to whiten upon exposure to atmospheric agencies, due to the formation of lead carbonate and sulphate. As its chief use is as a first coat these defects are of no consequence.

Recently a high-grade red lead containing about 98 per cent of Pb_3O_4 has been put on the market, which when ground in linseed oil to a paste form does not harden in the container. Its use obviates the inconvenience of mixing dry lead in oil, and so far as present knowledge goes, it is equal in every way to dry lead freshly mixed.

Some experts claim that the absence of lead monoxide prevents the paste hardening in the container, and that with an increase in the contents of true red lead the fineness of the pigment increases, thus producing a better working paint, one that gives a more continuous film, flows out better, and has less tendency to sag and run. Other experts [41] claim that the cause of hardening in the container of ordinary red lead is coarseness and not the presence of lead monoxide. The same authority states that

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[41] Private communication from H. A. Gardner.

some red leads containing only 85 per cent Pb_3O_4 are finer grained than any containing over 95 per cent and that such fine-grained red leads do not harden in the container. It is not known which of these claims is correct, but the read-lead pastes examined in this Bureau that did not harden in the container have been found to be of high purity; that is, above 95 per cent Pb_3O_4.

"Orange mineral" is a form of red lead having a lower specific gravity and lighter color than the usual form.

The essential parts of the Navy Department specification[42] for red lead read as follows:

DRY.

Composition.—The dry pigment to be of high-grade quality free from all adulterants, and shall contain not less than 94 per cent of true red lead (Pb_3O_4), the remainder to be practically pure lead monoxide (PbO).

Impurities.—To contain not more than 0.1 per cent of metallic lead, not more than 0.1 per cent of alkali figured as Na_2O, and not more than 0.5 per cent of total impurities, which include all substances other than lead oxides.

Fineness.—To be of such fineness that not more than 1 per cent remains after washing with water through a No. 21 new silk bolting-cloth sieve.

Comparison with standard sample.—To be of good bright color, and equal to the standard sample in freedom from vitrified particles and in other respects.

Practical test.—When mixed with pure linseed oil, petroleum spirits, and drier, as per standard formula, viz:

Red lead, dry	pounds	20
Raw linseed oil	pints	5
Petroleum spirits	gills	2
Drier	do.	2

and applied to a smooth vertical iron surface, it shall dry hard and elastic without running, streaking, or sagging.

(*e*) English Vermilion.—English vermilion is mercury sulphide. It is very opaque, and has a beautiful scarlet, but not very permanent color. Owing to its high price, its place has been taken by the modern organic lakes, so that it is not much used now, except for striping in carriage and machine painting.

(*f*) American Vermilion (Scarlet Lead Chromate, Chrome Red).—American vermilion is a basic chromate of lead. It is a brilliant scarlet, coarsely crystalline powder, which possesses good hiding power and color strength. Grinding, instead of improving the color as is usually the case with pigments, turns it to a dull yellow. It is fairly permanent to light, but is blackened by sulphides. It is still sometimes used as a color pigment, though its place is largely taken by the coal-tar reds. As a protective pigment in paints for iron and steel it equals or excels red lead, but its cost prevents its wide use.

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[42] Navy Department specifications, 52L2b, Oct. 2, 1916.

(*g*) LAKES.—Lakes are formed by combining the coloring matter of certain dyes with metallic bases. The lakes made from alizarin, formerly obtained from the madder plant but now produced artificially from coal tar, are very permanent and of fair hiding power, especially if precipitated on an excess of opaque base. Carmine, the coloring matter of cochineal, is used with alumina to form carmine lakes. "Rose pink" and "rose lake" are made from brazilwood or from artificial coal-tar dyes.

The number of coal-tar dyes is legion, and those that can be made to form lakes are very numerous. In general, they range in color through every shade of red, purple, and maroon. They are brilliant colors, of high color strength, but often very fugitive to light, and transparent. They are chiefly used in the paint and varnish industry as stains, or when diluted with a large amount of other pigment, which pigment gives the lake greater opacity, or the lake brightens or modifies the natural color of the pigment used.

Among the most important lakes are the "artificial vermilions." The first attempts to match natural vermilion by the use of coal-tar lakes was to precipitate an eosine upon red lead or orange mineral. Some of these products, called "vermilionettes," matched English vermilion very closely in color and tone, but were very fugitive to light. Later more permanent lakes have been developed, among which may be mentioned "para red," "Helio fast red," sometimes called "toluidine red," and "lithol red." These and similar materials are used in enormous quantities in the form of lakes frequently containing as little as 5 per cent color for railroad signals, automobile and carriage painting, etc. When properly made they are very brilliant, of high color strength, and more permanent than genuine English vermilion; but they do not have the same hiding power, and are therefore not successful for striping. Some of them are also slightly soluble in oil, and have a tendency to "bleed" into other colors, especially into white, and are injuriously acted upon by vapors of ammonia and many pigments. Permanent and satisfactory artificial vermilions are also made from alizarin as a lake, extended by red lead, blanc fixe, or whiting.

E. YELLOW PIGMENTS

(*a*) CHROME YELLOW.—Chrome yellows are compounds of lead with chromic acid, which range in color from deep orange to light yellow. "Chrome yellow medium" is a pure lead chromate, while "chrome yellow light," or "lemon" or "canary," is so made as to contain more or less lead sulphate or other insoluble lead salt, intimately mixed with the lead chromate. "Chrome yellow orange," which is a basic chromate, is precipitated from alkaline solutions. It varies in color from pale orange to almost scarlet.

All the chrome yellows are colors of considerable brilliance, good color strength, and hiding power. They are fairly durable, but are slowly affected by atmospheric conditions. Sulphides turn them black, hence ultramarine blue, which contains sulphide, must not be mixed with chrome yellows. Chrome yellows can not be used with silicate of soda, lime, or other alkaline substances, for these turn them orange or red.

(*b*) ZINC CHROMATE AND BARIUM CHROMATE.—These are both light yellow in color, and are used to a limited extent in paints. They are quite permanent, but lower in color strength and hiding power than lead chromate, and of such cost as to limit their use.

(*c*) OCHER.—"Yellow ochers" are natural earths found in all parts of the world. In color they vary from pale yellow (citron) to very dark, almost olive. The coloring matter is hydrated oxide of iron (limonite, $2 Fe_2O_3.3H_2O$). Various ochers contain from 10 to 60 per cent of the hydrated oxide, the remainder being siliceous matter or clay. The best grades are known as "French ocher," the "English ochers" being darker in color. American ochers range from those that are fairly good, though lacking in opacity, brightness, tinting power, and freedom from grit, to those that are simply yellow mud. When of good quality they are excellent pigments, working well with all vehicles and with other pigments, and are permanent in color. With white they produce fine cream or buff tints. "Golden ocher" is ocher strengthened in color and given a yellow tone by the addition of chrome yellow. This is brighter at first than ordinary ocher, but the chrome yellow fades after a time, leaving only the natural ocher effect.

(*d*) SIENNA.—"Raw siennas" were originally obtained in Italy and the best grades are still known as "Italian siennas." They resemble ochers in their general composition, being earthy substances colored by hydrated iron oxide. There is usually also a little manganese oxide present. They are brownish yellow in color, and more transparent than the ochers, a fact which renders them undesirable for body colors but makes them invaluable as staining and graining colors. With white they produce beautiful cream tints and have greater color strength than ochers. They are permanent and can be used with any vehicle or pigment.

F. BROWN PIGMENTS

(*a*) Burnt Sienna.—Burnt sienna, as the name indicates, is produced by calcining raw sienna. This process changes its color to an orange red or subdued red-brown of great richness. Two kinds are in use. "House painters' burnt sienna," strong in coloring matter, and opaque, is intended to serve as a tinting color; while "grainers' burnt sienna" is chosen for its transparency, richness, and clearness, and is used as a body color, especially in graining, its color being a characteristic cherry. It is also much used for the conventional mahogany but for this purpose is generally strengthened in reddish tone by adding rose pink or similar red colors.

(*b*) Umber.—*Raw Umber.*—Raw umber is a natural earth pigment of yellowish-brown color with an olive tone, similar in composition to the siennas but containing considerable amounts of manganese oxide. The best grades, known as "Turkey umber" come from Cyprus. Raw umber is permanent, mixes well with vehicles, is of medium opacity, and fair strength; giving drab tints with white, and a great variety of other tints when mixed with colored pigments, for which purpose it is much used.

Burnt Umber.—Burnt umber is obtained by calcining raw umber. It has a rich brown color, which, while darker than that of raw umber, should be free from redness. Its use is the same as that of raw umber, the tints formed being of a different order of drab.

(*c*) Metallic Browns or Mineral Browns.—These are made from those native iron ores (mined in all parts of the country, especially in the Appalachian region) which, upon roasting, develop colors ranging from bright red-brown to dark purple. They are used extensively for roof and barn painting, for iron bridges, freight cars, and similar work where a good substantial covering is required, without much regard to beauty of finish. They are opaque and fairly permanent, changing but little on exposure and can be mixed with other pigments with good results.

(*d*) Vandyke Brown.—Vandyke brown, also known as Cassel earth or Cologne earth, is a pigment of carbonaceous character, usually found in or near bogs. Its distinguishing feature is its solubility in dilute alkali, forming a solution which may be applied to wood and precipitated in the grain with dilute acid giving a very good and permanent "walnut" stain. A dry soluble form is marketed as "sap brown." Vandyke brown ground in oil and thinned with turpentine makes a good walnut oil stain which is not too transparent and is decidedly permanent. Its one objectionable feature is its very strong retardation of the drying of linseed oil. The color of Vandyke brown, may also be obtained by using burnt umber, drop black, and Prussian blue, producing a color that is permanent, but lacking the transparency of true Vandyke brown.

G. BLUE PIGMENTS

(*a*) Prussian Blue.—Prussian blue is formed by precipitating potassium ferrocyanide with ferrous sulphate and oxidizing the resulting pale bluish precipitate into the characteristic dark blue of this pigment. There are many closely related varieties depending on details of treatment in their production. Prussian blue is a transparent pigment of great strength, 1 pound giving to a ton of white lead a decided sky-blue tint. It is fairly permanent except in contact with alkalies or lime, which decolorize it rapidly. With white pigments it should give a decided blue tint, not purplish or muddy. Being very fine in texture it does not settle in the vehicle, and hence is used by implement manufacturers as a dipping paint for polished steel parts.

(*b*) Ultramarine Blue.—Ultramarine was formerly obtained from the mineral lapis lazuli, a semiprecious stone. It is now made artificially in large quantities and at low cost by heating together clay, silica, sodium carbonate, sodium sulphate, charcoal, rosin, and sulphur and treating the product by rather intricate processes of grinding, roasting and washing. It is bright but of low color strength, varying from a pure blue to colors bordering on green, which latter are called "green ultramarine." It is permanent when exposed to sunlight, alkali, or lime, but is affected by even weak acids. The sulphur in ultramarine darkens white lead carbonate and discolors chrome yellow and other colors containing lead. It is used largely in house painting; that is, for making tints with zinc white.

(*c*) Cobalt Blue.—Cobalt blue is a compound consisting of oxides of aluminum and cobalt. It as a fine greenish-blue color, is permanent to light, not affected by alkali or lime or acids, and can be mixed with any other pigment or color. Because of the high price of genuine cobalt blue, the so-called cobalt blue usually found in the market is a suitable ultramarine blue, mixed with a little zinc white to give a close imitation of cobalt blue.

(*d*) Blue Lead.—Blue lead (which is not a blue pigment but on account of its name is included here) is a by-product of lead smelting operations, consisting of the fumes from blast and Scotch hearth furnaces. In composition it is essentially a basic lead sulphate with excess of lead oxide, mixed with varying small quantities of lead sulphide, lead sulphite, zinc oxide, and carbon. In color it varies from a mouse gray to almost white. It is affected by exposure to light, but since it is not used for its coloring power this fact is of little importance. Apparently the sulphides and sulphites in it affect the oil when mixed as a paint so that after drying it is comparatively immune against darkening by coal gas. For this reason it is finding considerable use as a protective coating for metallic surfaces. It has great tendency to cause paint to thicken and "liver" if allowed to stand after thinning.

H. GREEN PIGMENTS

(*a*) Chrome Green.—Chrome green can be made by simply mixing together Prussian blue and chrome yellow. In color works the necessary solutions to produce both Prussian blue and chrome yellow are made up and then mixed together, the resulting chrome green being a very intimate mixture of the blue and yellow. In tone these mixtures range from very pale yellow green to very deep blue green. They have great covering power and good color strength but are not very durable and are subject to the limitations of both Prussian blue and chrome yellow. Because of the great hiding power and color strength it has become common to put out greens of a grade known as "commercial" which are composed of about 75 per cent of barytes or silicate to 25 per cent of color. For body pigment this answers very well but for tinting, the pure green known commercially as "chemically pure," is to be preferred.

(*b*) Chrome Oxide Green.—The true chrome oxide green is chromic oxide (Cr_2O_3), a rather expensive, permanent, dull color of satisfactory hiding power. A carefully made product of the best grade is known as "Guignets' green" or "viridian," which is more or less hydrated and usually contains boric acid. "Chrome ocher" is a clay stained with chromic oxide and is of little value.

(*c*) Emerald Green.—Emerald green is copper aceto-arsenite, which under its more familiar name of "Paris green" is used extensively as an insecticide. Because of its poisonous nature its use as a paint pigment has almost entirely ceased.

(*d*) Verdigris.—Verdigris is a basic acetate of copper of pale bluish green color, not permanent, but used to some extent for decorative effects and in marine paints as a protection against barnacles.

(*e*) GREEN EARTH (TERRE VERTE, OR VERONA GREEN).—The so-called green earths vary widely in composition and color but are usually complex silicates of magnesium or other alkali base and ferrous iron. The color is dull bluish green varying to a bluish gray. They are permanent, semiopaque and are used somewhat by manufacturers of mixed paints to produce certain neutral greenish tints with white, but their chief use is in "distemper." A good quality of green earth brightened with certain basic coal-tar dyes is used as a cheap lime-proof green color.

I. METALLIC PIGMENTS (BRONZES)

Very finely divided metals or alloys are used in the so-called bronze paints. They are known under various names which may either indicate the composition of the material as in "aluminum bronze," which is metallic aluminium, and "copper bronze," which is metallic copper; or the appearance as in "gold bronze," which is the term applied to finely divided alloys of copper, zinc, and tin, which have colors resembling gold. Bronze powders generally contain small amounts of oil or fatty matter such as stearine.

V. PREPARATION OF PAINTS

A. MIXING PAINTS

As previously stated, in general, a paint consists of a pigment (or a mixture of pigments) and a vehicle. The vehicle usually consists of linseed oil (or other drying oil), a drier, and turpentine or other volatile thinner. The linseed oil is added to furnish a binder for the pigments, the drier to hasten the drying process, and the turpentine to give the paint the proper flowing consistency and penetrating power, and in some cases to dissolve the resinous matter in the wood to be painted. A small proportion of oil to pigment also causes the paint to dry with a flat instead of a glossy surface. Turpentine has a greater effect than oil in thinning a paint, 1 volume of turpentine being approximately equal to 2 volumes of oil in this respect. Hence, when we increase the proportion of turpentine in the vehicle, if the consistency of the paint remains the same, we increase the proportion of pigment. It follows from this that the substitution of part of the oil in the vehicle by turpentine also causes the paint to dry flat. The nature of the surface to be painted and the conditions under which the work is done will determine the relative proportions of the ingredients to be used, which will vary considerably.

The incorporation of dry pigments into the vehicle to form a paint of desirable properties is a tedious and unsatisfactory process unless suitable machinery is available. It is the custom, therefore, for pigments to be ground in oil, japan, or other vehicles to a stiff "paste." While there is some tendency to separation of pigment and vehicle in such pastes, the separation is much less than with mixtures of painting consistency.

The most used paste paint pigment is basic carbonate white lead in linseed oil. That known to the trade as keg lead contains 100 pounds of dry white lead to 8 pounds of linseed oil. A standard grinding formula is 92.25 pounds of dry white lead to 1 gallon of linseed oil weighing 7.75 pounds. One hundred pounds of this paste occupies about 2.75 gallons and consequently weighs about 36 pounds per gallon. Zinc oxide paste is usually ground in the proportion of 37.75 pounds zinc oxide to 1 gallon of linseed oil, making about 1.83 gallons of paste which contain about 83 per cent of zinc oxide and weighs about 24 pounds to the gallon, though pastes having as low as 73 per cent of zinc oxide are sometimes marketed. The other opaque white pigments, the white extenders, and some of the colored body pigments are not commonly sold in paste form.

The amount of pigments to a given amount of oil in a paste depends upon the properties of the pigment and varies between wide limits. Thus, Indian red and Venetian red pastes contain about 80 per cent of pigment; yellow ocher and chrome yellow, about 75 per cent; raw sienna and raw umber, about 60 per cent; Prussian blue, about 50 per cent; and lampblack seldom above 35 per cent. In the case of some colors that are used in very small quantities it may be advisable to purchase them as dry colors.

To prepare a paint from a paste it is only necessary to add to it a small amount of vehicle, usually oil, and stir thoroughly with a spatula or wooden paddle, and repeat this process, known as breaking up the paste, until the desired consistency is reached. If the vessel in which the mixing is to be done is first wet with oil it will prevent the paste from sticking to the sides and will make the stirring easier. Sometimes a very little turpentine is first added, as this causes the paste to break up more readily. It is well after breaking up the paste to let it stand a day before finishing the paint so that the many small lumps that always escape the paddle will be softened by the oil into a smooth and uniform liquid. It should be thin enough to be stirred easily but still too heavy for painting.

If coloring pigments are to be added, they should be broken up in the same way and added to the main body of thinned paste in very small quantities and thoroughly mixed. If more is needed, it can be added a little at a time with thorough stirring until the desired result is obtained. It is well to experiment on a small scale before mixing the whole batch. If too much color is put in, it can not be removed and the fault can be remedied only by breaking up more of the main body of paste and adding it to that already made, which may cause more finished paint to be mixed than is needed and hence cause a loss. When the paste has been broken up and properly colored, the drier should be added and stirred in, then more oil or other vehicle to proper consistency for painting. To insure freedom from lumps the paint should be strained by pouring it through a paint strainer or a piece of fly screen or coarse muslin.

When a painter wishes to use large quantities of any pigment or mixture of pigments not ordinarily sold in paste form he can generally buy them in paste form by special arrangements with manufacturers. When it is necessary to use dry pigments they must first be ground to paste. This is best done by wetting the pigment with a little turpentine and rubbing it on a smooth marble slab with a stone muller to a stiff paste. A piece of glass or even a smooth board may be used instead of the marble slab, and a spatula or flexible knife may take the place of the muller. Oil may then be added a little at a time and the rubbing continued until a smooth, easily mixed paste results. This can then be mixed with any similar paste in the making of a paint. Under no circumstances should dry color be added to a paint until it has been worked up into a smooth paste, as otherwise it will form little masses of dry powder which will cause streaks under the brush no matter how much stirring is subsequently done.

When mixing paint the order in which the ingredients are added is important. For example, in making a tinted paint from white lead and zinc oxide pastes, first break up the pastes with just enough oil, add the zinc oxide to the white lead, then the tinting color, then the drier, then the rest of the oil, and last the turpentine. Each ingredient should be thoroughly incorporated by stirring before adding the next.

The amounts of oil, volatile thinner, and drier in a finished paint will vary, depending upon the nature of the pigment, character of the surface to be painted, whether under coat or finishing coat, and exposure (whether inside or outside). It was formerly held by practically all whose opinions appeared in print that for painting wood for outside exposure the less turpentine or other volatile thinner in paint for any coat the better the job, and much of the failure of paint was attributed to the use of volatile thinner by the painter. It is now generally believed that sound theory demands the use of volatile thinner in all under coats. In the painting of wood for outside exposure the priming or first coat should penetrate and fill the pores of the wood. Volatile thinner greatly assists this process. All coats except the last should dry flat and at least as hard and preferably harder than the succeeding coats. The last coat should dry with a gloss and hard enough not to take up an excessive amount of dirt; but since this coat gets the maximum drying and hardening effect of exposure to light and air it need not dry as hard at first as the under coats. It is possible that a paint coating may be too hard, which may cause cracking.

Considering the two most important white pigments used in paints for outside exposure—basic carbonate white lead and zinc oxide—we find that white lead is practically the only white pigment which is used alone in oil paints, zinc oxide being always used as an ingredient of mixed or composite paints. White lead with oil dries to an elastic and somewhat soft film. Increasing the amount of pigment in proportion to the oil tends to make this film harder. A liberal use of volatile thinner in all undercoats and the use of a moderate quantity, but not enough to cause drying flat, in the last coat is therefore to be advised with white lead paints. Zinc oxide causes the paint to dry hard and when present in large proportions may cause such hardening as to produce cracking. Hence, with paints containing zinc oxide the amount of turpentine admissable is less than with straight white-lead paints. With such paints undercoats require some turpentine to prevent drying with gloss, but the final coat does not need volatile thinner, since it dries hard without increasing the proportion of pigment to oil. Some definite proportions will be found in the chapter on "Specifications for painting" (see p. 69).

B. COLOR BLENDING

Directions for mixing colors to produce certain results in tint or shade can be given only in the most general terms. Different samples of the same color vary much in strength and tone, so that the same quantity will not always produce the same result. Moreover, the names used by different manufacturers for their pigments vary so much that directions given to produce a certain tint might produce entirely different results with different brands.

A large variety of colors can be purchased in paste form. If these are too bright and glaring, they may be corrected by adding a little of those other colors known as their complementaries. Thus, yellow is made less intense by adding a little blue and red; blue, by adding a little red and yellow; and red, by adding a little yellow and blue. Except in rare instances, addition of black to dull a bright color causes only a muddy appearance.

As a guide to the productions of tints by mixing pastes of different colors a few illustrations are given:

White lead and lampblack give grays from the lightest to the darkest, depending on the proportion of white and black used, 1 per cent of lampblack being sufficient to give quite a strong gray color. This "steel-gray" tint is "cold," in the parlance of painters, and to get a warm gray a little yellow ocher or sienna is added. If burnt umber is used instead of the ocher or sienna, a series of gray drabs is obtained.

Buff is obtained by tinting white lead with yellow ocher. Cream color results from adding a touch of Venetian red to a light buff. Ivory, a tint closely related to cream, is best produced by using a very little medium chrome yellow to tint white lead. About 5 parts white-lead paste, 2 parts yellow ocher or chrome yellow in oil, 1 part burnt umber in oil gives drab "stone" color or a series of yellow drabs if the proportions are varied.

A useful series of brown shades may be produced by mixing in varying proportions about 3 parts Indian red in oil, 2 parts lampblack in oil, and 1 part yellow ocher in oil. Venetian red may be used instead of Indian red and umber may replace the lampblack and ocher. For brown drabs white lead in oil is added to the above browns as desired.

Zinc oxide tinted with madder lake, carmine, or crimson shades of English vermilion, produces pink. White lead tinted with dark Indian red gives purple or lilac. A small amount of light Indian red may improve the purple effect.

About 2 parts of yellow ocher, 1 part of Venetian red, and 1 part white lead give "brick reds," the exact color depending on the proportions used.

"Sapphire blue" is obtained by tinting zinc white with ultramarine blue. "Sky blue" of various depths is produced by adding Prussian blue to white lead.

Chrome green, a mixture of Prussian blue and chrome yellow, is obtainable in many varieties, which may all be modified further by the addition of white, or black, or some other color. Thus, white lead tinted with medium chrome green (1 part to 100) gives "pea green." A little chrome yellow added to this gives "apple green." Lampblack added to a dark chrome green gives "bronze green." A richer effect may be obtained by using a medium chrome green as the base and adding ivory black and a little raw umber. Greens may also be obtained by using substitutes for the chrome yellow or Prussian blue, or both. Thus, white lead and yellow ochre, darkened with lampblack and burnt sienna, gives a dull green sometimes called "quaker green."

With practice a very good match of a given paint can be made, but for the last coat enough paint to cover all the surface should be made up before commencing the application, for the making of an exact match is a matter requiring much skill.

C. MIXING STAINS

1. Wood Stains.—The function of wood stains is to change or modify the color, and to bring out the grain and texture of the wood.[43] They may be classified as oil stains, water stains, spirit stains, and stains due to chemical change.

When we speak of oil stains we do not mean a stain made of oil and color only, as such a material would not properly penetrate into the wood fiber; but we mean that the binder contains oil, while volatile thinners, such as turpentine, benzene, or solvent naphtha, furnish the penetrating agent. Since it is possible to make a so-called oil stain without using any linseed oil, it seems more rational to consider oil stains as those which are thinned with *solvents* for oil, namely, turpentine, benzene, or solvent naphtha, while in water stains the liquid is water and in spirit stains the liquid is alcohol.

The pigments used in oil stains should be very finely ground and of the highest color strength, those colors which are somewhat transparent being, in general, more useful than the more opaque colors.

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[43] See Paint Making and Color Grinding, C. L. Uebele (1913); Hand Work in Wood, Wm. Noyes (1913); and The Expert Wood Finisher, A. A. Kelly (1912).

If one wishes to prepare his own stains, it is convenient to use colors "ground in oil." Stains are made from these by thinning with turpentine or turpentine substitute in the proportion of about 1 pound of paste color to 2 quarts of turpentine or turpentine substitute. The addition of a small amount of linseed oil gives more body to the stain, and with such an addition the stained wood may be rubbed to a soft luster without further finish. Oil stains may also be made from the colors ground in japan. According to Uebele,[44] about 10 pounds of pigment in oil, with three-fourths gallon of liquid drier, 7 gallons of boiled linseed oil, and 1½ gallons of turpentine will make 10 gallons of stain. The liquid portion may be cheapened by using 1 gallon of liquid drier, 3½ gallons of boiled linseed oil, and 4¾ gallons of turpentine substitute. The proportions of different pigments will, of course, vary, depending upon the colors desired and the color strength of the pigments used; hence the following proportions can be taken only as an indication of what may be used for certain stains:

Light oak.—50 per cent each of raw sienna and yellow ocher.

Dark oak.—80 per cent of raw sienna, with 10 per cent each of burnt sienna and burnt umber.

Cherry.—50 per cent each of burnt sienna and yellow ocher.

Walnut.—50 per cent each of burnt umber and Vandyke brown.

Mahogany.—60 per cent of burnt sienna and 40 per cent of maroon lake.

Another type of oil stains consists of solutions of oil soluble dyes (generally aniline dyes) in vehicles similar to the above. Much less color is required in this type of stain, seldom more than one-fourth pound to the gallon.

Oil stains are applied with a brush and the wood is then rubbed clean with cotton waste. The advantages of these stains are that they are easy to prepare and to apply, and they do not raise the grain of the wood. They have the disadvantages that they are apt to give a muddy effect, they do not penetrate very deeply into the wood, and they cover the grain somewhat, so that it is impossible to stain hardwood with them and at the same time keep the grain and texture of the wood clear. By "fuming" hardwood with ammonia or adding a little ammonia to the stain just before applying it, the penetration into the wood may be increased.

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[44] Paint Making and Color Grinding (1913).

Water and spirit stains are solutions of dyes in water or in alcohol. They are clear, penetrate deeply into the wood, and do not obscure the grain as oil stains are likely to do. However, they raise the grain of the wood. Water stains made from aniline dyes are likely to fade, though the addition of vinegar to certain of them is said to hinder this fading. The number of colors which may be used with these classes of stains is very large and no attempt will be made to give any list of them.

A method of producing a permanent black, which is a very satisfactory finish for wooden tops of laboratory tables, is as follows: Solution A, 125 g of copper sulphate, 125 g of potassium chlorate, and water to make 1,000 cc. Solution B, 60 g of aniline, 90 cc of hydrochloric acid (sp. gr. 1.2), and water to make 500 cc.

First paint with solution *A* and when dry with solution *B* and allow to dry several hours. Wash with hot water and repeat the whole operation until the wood is dark green. Finish by rubbing with raw linseed oil until a black surface is secured. By going over the work at intervals of one to two weeks with a cloth moistened with raw linseed oil it may be kept in perfect condition. The wood to be treated must be free from oil. Imperfections requiring putty should not be filled until the woodwork is stained. Putty colored with lampblack may then be employed.

The above aniline-black table-top finish is, in a sense, a stain due to chemical action since the two solutions react upon one another to produce the aniline-black in the pores of the wood. There are, however, other stains produced by the action of certain chemicals on constituents of the wood. Ammonia has much the same effect on oak as aging or weathering. It also seems to open the grain of oak and thereby makes it possible for other stains to penetrate better. It is best applied by moistening the wood and exposing it in a covered box to fumes of ammonia.

Iron salts such as the acetate form compounds having a dark-brown color when they are applied to certain woods such as oak, mahogany, and chestnut. Potassium or sodium bichromate gives brown or red stains on certain woods such as oak, ash, and walnut.

2. Shingle Stains.—Shingle stains differ from wood stains in that they are not intended to bring out the grain of the wood, but are intended to color and preserve shingles. They generally contain some creosote oil in the vehicle on account of its preservative properties. The pigments used should be of the best quality, have the maximum color strength, and be very finely ground in oil. Chrome green is used for green and various iron-oxide pigments for red and brown. The amount of pigment seldom exceeds 1½ pounds to 1 gallon of stain and the vehicle contains generally about 40 per cent of creosote oil, 40 per cent of heavy benzene, and 20 per cent of benzene japan drier. It is best to dip shingles in stain, but shingle stains may be applied with a brush.

D. READY MIXED OR PREPARED PAINTS

The increased number of raw materials available for paint making and the attendant difficulties of proper selection, in addition to the labor and skill required for compounding them by hand, has produced a large demand for paints thinned "ready for the brush." This demand has been strengthened by the fact that in recent years the use of paints for purely protective purposes has greatly increased and many new uses have been developed. No one is in so good a position as the manufacturer to test paints for their value under these new conditions and to devise special formulas to meet the various requirements. Under these circumstances a very large part of paint manufacture is the preparation of decorative paints of all colors and tints ready to apply; and the furnishing of special formulas for protecting iron work, for coating recently plastered walls, for cement surfaces, for damp proofing, or waterproofing, for washable wall finish, for enamels, and similar uses. One difficulty encountered in the case of ready-mixed house paints is the fact that one formula will not satisfy all the various demands made upon it. A paint properly proportioned to produce a third coat that will dry with a gloss finish for outside work will not usually be the best for the second coat, where a slightly flat surface is desired to provide a firm anchorage for the next coat. To make of it a suitable "primer"—that is, paint for the first coat—requires much thinning with oil or other vehicles, depending upon circumstances. These modifications, however, require no great skill to make and may be sufficiently covered in the directions on the container. Because of the extreme fineness of grinding necessary to produce high-grade enamels the ready-mixed goods of this class put out by reputable manufacturers will probably be more satisfactory than anything produced by hand mixing.

Many flat, washable wall paints owe their success to the use of tung oil varnishes and heavy petroleum spirits. They can be successfully compounded only in plants properly equipped. As produced by many makers they give satisfactory results in appearance and wearing qualities and cost less than ordinary paints. In addition to their use as wall paints they are satisfactory for undercoats upon which to apply enamel paints. Good paints for cement walls and floors are also on the market. As is well known, ordinary paint does not resist dampness nor wear well under moist conditions. Many attempts to produce damp proofing paints have been made but as yet with no great success. For the protection of iron and steel nothing is superior to red lead in linseed oil. Proprietary preparations for this purpose have nothing in their favor except ease of application and perhaps price.

The modern development of ready-mixed paints gives to both amateur and professional painters a source of supply in convenient form for a large number of their requirements, and if such paints are intelligently selected they may be expected to give entire satisfaction. However, high-grade service should not be expected from low-value products in paints any more than in any other kind of goods.

E. WATER PAINTS

1. **Whitewash.**—Whitewash[45] is the cheapest of all paints and for certain purposes it is the best. Lime, which is the basis of whitewash, makes a very sanitary coating, and is probably to be preferred for cellars and the interior of stables and other outbuildings.

Ordinary whitewash is made by slaking about 10 pounds of quicklime with 2 gallons of water. The lime is placed in a pail and the water poured over it, after which the pail is covered with an old piece of carpet or cloth and allowed to stand for about an hour. With an insufficient amount of water the lime is "scorched" and is not all converted into hydrate; on the other hand, too much water retards the slaking by lowering the temperature. "Scorched" lime is generally lumpy and transparent, hence the proper amount of water should be used for slaking, and an addition of water should be made to bring it to a brush consistency.

Numerous substances are sometimes added to whitewash to increase its adhesion. Among them may be mentioned flour, skimmed milk, glue, molasses, soap, alum, and sodium silicate. When organic substances, such as flour, milk, glue, molasses, etc., are added to whitewash it is advisable to add some pre-

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[45] Details of the composition and preparation of whitewash and other water paints may be found in White Paints and Painting Materials, W. G. Scott (1910).

servative to prevent putrefaction. The most commonly used preservatives are sodium chloride (common salt), zinc sulphate, alum, and formaldehyde. Even with the addition of preservatives, whitewash containing organic matter should not be used in damp interiors, owing to danger of decomposition.

An old receipt for whitewash, issued by the Lighthouse Establishment [46] (now Bureau of Lighthouses), and said to be very good for outside exposure, is as follows:

> Slake half a bushel of unslaked lime with boiling water, keeping it covered during the process. Strain it and add a peck of salt dissolved in warm water; 3 pounds of ground rice put in boiling water and boiled to a thin paste; half a pound of powdered Spanish whiting; and a pound of clear glue dissolved in warm water. Mix these well together and let the mixture stand for several days. Keep the wash thus prepared in a kettle or portable furnace, and when used put it on as hot as possible with painter's or whitewash brushes.

2. Cement Wash.—For certain purposes, especially on exposed places, a wash made of hydraulic cement is preferable to whitewash. It is made by mixing together 3 parts of Portland cement and 1 part of fine sand, with any desired coloring (e. g. Venetian red), and adding sufficient water to produce as thick a mixture as can be readily applied with a whitewash brush.

3. Calcimine.—Cold-water paints or calcimines have as their basis whiting or carbonate of lime instead of caustic lime, as in whitewash. This material itself does not adhere, and it is necessary to use a binder of some kind, generally glue or casein.

Ordinary white calcimine may be made by mixing 16 pounds of dry whiting with 1 gallon of water until free from lumps, and then adding a solution of one-half pound of glue in 1 pint of water. The glue can be dissolved most easily by soaking it several hours in cold water, and then heating on a water bath (for example, in a glue pot) until it is all dissolved. Sodium phosphate has also been recommended as an addition to calcimine. Tinting should be done by colors that are not affected by lime, namely, yellow ocher, siennas, umbers, Venetian red, para-red, maroon oxide, ultramarine blue, ultramarine green, chromium oxide, bone black, etc. If lampblack is used for tinting, it must be stirred up in hot water containing a little soap or in cold water containing a little borax, the alkali overcoming the greasy nature of the lampblack.

When casein is used in calcimines, it is necessary to add some preservative, for example, carbolic acid (phenol), chrome alum, thymol, or formaldehyde. Casein is found on the market in two

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[46] Whitewash and Cement Wash Formulas, Oct. 24, 1906.

forms, soluble and insoluble. The former usually contains some alkali to render it soluble; the later is pure casein. Since the insoluble pure casein is the form usually employed in calcimines, it is necessary to add some alkaline substance to render it soluble. The most common additions are soda ash (sodium carbonate), borax, and ammonia.

Typical casein calcimines are made as follows:

For interior use, 8 pounds of pure casein, 1 pound of soda ash (58 per cent), 60 pounds of "gilders' bolted whiting," and 12 pounds of plaster of Paris are first thoroughly mixed in the dry state. This mixture is treated with water to produce the desired brush consistency. Before using, it should be allowed to stand for a short time to allow the casein to dissolve.

For exterior use, 8 pounds of pure casein, 10 pounds of air slacked lime, and 1 pound of pulverized borax are mixed with 60 pounds of gilders' bolted whiting. The dry mixture is kept in sealed packages until wanted for use, when it is mixed with water as in the preceding paragraph.

Waterproof calcimine may be made by the use of a solution of casein in dilute ammonia. This is prepared by heating 1 pound of casein with 1 pint of cold water, diluting with 3 quarts of cold water, and adding 8 fluid ounces of ammonia. The whole solution is stirred until a smooth jelly is produced, after which one-fourth fluid ounce of formaldehyde (40 per cent) is added. This liquid answers as a binder for whiting or any other pigment, white or colored, which is not affected by alkali. The desired pigment is stirred into the casein liquid until a moderately thick paste is obtained, then the solution is diluted with water, alcohol, turpentine, or linseed oil, as desired, until a paint of proper brush consistency is obtained.

VI. APPLICATION OF PAINT AND VARNISH

A. SELECTION AND CARE OF BRUSHES

As in everything else, the best work in painting can not be done without good tools. Flat brushes of widths suitable for the various uses up to 5 or 6 inches wide are more generally used than other forms because a greater amount of surface can be covered at a stroke. With flat brushes, however, the paint can not be rubbed out as well as with a suitable round brush. For painting sashes and other small surfaces small oval brushes with a chisel-shaped end are most satisfactory. Varnish brushes are also made chisel shaped or slightly tapering instead of being square on the end, as this allows the varnish to be flowed on more evenly, which is essential. For whitewash or calcimine, a very wide brush may be used, since these are applied lightly to the surface and are not rubbed in.

Brushes for applying oil paints must be well cleaned after using, though for keeping overnight it is generally sufficient to wrap them in several thicknesses of paper. Some painters keep their brushes overnight by putting them in water. If, however, the brush is not to be used for several days, the paint should be washed out of it. Turpentine is one of the most satisfactory materials for washing a brush, but it is expensive and a brush can generally be washed as well with kerosene, which is much cheaper. After washing off the paint with kerosene the brush should be rinsed with gasoline or benzine, then thoroughly shaken, and well washed with soap and warm water. As soon as this washing is complete the brush should be shaken thoroughly so as to throw as much water out of it as possible, and hung up to dry with the bristles down; when dried the brush should be thoroughly protected from dust. If much painting is being done, it is less trouble to keep the brushes in turpentine or kerosene. For this purpose hooks should be fastened on the inside of a pail with a close-fitting cover, and the brushes should be suspended either by holes in the handles or by loops of string, so that the ends hang in the kerosene or turpentine in the bottom of the pail. The bristles should be submerged in the liquid, but should not touch the bottom of the pail. If kerosene is used for cleansing, it should be removed by shaking the brush and rinsing it in turpentine before using again with paint.

Brushes used with whitewash or calcimine should simply be washed and not put in the same liquids in which the brushes used for oil paints are kept. If a brush has been used for shellac varnish, it should be kept in alcohol or in the varnish itself. In general, a varnish brush may be kept in the varnish in which it is used.

B. APPLICATION ON WOOD

1. Varnishing.—The best general instructions which can be given for varnishing are: Apply smooth thin coats; allow ample time for the coats to dry; keep the freshly varnished work in dust-free rooms; always rub each coat to a dull finish before applying the next coat; and keep the brushes clean and the varnish cans closed. Dust is one of the greatest enemies to good varnish work and too much care can not be taken in excluding and removing it from all surfaces, brushes, and cans. Reliable instructions are generally furnished by varnish manufacturers, and are printed on the can label or in booklets. Detailed directions may be obtained in the various texts.[47]

(*a*) INTERIOR WORK.—Woods may be roughly divided into open-grained and close-grained woods; oak, chestnut, and ash being the most common of the first class; and pine, cedar, cypress, maple, birch, cherry, and whitewood of the second class. Before being varnished, the open-grained woods should be treated with a filler. Two classes of fillers are on the market, paste fillers and liquid fillers.

The paste fillers, which are most commonly used consist principally of "silex" or ground quartz rock, mixed with a quick-drying varnish to form a paste, which is thinned with turpentine before being used. Paste fillers are usually nearly colorless, but if it is desired to stain the wood, a suitable stain may be added to the filler. The filler, which should be rubbed in with a short stiff brush, will usually set in 15 minutes, after which, but before it has dried hard, the excess should be removed, for example, by rubbing excelsior across the grain of the wood.

Some liquid fillers are intended for use on open-grained woods, and are essentially ready-thinned paste fillers; but most liquid fillers are intended for use on close-grained woods, and are applied by simply brushing on. While some of them contain a small amount of pigment most of them are simply thin varnishes, often of very poor quality. Some authorities recommend ordinary shellac in alcohol as a liquid filler. It is generally best, however, to avoid liquid fillers, using instead the same varnish to be used for the second coat, either in its original condition or somewhat thinned with turpentine.

The first coat of varnish may be applied a day or two after filler or the stain has been used. The first coat should be allowed to dry for 5 to 10 days, after which it should be rubbed with curled hair or excelsior to remove the gloss. The second coat is then applied, and treated similarly, or rubbed with fine sand-paper or glass paper. If a first-class job with a gloss finish is desired, the next to last coat should be well rubbed with pumice

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[47] House Painting, A. H. Sabin (1908); The Hardwood Finisher, F. T. Hodgson (1902); The Expert Wood Finisher, A. A. Kelly (1912); 739 Paint Questions Answered, and 1,000 More Paint Questions Answered.

and water before applying the finishing coat. The final coat (preferably the fourth coat) may be left with the natural gloss, or rubbed with pumice and water if a dull or flat finish is desired.

The time between coats may be shortened to from one to three days by using a good quick-drying rubbing varnish for the undercoats, but if the time can be allowed, it is safer to follow the directions given above.

Shellac is often used as an interior varnish, especially where it is desired to retain the natural color of the wood. It should not, however, be used for exterior work or where it will become hot, as near a fireplace, since it is likely to blister. It should be applied in thin coats and given ample time to dry. The first two coats may be applied 6 hours apart, after that two days should be allowed between coats. It does not require rubbing except perhaps after every three or four coats. Since 8 to 12 coats are required for a first-class job, it is rather an expensive treatment.

(*b*) EXTERIOR WORK.—No filler is used in exterior work, since it is apt to be forced out of the wood by direct sunlight. All surfaces exposed to the sun, as window sashes, sills, inside blinds, etc., are considered as outside work. The material generally used is spar varnish, the successive coats being lightly sandpapered, except the last, which is usually left with the natural gloss. Exterior work, especially if exposed to the direct sunlight, will require varnishing annually, while good interior varnishing will last 15 or 20 years.

2. Painting.—(*a*) EXTERIOR.—*New Work.*—Any surface to be painted must be clean, dry, and free from grease. Many new woods, as yellow pine, spruce, and cypress, contain resin that tend to destroy the paint laid over them. A better job of painting would be obtained on outside work if a new house were allowed to stand unpainted for six months or more. By this exposure to the weather the resins are brought to the surface and either washed away or hardened, resulting in a much improved condition for painting. Since, however, such a procedure tends to cause the wood to crack, painters resort to several methods of treating new wood. For example, turpentine is added to linseed oil as the vehicle in the priming coat, even as much turpentine as oil sometimes being used, or benzol (coal-tar naphtha) may replace 30 to 40 per cent of the turpentine. This is claimed to dissolve the surface layers of resins and allow the paint pigment to penetrate into the fibers of the wood and prevent the future forcing of the resins to the surface. For knots and very sappy woods, a treatment often resorted to is to apply one or more coats of a solution of shellac in alcohol before priming. Another recommendation is to treat all knots and resin streaks with a brush coat of turpentine not more than 1 hour before applying the priming coat of paint. With improperly seasoned wood and especially on southern exposure, even the shellac coating or turpentine treatment is likely to fail. A treatment recommended for such severe conditions is to use equal parts by weight of white lead in oil and pure dry red lead. The red lead should be mixed to a paste in a vehicle of 2 parts of raw linseed oil and 1 part of turpentine, the white lead incorporated, and the mixture thinned with more of the vehicle to the consistency of thin paint, strained, and applied as the priming coat, which should be well rubbed in. After the priming coat is applied, all nail holes and cracks should be well filled with putty, pressed in hard.

The purpose of the priming coat is to fill the pores of the wood and to furnish a foundation on which to apply the subsequent coats. It should, therefore, be composed of good materials and be applied with much care, being brushed in thoroughly so that the paint is evenly distributed with no tendency to run. Much of the scaling of paint is due to an improper priming coat. As a rule, the pigment of the priming coat should be, in general, of the nature of that in the succeeding coats but variations are admissible. For example, many good painters prefer to prime with white lead, others prefer a mixture of about two-thirds white lead and one-third red lead. The priming coat should be made thin and the substitution of turpentine for part of the oil tends to make a flatter and harder coat. A greater proportion of turpentine should be in the vehicle of a priming coat where lead pigments alone are used than when the pigment contains some zinc oxide, since zinc oxide with linseed oil dries to a very hard coat and too small a proportion of oil may cause the paint to dry so hard that it will crack.

The second coat will not penetrate into the wood to any very great extent. It should not, however, dry with a gloss, because a glossy surface does not furnish a good foundation for the next coat. Substituting turpentine for part of the oil tends to cause the paint to dry flat. It must be remembered that turpentine has roughly twice the thinning effect of oil. Hence, when part of the oil is replaced by turpentine, to get the same amount of pigment on a given area of surface the proportion of pigment in the paint should be increased. No fixed proportion of oil and turpentine to apply to different pigments can be given; but for all coats except the last the vehicle should contain sufficient turpentine to cause the paint to dry flat. The final coat should dry with a gloss, hence it should contain either no turpentine in the case of hard drying pigments such as zinc oxide, which take a large amount of oil, or, at most, a small amount of turpentine, for pigments such as basic carbonate white lead, which dry with a softer coat and require a smaller proportion of oil. Often only two coats are applied, but three coats will generally be needed, and four coats are not uncommon. In general, many thin coats are better than a few thick ones. Each coat should be given ample time to dry thoroughly, usually not less than a week, before the next is applied, rather than hastening the process by excessive use of drier. It should be remembered that moisture is the great enemy to paint, and first-class work can only be done in warm dry weather.

Old work.—If the paint has worn satisfactorily, it will be in suitable condition to receive new paint and may be regarded as the primer coat. All dust, soot, and any loose scales of paint must be thoroughly removed by brushing, scraping, or sandpapering, and paint suitable for a second coat on new work should be applied. Any puttying needed should follow this coat. The finishing coat will be in every respect similar to the finishing coat of new work. If the old paint is loose or in such a condition as to be ready to break loose as soon as a new elastic coat is applied over it, as is very likely to be the case if unsuitable primer was originally used, it must be removed before repainting.

Probably the most efficient method of removing oil paint and varnish is by burning with a painter's torch. The heat causes the film to soften and it can be scraped off. This method, however, can be used only on flat surfaces and where slight scorching of the wood is not objectionable, and must be conducted with great care on account of the fire risk. A solution of caustic soda (concentrated lye) containing 1 pound to 4 gallons of water is also quite efficient. It should be applied with a fiber (not bristle) brush, or a swab until the paint softens so that it can be scraped off or removed by means of a wire brush. This solution is very injurious to the skin and should be used with great care. It also raises the grain of the wood, hence the surface treated with it should be subsequently well washed with water, then with vinegar, again with water, allowed to dry, and then sandpapered, before painting.

There are a number of paint and varnish removers on the market, most of which consist of mixtures of benzol, acetone, and methyl alcohol with the addition frequently of some wax-like body to retard the evaporation of the volatile solvents, which are the active constituents. The wax-like residue which may be left from a paint and varnish remover must be carefully removed by thorough washing with benzine.

On weatherboarding a vigorous use of a wire brush will probably be sufficient, if followed by a suitable priming coat to bind the remaining paint to the wood. To remove old paint from weatherboarding either by the torch or a paint remover, will probably be more expensive than taking off the boards and putting a new siding on.

Boat painting.—The requirements are a smooth surface and a water-resistant paint. Extra care in surfacing will yield a gratifying return in the speed of the boat. The bottom when perfectly dry, should be scraped or sandpapered until as smooth as possible, removing all old paint if necessary. On new work a thin coat of shellac may be applied to advantage. For the priming coat white lead in oil paste, tinted if desired, and thinned in a vehicle of equal parts of raw linseed oil and turpentine with just enough japan drier to cause the paint to dry in 24 hours, will generally be found satisfactory. When dry, any cracks and inequalities should be filled with putty made of white lead in oil stiffened by the addition of pure whiting and colored to suit the paint used. When the first coat is quite hard, the surface should be made as smooth as possible with sandpaper. The second coat should contain equal parts of white lead and zinc white in oil, thinned with a mixture of 2 parts of raw linseed oil, 1 part of turpentine, and just enough japan drier to cause the paint to dry in 24 hours. For the last coat 1 part of white lead and 2 parts of zinc white will probably give a more durable paint than any other combination. No linseed oil should be used in thinning for the last coat, but turpentine and a little drier should be first added to form a thin paste, followed by about one-fourth the volume of the best spar varnish. The paint should then be adjusted to good brushing consistency by the addition of either varnish or turpentine as required. Only the best grade of material should be used, for the extra outlay will be repaid many times over in the better service rendered. Satisfactory results may be obtained by replacing the third coat by a thin coat of spar varnish. If only two coats are used, they should be the first and third as described. Solid colors should be treated like the white after the priming coat.

If a natural finish is desired, several coats of spar varnish should be applied.

(*b*) INTERIOR.—A paint on the interior of a house, being protected from the weather, may be expected to last as a protective coating almost indefinitely, though light tints and brilliant colors may fade, and white paints containing large amounts of linseed oil will turn yellow, as will also white lead under certain conditions often found indoors. In selecting interior paints attention should be given to hiding power, beauty of finish, and permanence of color rather than to durability. In general, the same directions apply as in the case of outside work. However, more drier is required to insure rapid drying, and with white or light tints the proportions of white lead and of linseed oil should be reduced to avoid possible yellowing. A little varnish in the last coat will take the place of linseed oil as a binder and will also give a higher gloss to the surface.

Extra effort to obtain a high-grade result frequently is desirable in interior painting. To obtain a smooth surface and improve the final finish, each coat when dry may be rubbed lightly with fine sandpaper or with steel wool, avoiding scratches. Two or three coats of any good oil paint in which the vehicle contains less oil and more turpentine and drier than for exterior work, or of a flat wall paint, will furnish a good foundation upon which to apply two or three coats of good enamel paint. Better enamel paints can be purchased ready mixed than can generally be made on a small scale. The best white enamel paints consist of French process zinc oxide ground in a suitable varnish. Formerly dammar varnish was largely used for the vehicle in such paints, but while the vehicles in modern high-grade enamel paints may contain dammar varnish, they also generally contain some pale rubbing oil varnish. If tints are desired, the necessary coloring matter should be added to all coats, making the first a little deeper than required and lightening up on each succeeding coat. "Body" colors should be treated in the same way as white. A glossy finish may be obtained by applying a coat of interior varnish to the flat finish.

A variety of effects can be produced by slight modifications of the above general procedures. If an eggshell finish is required, the final coat should be rubbed with powdered pumice and water, using a felt or cloth pad. If this eggshell finish is further rubbed with rottenstone, moistened with olive oil, a velvety finish is obtained. If a high-gloss finish is desired the final coat should be rubbed with chamois skin without using any abrasive.

(*c*) FLOORS.—Where the service is severe, ordinary paint will not last so well as do some modified paints. The surface should be prepared in the usual way and primed with white lead in linseed oil, containing little drier. The paint should be rubbed in well, and when dry the cracks and nail holes should be filled with a genuine whiting and linseed-oil putty. About 10 per cent of dry white lead may be incorporated into the putty by thorough working, and the whole tinted to match the subsequent coats. For a kitchen floor the second coat may consist of equal parts of white lead and zinc white in oil, and such color as is desired, with drier and turpentine to give a flat finish; but for the third coat the same except instead of turpentine 1 to 4 pints of good floor varnish per gallon of paint should be added. If conditions require haste in drying, a good rubbing varnish may be added and a little turpentine is required. For porch floors which are exposed to the weather, better results will be obtained by omitting part or all of the zinc white in the second coat. Some zinc white in the third coat is desirable as it gives hardness to the film. Only the most durable hard-drying varnish obtainable should be used in floor paint. Each coat should be brushed to the utmost and given ample time to dry between coats. Owing to the hard service given floor paints they can not be expected to last long. When signs of wear appear a single application of the third coat paint will be sufficient. Specially prepared floor paints of excellent quality are on the market. These should be applied according to directions given by the manufacturer.

C. ON PLASTER

Old walls, especially of kitchens, have a thin layer of grease and smoke upon them that may not be perceptible, but will prevent paint from adhering properly. They should be washed thoroughly with soap and water, to which a little ammonia may be added, and finally rinsed with water. New plaster, being alkaline, does not afford a good foundation for paint. Neutralizing the alkalinity with acids is of doubtful value; it is better to treat the walls with a solution of 3 to 4 pounds zinc sulphate in 1 gallon of water and allow to dry thoroughly before painting.

If the walls have been whitewashed, the old whitewash must all be removed and the surface treated with zinc-sulphate solution as above.

Cracks in the plaster should be wet well and filled with a paste of plaster of Paris. Large cracks should be first cut out carefully in such a way that they are slightly wider at the bottom than at the surface. When the plaster of Paris has hardened, it should be scraped or sandpapered until smooth. It is likely to be more porous than the plaster of the wall and should therefore be given preliminary applications of the paint that is to be used on the whole surface.

Before applying calcimine to an ordinary plaster wall it is generally advisable to treat the wall with a coat of "size"; this treatment is also generally followed before papering a wall, and some painters use size before applying a coat of paint. This latter is not, however, considered good practice, it being considered better to apply a priming coat of paint.

Glue size is made by soaking good glue in water overnight, pouring off the excess of water, and dissolving the glue by pouring boiling water over it slowly with constant stirring, finally thinning with water to a proper brush consistency.

A size which is more resistant to moisture is obtained by dissolving separately 1 pound of glue in 1 gallon of boiling water as in making simple glue size; 1 pound of rosin soap (yellow laundry soap), cut in thin slices, in 1 gallon of boiling water; and 2 pounds of alum in 2 quarts of boiling water; then thoroughly stirring together the glue and soap solutions and adding the alum. This makes about 3 gallons, which will require 2 gallons of water to thin to proper brushing consistency for a porous wall and still more for a hard surface. One or more applications should be put on as hot as possible.

In painting plaster walls with ordinary oil paint the same general procedure may be followed as recommended for new woodwork, though the priming coat is generally a little thinner and some authorities recommend boiled oil instead of raw oil and drier in the vehicle (see pp. 11 and 12). The modern flat washable wall paints (see p. 54) are cheap and very satisfactory. In applying these the paint for priming coat should generally be thinned with about 1 quart of linseed oil to the gallon of paint and subsequent coats applied as purchased, though in all cases when using ready-mixed or prepared paints it is best to follow the manufacturer's explicit directions rather than any general instructions.

D. ON CEMENT

Cement contains much alkali and from its nature absorbs water very rapidly. These properties are destructive to paint and must be counteracted if paint is expected to give service on concrete. The alkali may be neutralized by treatment with dilute sulphuric acid or, better, by washing thoroughly with a solution of 3 to 4 pounds of zinc sulphate in 1 gallon of water. If the cement surface has been exposed to the weather for several months, the need of the zinc sulphate is not so great, but the saving in paint by this treatment is sufficient to make it profitable under any circumstances. When the surface is in condition, it should be primed with paint made from white lead in oil, thinned with linseed oil in the proportion of 1 gallon of oil to 10 pounds of white lead, with no driers of any kind; or any lead and zinc paint somewhat thinned with linseed oil may be used. After this coat has hardened to the touch any kind of paint may be applied for the remaining coats.

Cement floors should be prepared as above and painted as described under floor painting (p. 65), using, however, a larger proportion of varnish.

E. ON BRICK

Bricks, even when hardbaked, absorb water in very large amounts. It is therefore even more important than in the case of wood that the surface to be painted be thoroughly dry. All loose plaster and crumbling brick must be removed by thorough brushing. Mold can be cleaned off by washing in a mixture of equal parts of hydrochloric acid (muriatic acid) and water. To neutralize the alkali in the mortar, the joints of new brickwork may be treated with a solution of zinc sulphate, as in cement painting.

Before painting a brick wall it is a good plan to fill the pores—in the language of the painter, "kill the suction"—by applying a coat of boiled linseed oil thinned with turpentine or raw oil with some liquid drier. Brick color can be obtained by using Venetian red, sometimes with white pigments, to lighten the color, and yellow ocher or metallic brown (all ground in oil) to give the exact color desired. Whatever pigment is used it should be thinned with raw linseed oil and a little oil drier. The first coat should be rubbed in well. When it is dry, the joints should be filled with a putty made of linseed oil and whiting and colored with the same pigments as those used in the paint. For the second coat the pigment should be mixed with 2 or 3 parts of linseed oil, 1 part turpentine, and a small amount of drier and be brushed out well and uniformly. For a gloss finish the pigments that give the desired color should be mixed with linseed oil and a little drier and flowed on in such a way that it will not run. If a flat effect is desired, 3 parts of oil to 1 part of turpentine should be used for the second coat, and for the last coat the pigment, ground to a stiff paste in raw linseed oil, should be thinned with a vehicle of one-third liquid drier and two-thirds turpentine.

F. ON METALS

Tin, galvanized iron, and other metals used for roofing, spouts, garages, and other purposes present difficulties in painting. Often the paint does not stick well, probably owing to a very thin film of grease left on the material in the process of manufacture. Oil or grease must be scrupulously removed by scrubbing with soap and water or with a cloth moistened with benzine. All rust must be cleaned off thoroughly down to the base metal with scrapers, wire brushes, or sandpaper and finally with dry scrubbing brushes. Galvanized iron and zinc may be made to hold paint if first treated with a solution containing 2 ounces of copper chloride, copper acetate, or copper sulphate in one-half gallon of water. This solution, which should be prepared in a wooden or stoneware vessel, should be applied evenly to the metal and allowed to stand overnight. This treatment gives the paint a firm anchorage, but removes some of the surface metal, especially on galvanized iron. Conseqeuntly, only a thin coating should be applied, 1 pint being enough to cover about 300 to 350 square feet.

For the priming coat on metal surfaces 25 to 30 pounds of pure dry red lead should be mixed in 1 gallon of pure raw linseed oil by stirring the oil in gradually, finally straining through a wire gauze if it becomes lumpy. No drier is usually needed, but 1 gill may be used if the job is a hurried one, and one-half pint of turtine should be added if other coats of paint are to be applied over it. It should be brushed out so thoroughly that 1 gallon of paint will cover about 700 square feet. Red lead is expensive and rather hard to apply, but with the possible exception of American vermilion (scarlet lead chromate), which is even more expensive, no better paint is known for adhering to metal work and protecting it. It may be followed by one or more coats of any kind of paint desired.

If a cheaper treatment is necessary red iron oxide, Venetian red, or metallic brown, to which some authorities recommend the addition of 15 per cent of zinc oxide, in linseed oil may be used. Graphite paint has also been recommended.

To enamel iron beds, first clean the surface with soap and water or with a cloth moistened with gasoline. Touch up any bare spots with white lead in oil. When these are dry retouch them with enamel, let dry and give one or more coats to the whole surface.

The severe conditions imposed on an enamel for the inside of bathtubs necessitates the use of only the very best of material. A good undercoating may be made with basic carbonate white lead with very little oil, thinned with turpentine and enough liquid drier to permit sandpapering in 24 hours. Two coats evenly sandpapered will serve as a good foundation upon which to apply a special bathtub enamel, which should generally be bought ready prepared.

VII. SPECIFICATIONS FOR PAINTING

Among paint producers and users two groups may be found, one advocating the use of composite pigments and the other favoring single pigment paints. The arguments for these two groups have been given in the preceding text, but it is well to consider the specific recommendations made by representative adherents of these two views. The New Jersey Zinc Co., the largest manufacturer of zinc oxide, may be taken as representing fairly the views of the advocates of composite pigment paints and the National Lead Co., being the largest manufacturer of basic carbonate white lead and red lead, represents the views of the advocates of single-pigment paints.

The following are the latest available specifications of these two companies, the only changes being the omission of names of particular brands of material:

SPECIFICATIONS OF THE NEW JERSEY ZINC CO. FOR PAINTING

Unless otherwise provided, the contractor for painting shall furnish all materials, labor, transportation, scaffolding, utensils, etc., of every description required to execute all work herein called for or implied by the drawings.

The whole of the painter's work to be carefully executed by the best methods known to the trade and all be left in perfect, complete, and undamaged condition, without exception.

The work to be thoroughly cleaned, sandpapered, and dusted before applying paint. (This clause may be omitted in the case of rough exterior painting.) All surfaces to be thoroughly dry before applying paint. Painting to be done only in dry weather and never when the temperature is below 40° F., except by permission of the architect.

All knots, resinous and sappy portions shall be properly shellacked, confining the shellac carefully to these portions.

The color of the paint to be as directed by the architect, and all new surfaces to receive not less than three coats of paint.

Contractor shall submit to the architect samples of the colors selected and the finished work shall conform to the approved samples.

Each coat shall be thoroughly dry before succeeding coat is applied.

The priming coat shall be white if the finish is to be white or of a light tint; otherwise it shall be of approximately the same general color as the finishing coat. It shall be well and thoroughly brushed into the surface.

After priming, all nail holes, open joints and other imperfections shall be solidly and smoothly filled with pure linseed oil putty.

After the putty has dried two coats of paint of the color selected shall be applied. (Where a superior job is desired, the specification should be three instead of two coats in addition the the priming coat.)

Exterior.—New Woodwork.—If the wood to be painted is cypress, the priming coat shall contain in addition to the other "thinners" used, one-half pint of solvent naphtha (benzol) or of toluol to the gallon of paint ready for the brush.

If the wood be yellow pine, the priming coat shall contain one-half pint of pure wood or gum turpentine to the gallon.

The white paint to be applied either as a body color or as a base for tinting may be according to agreement in each case, a ready-mixed paint of approved composition or a semipaste paint of approved composition. Whatever form of paint may be selected the composition of the pigments shall approximate the following percentages, excepting in those cases where a higher zinc-oxide content is specified, in which cases the percentages of the other ingredients shall be correspondingly lowered:

	Alternative formulas				
	Per cent	Per cent	Per cent	Per cent	Per cent
Zinc oxide[48]	45	50	50	50	50
Basic carbonate white lead	20	20		35	50
Basic sulphate white lead	25	20	35		
Asbestine or silex or barium sulphate	10	10	15	15	

[48] The beneficial effects of zinc oxide will be apparent even when as little as 25 per cent is present. Forty-five or 50 per cent is, however, preferable in every respect. For exterior painting in warm climates or in the neighborhood of the seacoast, the higher percentage is absolutely necessary for good results. In interior painting, also, a high percentage of zinc is indispensable to prevent color changes.

If a semipaste paint is used, the pigments shall be ground in pure raw linseed oil, without volatile thinners or driers, the percentage of such oil to be not less than 25 per cent of the total weight of the completed paint.

For application, this paint shall be suitably reduced for the several coats by the painter, by adding as he deems necessary the requisite liquids. For such reductions he shall use nothing excepting pure raw linseed oil, having iodine value (Hanus) not less than 175, pure turpentine and liquid drier (with the exception noted above as to the use of benzole or toluol on cypress). The total percentages of turpentine and liquid drier shall not exceed 5 per cent of the total weight of the completed paint. The liquid drier or japan used shall contain no rosin compounds.

If a paste paint is used, it shall conform in every respect to the specifications for semipaste paint, excepting that the proportion of pure raw linseed oil used for grinding shall be reduced to the extent necessary. The restriction for mixing and reducing to working consistency shall be the same as for semipaste paint.

If a ready-mixed paint is used, the specifications as to the white pigment and the liquids shall be the same as for the semipaste paint, excepting that in this case the volatile thinners, the driers, and the tinting colors shall have been added in the process of manufacture. In that case the proportion of pure raw linseed oil in the completed paint shall in no case fall below 31 per cent; the total percentage of volatile thinners (which may be either turpentine or petroleum spirit) shall in no case exceed 5 per cent, including that contained in the liquid drier; the moisture shall not exceed 1 per cent; and the paint shall contain no rosin acids; the coloring matter used for tinting shall be commercially pure pigments.

Such paint shall be applied as furnished, excepting that the painter may add, as conditions require, within the specifications, pure raw linseed oil, turpentine or benzine or pure tinting colors.

Not less than three days of 24 hours each shall be allowed for the drying of each coat before succeeding coat is applied.

When tints are specified, the tinting shall be done with the use of pure linseed oil colors.

OLD WORK.—*Repainting.*—All loose or loosely adherent paint shall be removed by scraping, sandpapering, etc. Where necessary, old paint shall be removed by burning or with paint and varnish remover, as may be agreed.

Sandpaper and touch up with one or two coats, as may be necessary, all portions from which the old paint has been removed. Then apply two coats of the color selected.

NEW WORK.—*Plaster, Cement, and Concrete.*—Close all cracks and other surface imperfections with plaster or cement. After drying apply to the entire surface a solution of zinc sulphate dissolved in water (8 pounds to the gallon),[49] allow 36 hours for drying, then apply four coats of paint, under the same specifications as for exterior woodwork, new.

Repainting Cement, Plaster, etc.—Scrape off loose or loosely adherent paint, close cracks and surface imperfections with plaster or cement, allow to dry thoroughly; treat all fresh plaster, etc., with zinc-sulphate solution, as specified for new work on plaster, etc.; coat all bare places with one or two coats of paint, as may be necessary; paint over all, as specified for new woodwork, exterior.

Iron and Steel (Excepting Galvanized Iron).—All loose mill scale and all rust shall be thoroughly removed before painting by the use of hammers, scrapers, and wire brushes, and all grease shall be carefully washed off with benzine. Three coats of paint shall be applied.

The pigments for the priming coat shall consist of 85 per cent iron oxide and 15 per cent zinc oxide. This paint may be purchased either in paste or ready-mixed form with the zinc oxide incorporated in the process of manufacture, or it may be incorporated by the painter by means of suitable and proper apparatus. The iron oxide used shall contain no free sulphur, sulphates, or acid, and shall contain not less than 45 per cent of pure unhydrated ferric oxide, without addition of any compound of calcium, barium, aluminum, or magnesium. The oil contained shall be pure raw linseed oil. The only constituents allowable besides those named shall be turpentine or benzine and liquid drier, which shall be free from resins or gum resins and resin compounds, in other words, the drier shall be pure oil drier, reduced if desired with turpentine or benzine or both.

The second and third coats shall be any approved pure linseed oil paint of the desired color; though it is specified that where white or a tint requiring the use of white is necessary, the white paint used shall conform in all respects to the specifications governing similar paint on woodwork.

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[49] This is apparently an error. Charles MacNichol, the originator of this method of treatment, recommends 3 to 4 pounds per gallon.

Repainting Iron and Steel.—For repainting, the specifications shall be the same as for new work, all loosely adherent paint to be removed before painting, all rust to be removed by sandpapering or scraping, and bare spots to be given a preliminary coat of the priming paint, which shall be allowed to dry properly before the first coat is applied.

Galvanized Iron.—The entire surface to be treated with a solution of copper acetate [50] in water (6 ounces to the gallon). Allow to dry, then paint according to the specifications for iron and steel.

Copper (Flashings), etc.—Sponge thoroughly with 160° benzole; then paint according to the specifications for iron and steel.

Tin Roofs, etc.—Remove all rosin, etc., then apply a priming coat, as specified for iron and steel. Then one finishing coat of the same or of other paints permissible under the specifications for iron and steel, according to color required.

Interior.—

WOODWORK.—For interior woodwork, when painted, the same specifications shall apply as for exterior woodwork; excepting that the reductions shall be governed by the specifications for plaster and cement surfaces, which follow.

Plaster and Cement Surfaces (Excepting Floors).—If the surface to be painted shall have stood less than one year, it shall be treated before painting with a saturated solution of zinc sulphate (about 8 pounds to the gallon).[51] The surface shall be thoroughly coated with this solution applied by a broad, soft brush (a kalsomine brush) and allowed to stand not less than 48 hours before painting. The priming coat on such surfaces, whatever the subsequent finish, shall be made from a flat wall paint or wall finish containing oxide of zinc, lithopone, etc., but free from pigments containing lead in any form. To this paint, for the priming coat, shall be added about 30 per cent of pure raw linseed oil.

If an oil-paint finish is required, the subsequent coats (two or three, as may be required) shall be any approved pure oil ready-mixed paint conforming to the general specifications for exterior work, excepting that the proportion of basic carbonate white lead shall in no case exceed 20 per cent, and that the proportion of turpentine in the vehicle shall be increased as follows:

If a paste is used, the vehicle added to reduce to working consistency shall consist of 50 per cent pure raw linseed oil and 49 per cent pure turpentine, together with the necessary drier, which shall be as specified under new woodwork, exterior.

If a semipaste paint be used the added vehicle shall consist of 30 per cent pure raw linseed oil and 70 per cent pure spirits of turpentine; the drier being governed as in the preceding paragraph.

If a prepared paint is used, before stirring, about one-fifth of the thinner portion shall be poured off and turpentine substituted therefor. If an interior prepred paint is selected, it will be satisfactory, if the percentage of zinc oxide is not under 45 per cent; the basic carbonate white lead not over 20 per cent and the asbestine, silex or barium sulphate not in excess of 20 per cent.[52]

Alternative Specification.—Prepare the surface and treat with zinc-sulphate solution as specified. Then give all surfaces four coats of paints of the color selected. Paint to be composed of 80 parts by weight of French process zinc oxide and 20 parts white lead ground in pure linseed oil.

The vehicle in the first coat to consist of 50 per cent pure linseed oil, 40 per cent pure turpentine, and 10 per cent approved mixing varnish.

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[50] The copper salt roughens the smooth surface and enables the paint to adhere. Other salts of copper act in the same way, but liberate strong acids which are injurious to paint.

[51] See footnote on p. 71.

[52] Where an exceptionally good oil paint finish is required there should be specified, in addition to the foregoing, a finishing coat of good varnish.

The vehicle in the subsequent coats to consist of 30 per cent pure linseed oil, 50 per cent pure turpentine, and 20 per cent mixing varnish; the last coat to be lightly and evenly applied.

Cement or Concrete Floors.—To be governed by the same specifications as exterior plaster, cement, etc.

Enamel Finish.—Where such finish is to be produced on plaster or cement surfaces, the preliminary treatment and the priming coat shall conform in all respects to the specifications for flat finish on plaster and cement surfaces, the priming coat and one or two subsequent coats being what is commonly known as flat wall paint, which, if white or a tint is required, shall contain oxide of zinc as an ingredient. The color to be selected for this priming coat is left to the judgment of the painter, in accordance with the effect required in the completed work.

Over the priming coat not less than two additional coats shall be applied, the exact number of coats to be specified in each case. If only two coats besides the flat coats are required, the first of these coats shall be an enamel paint or varnish of acceptable quality and the finishing coats shall be composed of similar enamel and an approved flowing varnish in equal proportions.

If the enamel used contains any white pigment, not less than 50 per cent of such white pigment shall be French process oxide of zinc, and no part of it shall consist of a lead pigment or lithopone.

If more than two coats are desired in addition to the flat coats, the first and second additional coats shall be as above specified, and the third or finishing coat shall consist of an approved flowing varnish, to which shall be added only enough of the enamel used in the preceding coats to give the varnish a distinct tint.

If a rubbed finish is desired, each enamel coat shall be properly rubbed to a perfectly smooth surface, and if a gloss finish is required the finishing coat shall be finished by rubbing with chamois skin.

Enamel Finish on Woodwork.—The same specifications as for work on plaster shall apply, with the exception of the priming coat, which shall be the same enamel paint or varnish that is used for the succeeding coat, excepting that it shall be within the discretion of the painter, if he deems it advisable, to increase the fluidity of the priming coat by the addition of pure linseed oil, pure gum turpentine, or both.

Stippled Wall Painting.—The first coat shall be as of flat wall paint specified for the painting of plaster and concrete.

The second coat shall consist of equal parts of French process zinc oxide and white lead in pure linseed oil; the vehicle used for thinning to consist of equal measures of pure refined linseed oil and turpentine.

The third coat shall consist of stippling putty and French process zinc oxide in linseed oil mixed with an approved grade of hard oil finish; this coat to be lightly and evenly stippled.

The fourth coat to consist of pure French process zinc oxide in linseed oil (of the required tint). This coat to be applied evenly and to be only of sufficient thickness to give the proper tint and show stippling.

SPECIFICATIONS OF THE NATIONAL LEAD CO. FOR GENERAL PAINTING

WOODWORK.—1. *Preparation of Surface.*—All woodwork must be thoroughly dry and seasoned before any paint is applied. No exterior painting is to be done when rain or snow is falling, during fog, or until after dew or moisture which may be on the surface has completely disappeared. From old work which has been painted before, all loose paint, scales, dirt, and dust must be entirely removed. If there are scales, a stiff putty knife, a scraper, steel wool, or steel shavings may be used, according to conditions. Where window frames, sash, doors, piazzas, etc., show cracks or scales, use a paint burner or liquid paint remover to remove the old paint. Wash off with benzine or turpentine all parts where remover has been used. Where no scales or cracks appear, sandpaper the surface gently with No. 1/2 or No. 1 sandpaper and dust thoroughly.

2. *Knot Killing.*—Immediately after the woodwork is in place, all knots and sappy streaks shall be varnished with pure grain-alcohol orange-shellac varnish (knot killer). Where knots are very resinous, a little dry red lead may be used with the shellac.

3. *Putty.*—After the priming coat of paint, as hereinafter specified, is thoroughly dry, putty up all knot holes, dents, cracks, and other defects in the surface with a pure linseed-oil putty composed of equal parts of white lead and whiting. If desired, 1 part powdered litharge to 5 parts each of white lead and whiting may be added, except on light tinted work. On repainting old work, places where putty is to be applied should receive a coat of half linseed oil and half turpentine before puttying.

BRICK, STONE, CONCRETE, AND PLASTER.—4. *Preparing Brick and Stone Surfaces.*—If any mortar has become loose and washed out, repoint all such damaged places with mortar or Portland cement before any paint is applied. Boiled oil and turpentine, half and half, may be applied on new brickwork before first coat. After priming, correct small defects in the surface with putty. New brick shall not be primed until dry. At least two or three days of dry weather shall precede painting. No painting shall be done in cold weather. Treat new mortar or cement as in paragraph 5.

5. *Preparing Stucco or Concrete.*—Stucco or concrete work should stand and dry at least a year before paint is applied. If painted within less than a year, it may be aged artificially by washing with 10 parts zinc sulphate to 90 parts water, or with ordinary carbonic acid water.

6. *Preparing Plaster Walls.*—When thoroughly dried, go lightly over the wall with fine sandpaper or wide putty knife to remove loose plaster, taking care not to scratch the surface. No painting shall be done over fresh plaster.

IRON, STEEL, AND OTHER METAL WORK.—7. *Structural Iron and Steel before Erection.*—Before it leaves the shops all structural iron and steel work shall be cleaned of all mill scale, dirt, rust, and oil and receive one coat of pure red lead and linseed-oil paint, as specified in paragraph No. 13, mixed according to formula No. 23*a*. Surfaces which will be inaccessible after erection shall receive two coats of the same paint before erection.

8. *Structural Iron and Steel after Erection.*—All structural steel and iron work shall be cleaned after erection. If there are abrasions in the paint, they shall be repainted with red lead and oil paint, as specified in formula No. 23*a*, after removing all rust with a stiff wire brush. After retouched places have dried, the entire surface shall receive one coat of red lead and oil paint, as specified in formula No. 23*b*. If steel or iron is to be exposed, add a third coat, as specified in formula No. 24*a*.

9. *Preparing Other Metallic Surfaces.*—All metallic surfaces such as are mentioned in paragraphs Nos. 10 and 11 shall be thoroughly cleaned; where solder fluids have been used the surface shall be scrubbed when possible with sand soap and water and thoroughly dried before paint is applied. All loose paint and particles shall be removed from old painted metal surfaces with a wire brush or a scraper.

10. *Painting Interiorly Exposed Metal.*—All interiorly exposed metal work, such as pipes, automatic sprinklers, steam and hot water radiators, and all interiorly exposed structural metal work, shall receive two coats of red lead and oil paint, as specified in paragraph No. 13, mixed according to formulas Nos. 23*a* and 23*b*.

11. *Painting Exteriorly Exposed Metal.*—All exteriorly exposed metal surfaces, such as tin, galvanized iron, iron or steel used in roofing cornices, valleys, gutters, downspouts, railings, gratings, fire escapes, smokestacks, etc., shall receive three coats of red lead and oil paint, as specified in paragraph No. 13, mixed and applied according to

paragraph No. 24. Paint on the underside of roofing shall be allowed to dry hard before the roof is laid.

12. *Finishing Metal Work to Suit Color Scheme.*—Where the color of red-lead paint specified for metal work does not conform to color scheme, white lead and oil paint tinted as desired shall be applied over the red-lead paint.

THE PAINT AND ITS APPLICATION.[53]—13. *Designation of Paint to be Used.*—All woodwork, brick, stone, and concrete which are to be painted shall be painted with pure white lead in oil, pure linseed oil, pure turpentine, and pure turpentine drier, mixed according to the formulas hereinafter designated for each kind of work. Each coat must be allowed to dry thoroughly before the next is applied. All metal shall be painted first with pure dry red lead, or red lead in oil, pure linseed oil, and pure lampblack ground in oil, thoroughly mixed, according to formulas hereinafter given for each specific purpose. Dry red-lead paint shall not be mixed more than 24 hours before application. When preferred, white lead and red lead mixed according to formula 21 *b* may be used for priming new woodwork, brick, stone, stucco, or concrete.

14. *Driers.*—Only the best turpentine drier shall be used. Owing to the difference in strength in driers, the painter is permitted to vary the quantity of drier in any of the following formulas at his discretion. Use only enough to set the paint sufficiently. On exterior work in cold weather, from one-fourth pint to one-half pint more turpentine drier should be used than is given in the formulas.

15. *Tinting Materials.*—In producing tints and shades, colors in oil of high grade shall be used. If colors in oil are used in quantities large enough to affect the consistency of the paint, the quantity of thinners named in the formulas shall be increased in amount equal to one-half the weight of the tinting material. Break up the white lead with oil to a semipaste; break up the tinting colors with turpentine; then mix both thoroughly before thinning the mixture.

FORMULAS.—The following formulas take no account of tinting materials. See paragraph No. 15 when adding colors to the formulas.

16. *New Woodwork Outside.*—All paint for new woodwork outside shall consist of the materials named in paragraph No. 13, and shall be mixed as follows:

(*a*) Priming coat[54] (see also 21 *b*):

Pure white lead in oil	pounds	100
Pure raw linseed oil	gallons	4
Pure turpentine	do	2
Pure turpentine drier	pint	1

(*b*) Body coat:

Pure white lead in oil	pounds	100
Pure raw linseed oil	gallons	1½
Pure turpentine	do	1½
Pure turpentine drier	pint	1

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[53] In paragraphs 13 and 15 the mention of certain specific brands which appear in the original have been omitted.

[54] The painter may exercise his own discretion in using a larger or smaller quantity of oil according to whether the wood is oil absobent, as white pine, poplar, and basswood, or less permeable, as yellow pine cypress, spruce, and hemlock. The painter may, in rare cases, find it advisable to increase the quantity, of turpentine, as in southern exposures, to prevent blistering. Where this is done a corresponding decrease shall be made in the specified amount of linseed oil. If the wood is very resinous, prepare it for priming by brushing on a mixture of 1 pint linseed oil, 1 pint turpentine, 1 pint turpentine drier. We are aware that painters often use a much heavier primer than the above. When owners or architects specify only two coats on new wood, a heavier primer is necessary, in order to cover the wood satisfactorily. In such cases reduce the quantity of oil and turpentine to suit conditions. We very strongly recommend, however, that three coats always be applied, one of which should be a thin priming coat, as specified in our formula, well brushed in. If this practice were universal, there would be less blistering of paint and the owner would get more for his money. We urge upon architects and painters to educate owners to call for three coats.

(*c*) Finishing coat:

Pure white lead	pounds	100
Pure raw linseed oil	gallons	3½–4½
Pure turpentine	pint	1
Pure turpentine drier	do	1

17. *New Woodwork Inside.*—All paint for new woodwork inside shall consist of materials named in paragraph No. 13, and be mixed as follows:

(*a*) Priming coat (see also 21 (*b*)):

Pure white lead in oil	pounds	100
Pure raw linseed oil	gallons	3
Pure turpentine	do	4
Pure light turpentine drier	pint	1½–2

(*b*) Body coat:

Pure white lead in oil	pounds	100
Pure raw linseed oil	gallons	1½
Pure turpentine	do	1½
Pure light turpentine drier	pint	1

(*c*) Finishing coat, gloss:

Pure white lead in oil	pounds	100
Pure raw linseed oil	gallons	3
Pure turpentine	do	½
Pure light turpentine drier	pint	½–1

(*d*) Finishing coat, flat:

Pure white lead in oil	pounds	100
Light enamel varnish	pint	1
Pure turpentine	gallons	3
Pure light turpentine drier	pint	½

(*e*) Finishing coat, eggshell gloss:

Pure white lead in oil	pounds	100
Pure raw linseed oil	gallons	1
Pure turpentine	do	2½
Pure light turpentine drier	pint	½

18. *Woodwork Inside, Special Finish.*—All interior woodwork upon which a specially high-grade finish is desired, shall be treated as follows, using materials named in paragraph No. 13 (for formulas 18*a* and 18*b*, see p. 77):

(*c*) New woodwork must be smooth, dry, and cleaned of all dust before painting. Apply first a coat of orange shellac, thinned with grain alcohol. Let the shellac harden, and sandpaper off. Apply a coat of paint composed of materials named in paragraph No. 13 and mixed according to formula No. 18*a*. When dry and hard, putty defects as described in paragraph No. 3.

(*d*) Old painted woodwork must be rubbed smooth with sandpaper, steel shavings, or steel wool, until all gloss has disappeared. Apply one coat of paint composed of materials named in paragraph No. 13, and mixed according to formula No. 18*b*. The first coat on old varnished woodwork may consist of 3 gallons turpentine and 1 pint of good inside varnish to 100 pounds of white lead. Putty defects as prescribed in paragraph No. 3.

(*e*) From this point new and old work shall be treated alike. When first coat is dry, rub down with No. 0 sandpaper. Repeat coats of formula No. 18*b* until no dark places show through.

(*f*) Next, make an enamel by adding pure white lead, as specified in paragraph No. 13, to light enamel varnish in the proportion of 3 pounds of white lead to 1 gallon of varnish. Break up the white lead with a little turpentine to a thick paste and then mix well with the varnish. Apply as paint. After the enamel is dry, rub down with pumice and water, and apply a second coat of the same enamel.

This completes full gloss finish.

(*g*) For silk finish rub down the last coat with fine pumice and water, clean off and finish with rottenstone and water. Finally, chamois down. (Or expense of rubbing down last coat may be avoided by applying one coat of eggshell enamel.)

(*h*) To obtain old ivory effect, tint last flat coat (paragraph 18*e*) with just enough raw sienna and medium chrome yellow to turn it off the white, before applying enamel (paragraph No. 18*f*). The enamel coats must be tinted in like manner.

(*i*) Where whiteness is desired, mix the lead for the last coat before the enamel coat with turpentine, 100 pounds to 2 gallons, and let it stand overnight or longer to settle. Then draw off the thinners from the top and bring to brushing consistency by adding turpentine and light enamel varnish.

(*a*) Body or first coat over shellac, new work:

Pure white lead (drawn as above)	pounds	100
Turpentine	gallons	2
Light enamel varnish	do.	¼
Light turpentine drier	pint	¼

(*b*) Body or first coat over old work:

Pure white lead (drawn as above)	pounds	100
Pure turpentine	gallons	2
Light enamel varnish	do.	¼
Light turpentine drier	pint	¼

19. *Old Woodwork Outside.*—All old woodwork outside shall be painted with materials named in paragraph No. 13, mixed as follows (if badly weather beaten, use more oil and less turpentine for priming):

(*a*) Body coat:

Pure white lead in oil	pounds	100
Pure raw linseed oil	gallons	2
Pure turpentine	do.	2
Pure turpentine drier	pint	1

(*b*) Finishing coat:

Pure white lead in oil	pounds	100
Pure raw linseed oil	gallons	3½–4½
Pure turpentine	pint	1
Pure turpentine drier	do.	1

20. *Old Woodwork Inside.*—All paint for old woodwork inside shall be of material as named in paragraph No. 13, mixed as follows:

(*a*) Body coat:

Pure white lead in oil	pounds	100
Pure raw linseed oil	gallon	1
Pure turpentine	do.	2
Pure light turpentine drier	pint	1

(*b*) Finishing coat, gloss:

Pure white lead in oil	pounds	100
Pure raw linseed oil	gallons	3–3½
Pure turpentine	pints	2
Pure light turpentine drier	do.	1–1½

(*c*) Finishing coat, flat:

Pure white lead in oil	pounds	100
Pure raw linseed oil	pint	1
Pure turpentine	gallons	2
Pure light turpentine drier	pint	1–1½

(*d*) Finishing coat, eggshell gloss:

Pure white lead in oil	pounds	100
Pure raw linseed oil	pints	3
Pure turpentine	gallons	2
Pure light turpentine drier	pint	½

21. *Brick, Stone, Stucco, and Concrete.*—All brick, stone, stucco, or concrete which are to be painted shall be painted with materials named in paragraph No. 13, mixed according to the following formulas. Strictly kettle-boiled linseed oil shall be used as specified whenever possible, especially on stucco and concrete. If strictly kettle-boiled oil is not available, the alternative specifications for raw oil and a drier shall be used.

(*a*) Priming coat:

Pure white lead in oil	pounds	100
Pure boiled linseed oil	gallons	7
(Or 7 gallons pure raw linseed oil and 1½ pints turpentine drier.)		
Turpentine	do	1

(*b*) Alternate priming coat (often preferred for wood, stucco, stone, or concrete):

Pure white lead in oil	pounds	70
Pure dry red lead or red lead in oil	do	30
Pure raw linseed oil	gallons	5
Pure turpentine	do	½
Pure turpentine drier	pints	1–1½

(*c*) Body coat:

Pure white lead in oil	pounds	100
Pure linseed oil (one-third boiled, two-thirds raw)	gallons	4
(Or 4 gallons pure raw linseed oil and 1 pint pure turpentine drier.)		

(*d*) Finishing coat:

Pure white lead in oil	pounds	100
Pure linseed oil (one-third boiled, two-thirds raw)	gallons	3½
(Or 3½ gallons pure raw linseed oil and 1 pint pure turpentine drier.)		
Pure turpentine	pint	1

22. *Plaster Walls.*—For painting plaster walls (interior) use materials named in paragraph No. 13, mixed according to the following formulas:

(*a*) Priming coat:

Pure white lead in oil	pounds	100
Pure boiled linseed oil	gallons	7
Pure turpentine	do	1

(*b*) Body coat:

Pure white lead in oil	pounds	100
Pure raw linseed oil	gallons	1½
Pure turpentine	do	1½
Pure turpentine drier	pint	1

(*c*) Finishing coat, flat finish:

Pure white lead in oil	pounds	100
Pure turpentine	gallons	2½
Light enamel varnish	pint	1
Pure turpentine drier	do	½

(*d*) Finishing coat, eggshell gloss finish:

Pure white lead in oil	pounds	100
Pure raw linseed oil	gallon	1
Pure turpentine	do	2½
Light turpentine drier	pint	¼

(*e*) Finishing coat, oil gloss finish:

Pure white lead in oil	pounds	100
Pure raw linseed oil	gallons	3
Pure turpentine	do	1
Pure turpentine drier	pint	1

(*f*) Finishing coat, varnish gloss finish: 1 gallon light enamel varnish, mixed with 3 pounds pure white lead, drawn as specified in paragraph No. 18.

23. *Interiorly Exposed Metal Work.*—All interiorly exposed metal work shall be painted with materials as specified in paragraph No. 13, mixed according to the following formulas:

(*a*) Priming coat:

Pure dry red lead	pounds	30
(Or 40 pounds red lead in oil.)		
Pure raw linseed oil	gallon	⅔
Pure boiled linseed oil	do	⅓
Pure turpentine	pint	½

(*b*) Body coat:

Pure dry red lead	pounds	28
(Or 38 pounds red lead in oil.)		
Pure raw linseed oil	gallon	⅔
Pure boiled linseed oil	do	⅓
Pure turpentine	pint	½
Lampblack ground in oil	ounces	4

24. *Exteriorly Exposed Metal Work.*—All exteriorly exposed metal work shall be painted with materials specified in paragraph No. 13, the first two coats mixed according to formulas Nos. 23*a* and 23*b*. The tendency is to apply the paint too thin. An excess of oil on metal gives a soft, elastic ground coat which is often detrimental to the following coats. Adhere strictly to the formulas and brush each coat out well. Mix the third coat as follows:

(*a*) Finishing coat.

Pure dry red lead	pounds	28
(Or 38 pounds red lead in oil.)		
Pure raw linseed oil	gallon	⅔
Pure boiled linseed oil	do	⅓
Pure turpentine	pint	½
Pure lampblack ground in oil	pounds	4

In considering the merits of these two specifications it may be safely stated that they are both good. On the whole, it is believed that there is more evidence upon which to base preference for the red-lead paint for metal. On the other hand, the evidence in regard to painting wood indicates that the paints containing zinc oxide are, on the whole, superior to those containing white lead alone. It is believed, however, that the specifications could be broadened and opportunity permitted of taking advantage of fluctuating market conditions in securing better prices by allowing the composition of the pigment to vary within the following limits:

Zinc oxide, not less than 25 per cent nor more than 50 per cent;
Basic carbonate white lead, not less than 20 per cent nor more than 75 per cent;
Basic sulphate white lead, not more than 35 per cent;
Extending pigments (magnesium silicate, silica, or barium sulphate), not to exceed a total of 15 per cent.

The requirements as to vehicle are satisfactory in so far as they apply to finishing coat, but a larger proportion of volatile thinner is to be recommended for all undercoats.

The following modification of the vehicle requirements is therefore suggested: [55]

For application this paint shall be suitably reduced for the several coats by the painter by adding as he deems necessary the requisite liquids, which must be only pure clear raw linseed oil, liquid drier free from rosin, and turpentine or mineral spirits. The total volatile thinner, including that contained in the liquid drier, shall for all coats except the gloss-finishing coat not exceed 25 per cent of the total vehicle, and for the gloss-finishing coat shall not exceed 10 per cent of the total vehicle.

It is also suggested that the various coats differ slightly in tint. For example, if a white paint is to be applied, the undercoats may be tinted gray or buff, the priming coat being the darkest, the successive coats grading up to a very pale tint for the next to last coat, with white for the finishing coat. This tinting will have no effect on the quality of the paint, but will very materially aid in inspecting the work as it progresses.

VIII. GLOSSARY [56]

Bloom: A clouded or fluorescent appearance on a varnished surface.

Bluing: A decided "blue cast" in finished work on varnished surfaces.

Body pigment: One that constitutes the bulk of the pigment in a paint.

Body up: To thicken.

Breaking up: The initial process in thinning a paste. (See p. 47.)

Checking: Practically the same as crazing.

China wood oil: Tung oil.

Chinese wood oil: Tung oil.

Chipping: Scaling off in small pieces.

Cold: Bluish in effect; not suggestive of warmth. (See p. 50.)

* **Color:** A generic term referring inclusively to all of the colors of the spectrum, white and black, and all tints, shades, and hues which may be produced by their admixture.

Color involves a definite effect produced by the action of light upon the retina of the eye dependent upon the optical composition of the light. This term is also used in reference to material substances such as pigments, stains, dyes, etc., but in specifications it should be recognized that color is primarily a physiological sensation.

* **Covering power:** The use of this term should be avoided if possible. This term has been used so loosely that it might mean hiding power, spreading power, or the simple property of producing a coat.

Cracking: The intensification of crazing.

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[55] Compare pp. 46 and 60.

[56] Definitions marked with the asterisk (*) are quoted from "Standard definitions of terms relating to paint specifications," A. S. T. M. (1916), pp. 591–593.

Crawling: The failure of varnish to spread or flow out smoothly on a surface.

Crazing: The formation of fine interlacing cracks on a surface.

Deadening: The loss of luster; in effect, the opposite of sweating.

Distemper: A pigment mixed with a vehicle soluble in water in distinction to oil colors.

* **Drier:** A material containing metallic compounds added to paints and painting materials for the purpose of accelerating drying.

* **Dry:** In paint materials, containing no uncombined water. In paint films, completely solidified.

* **Drying:** The solidification of a film.

Enamel Paint: A varnish paint; that is, one in which the vehicle is a spirit or oil varnish.

Extender: A pigment lacking in some of the properties required for body pigments, but which is used with them on account of its cheapness or to impart some particular property that it possesses.

* **Fineness:** A term used to denote the extent of subdivision and expressive of the number of particles of pigment in a unit volume exclusive of voids.

According to this definition, if pigment *A* has a specific gravity of 6 and pigment *B* a specific gravity of 2, and if these two pigments have equal fineness, in 6 g of pigment *A* there would be the same number of particles as in 2 g of pigment *B*.

Flaking: Same as chipping.

Flat: Without gloss.

Flouring: The gradual crumbling of varnish into dust. (See rusting.)

Greening: A decided "green cast" in finished work on varnished surfaces.

Gum: The term applied to varnish resins, except rosin and dammar. (See p. 20.)

* **Hiding power:** The power of a paint or paint material as used to obscure a surface painted with it.

In this definition the word "obscure" means to render invisible or to cover up a surface so that it can not be seen.

***Hue:** The predominating spectral color in a color mixture.

Japan drier: See "drier"; also see pp. 14 and 15.

Japans: See "drier"; also see pp. 14 and 15.

Livering: The coagulation of varnish or paint to a viscous liver-like mass.

***Nonvolatile vehicle:** The liquid portion of a paint excepting its volatile thinner and water.

***Opacity:** The degree of obstruction to the transmission of visible light.

In this sense "opacity" is a relative term, it being considered that given a film sufficiently thin, in paint technology at least, there is no absolutely opaque substance.

***Paint:** A mixture of pigment with vehicle, intended to be spread in thin coats for decoration or protection, or both.

According to this definition, a mixture of pigment and varnish is a paint and, on the other hand, a solution of stains in oil or varnish, no pigment being present, is not a paint.

***Pigment:** The fine solid particles used in the preparation of paint and substantially insoluble in the vehicle.

Asphaltic materials are not pigments except when they contain substances substantially insoluble in the vehicle in which they are used.

Pinholing: Same as "pitting."

Pitting: The appearance of numerous minute holes on a varnished surface.

Rusting: The breaking up of a varnished surface into fine particles.

***Shade:** A term descriptive of that difference between colors which results from a difference in luminosity only, the other color constants being essentially equal. A darker shade of a color is one that has a lower luminosity.

Primarily, the term "shade" is akin to shadow, designating darkness or reduced illumination, and therefore when strictly used should express only such changes as depend on reduced luminosity. It has been defined by several authorities as the mixture of black with a color, thus establishing its opposite character to "tint," but by extension of its relative sense it has been frequently and widely used to include lighter shades by use of the adjectives lighter or paler. Although such expressions apparently involve a contradiction, it is clear that while we may have a shade of color or darker color of the same sort, it is easy to conceive of another shade not quite so dark and therefore lighter.

Short: A paste or viscous substance is short when it is more or less crumbly, can not be drawn into a string between the fingers, breaks readily, lacks cohesion. Not to be confounded with the meaning of the word in "short oil varnish," when it means a varnish containing a small proportion of oil.

Size: A solution of a gelatinous material, as glue, starch, or resin, to fill the pores of a surface. (See p. 66.)

* **Spreading rate:** The rate at which a paint or paint material as used is brushed out to a continuous uniform film, expressed in terms of the area to which a unit volume, as used, is applied.

This term must not be confused with the much-abused term "spreading power." The use of the term "spreading rate" is illustrated in the following sentence: "The paint when spread on a planished iron surface at the rate of 600 square feet to the gallon will not sag or run when placed in a vertical position at 70° F."

Sweating: The reappearance of luster on a varnish surface which has been rubbed to a dull finish.

Tackiness: Stickiness.

Tacky: Sticky.

***Tint:** A color produced by the admixture of a coloring material, not white, with a white pigment or paint, the white predominating.

***Tone:** The color which principally modifies a hue or a white or a black.

Tooth: The property of certain pigments of imparting a degree of coarseness or roughness to a paint coating, causing the paint to adhere to the surface in brushing it on or preventing it sliding over the surface without properly adhering.

Varnish: A liquid with or without resin or waxes, in partial or complete solution, intended for decoration or protection, or both, and capable of being spread in a thin homogeneous film which will form hard coatings.

***Vehicle:** The liquid portion of a paint.

Here anything that is dissolved in the liquid portion of a paint is a part of the vehicle.

***Volatile thinner:** All that portion of a paint, water excepted, which is volatile in a current of steam at atmospheric pressure.

Wrinkling: The formation of furrows and ridges.

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