PAINTS
FOR
STEEL STRUCTURES

BY

HOUSTON LOWE

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INTRODUCTION

TO FIRST EDITION

About thirty years ago practice in the making of linseed oil, varnishes, japans, and colors first brought the writer into daily contact with questions regarding the manipulation of paint, its properties, and the results of the various operations to which it was subjected. Painters, engineers, architects, builders, and constructors have since been continuously asking questions whose answers involved thought and experiment.

At one time paint-making was an art, then it became a trick, now it is a science. This little handbook is written by a paint-maker, and is the direct result of study recently given to the manufacture and properties of structural steel and the use of paint in its preservation. It is published in the hope that some of the mysteries heretofore associated with the paint business may be cleared up.

DAYTON, O., 1899.

INTRODUCTION

TO FIFTH EDITION

During the ten years that have passed since the first edition of this book, the author has continued his observations, experiments, and tests on a more elaborate scale than ever before and with careful attention to every point needing consideration.

In these experiments he has been assisted by his colleagues, Mr. John R. Dempsey (painter) and Mr. Donald A. Kohr (chemist and paint-maker), to whom he hereby makes grateful acknowledgment.

In this edition of the book many changes have been made, due largely to the increasing knowledge of the problems presented. Some of these have been made at the suggestion and with the counsel of Prof. L. H. McFadden, formerly Professor of Chemistry and Physics in Otterbein University, who has also prepared most of the section on "Rust"—a subject to which much attention has recently been given.

Increasing knowledge and experience have served to strengthen the author's faith in the hypothesis under which he has been working.

DAYTON, O., Sept. 1, 1909.

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HYPOTHESIS

"The earth hath bubbles, as the water has, and these are of them." —*Shakspere.*

"Substantial progress in any science is impossible in the absence of a working hypothesis, which is universal in its application to the phenomena pertaining to the subject matter."

Paint-making has been rescued from the domain of empiricism and has become an exact science. One skilled in it can now practise it with a certainty of results, in an exact proportion to his knowledge of its principles, and to his ability in applying them to work in hand.

The theory that oil, or the binder, is the life of paint, that is, the thing that makes it wear, is misleading, and has been the cause of most of the blunders and failures with it in the past. An excess of linseed oil in paint is as much an adulteration of paint as the introduction of useless or harmful pigment. We work upon the hypothesis that the solids are coefficient with the liquids in producing the best materials, and that the secret, if there be any, lies in the proper adjustment or determination of the amount and kind of each needed to secure a perfect product. No amount of theoretical and empirical knowledge can determine questions of this kind. There are to-day many signs, however, that in the struggle for victory men are accepting the logical conclusion from classified facts, their mutual relations and sequences, that properly prepared paint is bound to win out, because it is based upon "sound idealism." The "crude materialism" of the advocates and exploiters of this, that, and the other "pure" pigment or binder, is but a relic of past ignorance, or worse, and is doomed to lose its force and to find its proper place.

PAINTS FOR STEEL STRUCTURES

PAINT AND PAINTING

"Blind fear that seeing reason leads, finds safer footing than blind reason stumbling without fear."

—*Shakspere.*

PAINT

"Give it to me to use! I mix it with two in my thought."

—*Browning.*

Paint is pigment plus binder, plus paintmaker. Paints for steel may be divided into three general classes, namely, Oil Paints, Varnish or Resin Paints, and Tar Paints.

We are now treating of Oil Paints, that is, pigment mixed and mulled with oil, and especially designed to preserve, to protect, and to better the appearance of surfaces to which they are applied.

In Oil Paints of value the end aimed at is a close union of solids or pigment and liquids or binder, that is, we take inorganic solid matter in a finely divided state and mix with it organic liquid matter, and then try to link them together either mechanically or chemically. Ordinary mechanical mixtures in which the solids and liquids have little or no affinity for each other, or in which the powders are feebly suspended in the liquid, scarcely deserve the name of paint.

The essentials of a preservative and protective covering for structural steel may be stated as follows:

I. MECHANICAL PROPERTIES. That it must work properly, that is, offer but a slight resistance to the stroke of the brush, and be of such fluid nature as to flow together after the brush so that the resulting covering, or skin, is one of even thickness.

II. CHEMICAL PROPERTIES. That it must not only dry, or oxidize, fast enough, but dry simultaneously throughout; not harden on the surface and remain soft underneath, or in painters' parlance, "skin over."

III. PHYSICAL PROPERTIES.

(1) *Hardness.* That it must be of such nature that when it has formed a skin upon the surface of the metal it can take other coats of paint without softening under them. And further, that the skin formed must be hard enough to wash clean by rain-fall.

(2) *Indestructibility.* That it must wear well, provided a sufficient number of coatings of it is applied.

(3) *Impenetrability.* That it must ex-

clude moisture and gases from the metal covered with it, that is, prevent its corrosion.

How best to secure these essential features, is a problem which has puzzled the heads and vexed the hearts of painters, chemists, and engineers for years, and it will probably continue to do so for years to come or until some means are devised under which it will be possible to determine quickly what coatings satisfy the requirements of service and use. As manufacturers of both oil and varnish paints, our faith is, at the present writing, established in oil paints, because years of study, observation, and experience have demonstrated their superiority for steel, if well made, to coatings of any other kind.

Varnish paints are more sensitive to changes of temperature than oil paints and less apt to adhere well to damp surfaces. Given ideal painting conditions, varnish paints undoubtedly can be made that will out-wear on steel the best oil paints, but these conditions are not readily attained.

From "sense impressions," gained by study of the phenomena pertaining to paint, both wet and dry, our present conception is that pigment is the objective element and liquid the subjective element in it. The pigment is the male principle; liquid, the female. In order to give expression to our thoughts upon this question, it appears necessary to consider the nature of linseed oil. Many books have been written upon this subject and there is yet much to learn. Nature did not design linseed oil for painters' use, but for sustaining the life of the flax plant. Linseed oil, even if of good quality, is not sacred, but, after centuries of use, it still holds its own as the best oil for painters' use where durability and drying are the main considerations.

Linseed oil in drying changes from a liquid, first into a sort of jelly of a colloidal nature, with a tendency to catch and retain air bubbles, and then to a solid rubber-like substance, which not only holds itself together, but also clings to any dry substance upon which it is formed. Linseed oil in drying takes something from the air, namely, oxygen, and gives off something to the air, namely, carbon-dioxide and water. Mulder beautifully describes the process and calls it "the breathing of the drying oils." In his book, "*Die Chemie der austrocknenden Oele*," he named the solid, rubber-like substance into which a layer of linseed oil finally hardens, "linoxyn." Linoxyn is a solid, not a liquid. It is insoluble in many liquids and is far less soluble in any solvent than linseed oil. We have had specimens of it for months in dilute acid and weak alkaline solutions; also in spirits of turpentine, petroleum, naphtha, linseed oil, alcohol, chloroform, acetone, carbon-bisulphide, and water, and in most of these liquids we find but slight decomposition or solution of it. These experiments indicate its power of resistance to atmospheric influences.

A layer of dried linseed oil (linoxyn) is not waterproof, although no compound is probably chemically more resistant to atmospheric influences (not mechanical wear). For example, it is claimed that a gallon of oil spread upon one hundred square feet of surface will outwear a gallon of any paint spread upon the same area of a similar surface; but it may be noted that it will require about three times as many coatings of the oil to use up the gallon as it will of the paint to use it up. From this we conclude that a layer of the paint is about three times as thick as a layer of the oil. Experiments of this kind demonstrate that one of the functions of pigment is to increase the thickness of the layer of dried paint, and that this increase of thickness is in direct proportion to the volume or fineness of the pigment. They also determine that, given the same volume of oil and the same weight of pigment, the greater the volume of the latter—that is, the finer the division of its particles—the more slowly will the paint dry and the longer will it wear.

Pigments in general use for structural oil paints, as related to their mutual action with the steel which they cover, may be classified as (1) stimulators of rusting, or pigments whose moist contact with steel produces greater corrosion than moisture alone; (2) inhibitors, or pigments whose moist contact with steel produces less corrosion than does pure water alone, and (3) indeterminates, or pigments whose moist contact with steel produces neither increase nor diminution of rusting.

Not enough preliminary experimental work has been completed yet to classify confidently many of the pigments, but the reports available indicate very strongly that precipitated barium sulphate (Blanc fixe), second grades of barytes, some ochres, some red oxides, lampblack, graphite, in fact, all the carbons except willow charcoal, are stimulators of rusting. In the case of some pigments stimulation of corrosion is due to the acid quality of soluble constituents. In the case of other pigments, such as carbons, the unlike chemical action of moisture on the particles of pigment and adjacent particles of the steel surface may cause a difference of electrical potential, and thus establish electrolytic corrosion.

In the inhibitive class are willow charcoal (on account of alkaline ash), one grade of Prussian blue, zinc oxide and notably zinc chromate, and barium and calcium chromate.

Pigments fit for use in structural oil paints are of two general classes, as they relate to the oil, viz., those which react more or less with it, notably the carbonates and all of the lead pigments; and those that have no chemical action on the oil or binder, called inerts, such as the carbons, silicates, probably ferric oxides, etc. The former class produces the quicker drying and the less durable paints; the latter, the slower drying and the more durable coatings; *e.g.*, a paint made from white lead and linseed oil when properly applied to a sound surface cannot be expected to protect it, under fair conditions, more than five or six years, whereas a paint made from a good natural iron oxide and the same oil, applied to a like surface under similar conditions, will protect it easily twice as long. The observer will note this if he will recall his observations of the durability of paint made from ordinary mineral colors on barns or freight cars, as compared with the more delicate tints used on houses and more elaborate structures.

Another feature of interest pertaining to inert pigments is, that where the same liquids are used with them for the paint for each coating applied, the observer finds that the dried paint seldom cracks, peels, or blisters, and if it does the inference should be that his paint contained an inadequate amount of pigment. Given a perfect binder, the paint problem would be simple and the only function of pigment would be to color and obscure the surface; then the hypothesis under which we are working would fall. Until, however, a binder is obtained that will dry fast enough, that when dry is impervious to moisture and gases, and that will not wear out, pigment will be necessary to shield and to protect the dried oil from the agencies that destroy it, the chief of which are rainwater and sunshine.

A pigment that will not hold the oil produces a fugitive paint. Any pigment that will take and retain oil or binding material, and that is not changed by the agencies that destroy dried oil, or the binder, will make a durable paint for structural steel provided it is fairly treated and properly applied to a surface in fit condition to receive paint.

The decay of paint is due to chemical change, and nearly all chemical reactions are accelerated by water and heat. It is therefore necessary in designing protective coverings that materials be used which are repellent of moisture and as slightly affected by heat as possible.

To understand the pigment question one needs some knowledge of forces which are insensible at sensible distances, viz., molecular forces, such as surface tension and chemical affinity. All phenomena taking place in paint are due either to physical action (heat, light, electricity) or to chemical action, that is, the tendency of different kinds of matter by interaction to produce new substances.

Andés in his work on Anti-Corrosive

Paints, in discussing the number of coats of oil paint that must be applied to iron in order to secure efficient protection against rusting, says that in establishing a standard, preference must undoubtedly be accorded to paints requiring a large proportion of oil to make them work properly. He says: " It may be laid down as a normal standard, that presupposing the use of good paint, one bottoming coat and three subsequent coatings, laid on at suitable intervals, will be required to produce a layer of sufficient thickness on iron to keep moisture away from the metal and to protect the latter from rust for a certain time." The first, or prime coat upon a surface of steel, in a fit condition to receive paint, is of the greatest importance, especially as to its drying, hardening, adhesiveness, and impermeability to water.

We work upon the theory that the paint used for priming naked steel should be of a preservative nature, *i.e.*, of such a nature that it will not only possess the power to inhibit the corrosion of the metal but also the power absolutely to exclude air and water from the metal, and that the finishing or top coats should be of a protective nature, that is, of such nature that they will protect the primer or bottoming paint from the action of rainfall, sunshine, and other external deteriorating conditions. As the first or prime coat must form a receptive foundation that will be able to hold all subsequent or protective coatings both on and up, it should be largely formed of basic materials, so composed as to secure on the surface of the metal a firm and unyielding coating of an elastic, durable, cohesive, and adhesive cement; it is probably necessary that this cement be made from a pigment that secures chemical action between itself and the liquid with which it is mixed, for it is only through the use of such a pigment that we can secure a skin, or covering, upon unheated metal that will be impervious to air and water.

Theoretically, red lead in competent hands is the best pigment to use with linseed oil for making a primer for naked steel. It forms a rapid-drying, firm, unyielding, impervious, non-corrosive, somewhat inhibitive, and receptive covering upon the metal, its only defect being that it will undergo chemical change when exposed to ordinary atmospheric conditions; therefore the necessity at all times of protecting the red lead with outer coatings of paint made from linseed oil and pigments that have no chemical action upon it, such as the carbons, ferric oxides, etc.; that is, paint made from inert pigments. Red-lead paint forms the best foundation. No one builds a stone house upon a wood foundation, but may build a wooden house upon a stone foundation.

Unfortunately, or otherwise, the cost of red lead, its great specific gravity, or weight, the great fatigue attendant upon its proper application, the improbability of getting an even coating on the surface, its tendency to fatten or set, the trouble of mixing the dry pigment with the oil, its rapid settling when so mixed, and its poisonous nature, have prevented its adoption where its virtues have been acknowledged. False ideas of economy have too often been responsible for unwise attempts to preserve valuable structures with coverings made of inferior materials, the only logical conclusion, that "the best is not good enough," being entirely lost sight of.

As to the character of the pigments that should be used with linseed oil for making paint for use as top coats over a red-lead primer, it is important that the pigments used be both chemically and physically inert, that they be in a finely divided state, and that they have an affinity for linseed oil. Given these features, whether the pigment is lampblack, graphite, oxide of iron, charcoal, silica, mica, aluminum, or what not, is a matter of little importance so far as durability is concerned. Where three or more coats are to be applied, and it is not practicable to use more than two kinds of paint, we recommend for middle coat mixtures of topping and bottoming coats.

Paint-users have no just reason for condemning this, that, or the other pigment or binder, as tested upon any given structure, unless they know, first, the history and characteristics of the material used; second, the kind and condition of the surface to which it was applied; and, third, the method of application. Many pigments, such as some kinds of red lead, iron oxide, carbon, and white lead, may give good results, if fairly treated; but, if improperly compounded and applied, prove failures. Engineers, architects, and builders should demand paints that do not require great skill, and which do not involve great fatigue in their proper application.

A perfect paint for structural steel would be one in which the pigment (inorganic) and binder (organic) formed a close union (marriage), so that there could be no separation of them—no precipitation of the pigment. In other words, it would form and secure upon the surface of the metal an even covering of an adhesive, cohesive, elastic, harmless, and durable cement, impervious to, and unaffected by either moisture, sunlight, or gases.

DESIRABLE FEATURES OF AN ANTI-CORROSIVE METAL COATING:

1. It should hide the surface.
2. Should cement itself together, and also cement itself to either damp or dry metallic surfaces.
3. Should expand and contract without breaking its own body.
4. Should present a hard, yet tough, outer surface.
5. Should be impervious to water, carbonic acid, or other gases.
6. Should be unaffected by sunshine, heat, frost, dew, or climatic changes.

7. Should be unaffected by ordinary mechanical abrasion.
8. Should wear evenly.
9. Should fail by gradual wear, not by disintegration.
10. Should leave a good surface for repainting.
11. Should not require an unreasonable amount of skill or muscle in application.
12. Should be homogeneous.
13. Should dry fast enough.
14. Should not be readily ignited.
15. Should have power to absorb and remove moisture or dampness from the metal.
16. Should have properties that will prevent corrosive action of traces of water in contact with the metal.

MAIN CAUSES FOR DETERIORATION OF PAINT:

1. Water. (Dissolution.)
2. Action of light and heat. (Chemical and physical change.)
3. Chemical action between pigment and binder. (Disintegration.)
4. Abrasion or mechanical injury. (Motion.)
5. Action of deleterious gases. (Foul air.)

WHY A WORTHY METAL COATING SOMETIMES FAILS:

1. Because of improper application. (Incompetent or careless users.)
2. Because of insufficient quantity on a given surface; not renewed at right time. (Perishes quickly.)
3. Because of an unstable foundation to

stick to. (Dirt, grease, dampness or scale under it.)

4. Because the under-coating is more elastic than that over it. (Cracks.)
5. Because not protected when drying. (Wet paint sensitive.)

PAINTING

"To be a painter have a heart and colors."
—*Munkacsy.*

Painting is paint plus painter, plus the painter's employee. It is possible to-day to get paint uniformly well prepared for almost any purpose. A painter or paint-user of the present time who attempts to mix and grind his own paints is as unlikely to succeed as if he were to attempt to make his own varnishes, brushes, etc. The coating of structural steel with paint is for the special purpose of preventing air and water from getting at it, as a combination of these will destroy steel, and that quickly, if carbonic or some other acid be also present. It is not our purpose to suggest or discuss methods of applying coverings to structural steel other than to insist that a mechanic, to do good work, must have good tools to work with, and fair conditions under which to do the work set before him. Many worthy paints are ruined because flowed on with a broad, thin, flat brush, not much better than a common whitewash brush, instead of being rubbed out and into the surface well with a good, full, round bristle brush; and then, again; painters are apt, if the pigment used is heavy, or the parts to be covered are difficult of access, to add an excess of thinners to save labor or cost of material. A layer of air exists on all surfaces; hence the importance of rubbing out paint thoroughly, as otherwise bubbles ot air may be covered, which, coming through the paint, render the coating porous. It is known that the durability of any oil paint depends largely upon the number of particles of pigment upon a given area of surface, and that the more particles of pigment the better the protection to the binder and to the metal underneath; the evil of thinning too much is, therefore, obvious. As to the spraying of paint upon structural steel by means of an air compressor, it is argued that this method conveys air and moisture to the metal and corrodes it; besides, its many other disadvantages have led to its abandonment wherever tried. The adherence of paint will be increased if the metal is moderately heated before it is primed, because if it is warmed by artificial heat the surface will be dry. " Mill marks," even though made with inferior paint, generally afford excellent protection to steel because the paint was applied to the metal when it was clean and warm.

When painting is to be done in the field, or under conditions that make it impracticable to warm and dry the metal artificially, it is a good plan to apply paint heated to a temperature of about 150° F., especially when the temperature of the atmosphere is below 55° F. This warming of paint may be attained by placing the pails of paint in vessels of hot water. It is important that one should always note the atmospheric conditions when the work of painting is being done. A temperature of about 70° F. and an atmosphere that is free from moisture favor the right kind of drying. The humidity of the atmosphere is even more important than its temperature. Nothing retards drying more than dampness and darkness.

To aid in the inspection of new work, a shop coating of linseed oil is often specified. This does, in a measure, protect the iron from rust, but a very uneven film of dried oil will probably be secured from this method of treatment. Oil applied to a vertical surface runs off until the layer reaches a certain thickness. Where the current meets with an obstruction it piles up into a thick and uneven coating. These thick parts of the layer may require months to harden into a substance firm enough to be fit to paint over. The results are most disastrous in cold weather when oil thickens and contracts. As painters express it, oil, when applied to cold steel, crawls, wrinkles, and crinkles. If linseed oil is used as a primer on steel, it should be used hot, not warm, then it will penetrate the skin of the metal and one may gain a thin and even film, hard enough to form a surface fit to receive paint.

Many places, such as "the under and inner sides of girders, bolt heads and nuts, rivets, etc., which should be painted with great care to prevent the incursion of water, are often overlooked or neglected. To aid inspectors, a proper check upon the workmanship can be secured by selecting different colors for the several coatings, so that uncoated or defective places may be readily detected."—(*Andés.*) It is also important that connecting parts, that is to say, joints and fittings be heavily coated with a lute, preferably of red lead, before the work is assembled.

A distinguished British painter and author writes: "The less paint that is put on at each operation, consistently with a proper covering of the ground, the better will the ultimate result be." "Less paint and more painting," he impresses as a need "to quite 90 per cent. of painter students." "The under coats should dry more quickly and be harder than those above them, and the difference in drying between two adjoining coats should not be very great."

We have made numbers of experiments that give to us ocular demonstrations of the fact that a first coating of good red-lead paint, covered by a layer of good carbon or ferric oxide paint, will prevent corrosion for a much greater period than two coatings of any one kind of paint.

To secure durability with paint it should always be used fairly thick, and then well rubbed out under the brush into thin and even layers. If not well brushed it will lack firm adherence. From micrometer measurements with the microscope, we find that single coats of dried paint vary in thickness from $\frac{1}{500}$ to $\frac{1}{1000}$ of an inch, the difference being due either to the manner of application, that is, whether under light or heavy pressure of the brush, or to the difference in the consistency of the paints tested. Few realize the thinness of coatings of paint or the strains to which its dried films are subjected.

Viaducts, tunnels, crossing bridges, and like structures, require different treatment from structures exposed chiefly to the action of rain-water and sunshine. Linseed oil, in drying, as already explained, undergoes a metamorphosis; and the result of this process is a solid, linoxyn. A film of this dried linseed oil, or linoxyn, is not quickly formed without dry air and light, but once formed, is much more stable and better able to resist the agencies that destroy paint than a thin layer of undried linseed oil; in other words, wet paint is much more sensitive than dried paint. Therefore, in locations that are ill-ventilated, that get no sunshine, that are damp and filled at times with steam and acid gases, one must have material of a different kind for coating steel. We have found varnish or resin paints best adapted to work of this kind, and especially so where a primer coating of red-lead paint, so composed that it will dry rapidly, has been used.

Much has been said and written of late regarding the apparent failure of paints of wide reputation when applied to steel cars. From a limited personal knowledge and from information gained from others who have handled thousands of hopper-bottom gondolas and box cars with steel under frames, we are led to conclude that some contract shops use less of the paint specified than has been presumed. What they do use is frequently applied in the open under such unfavorable weather conditions, and under conditions of painting contracts at such a low rate per car, as to preclude the possibility of either employing competent workmen to apply the paint or such application of it as to prevent corrosion. Good paint illegitimately thinned with cheap oils or japans is practically rendered of little protective value, and to apply it to steel cars more or less covered with rolling-mill scale, dew, frost, snow, slush, ice, grease, etc., is waste of time, thought, and material. There is no reason why paint applied to steel cars should not wear as well as paint applied to any other steel structures, provided it is used under fair conditions, applied by competent workmen, and enough time for drying is allowed to elapse between coatings. The only way to secure better painting is to employ competent and vigilant inspection of the painter's work.

FACTORS THAT AFFECT RESULTS IN PAINTING.

1. Location of the structure, for example, seaboard or inland.
2. Kind and condition of the surface.
3. Quality of the paint and its temperature.
4. Workmanship of the painter.
5. Number of coats applied and their sequence.
6. Time allowed to elapse between coats.
7 Atmospheric conditions when painting is done.

STEEL

"This is the very painting of your fear."

"Steel is iron plus carbon and other impurities, plus metallurgists." Prof. Henry M. Howe, in his recent work, "Iron, Steel, and Other Alloys," writes in part as follows:

"What are the iron and steel of commerce and industry? Examined under the microscope they prove to be composite or granitic substances, intimate mechanical mixtures or conglomerates of microscopic particles of certain quite distinct, well-defined, simple substances, in widely varying proportions. * * * *

"The chief of these substances are:

"1. Pure (or nearly pure) metallic iron

called *ferrite*—soft, weak and very ductile. * * * *

"2. A definite iron carbide called *cementite*, which is harder than glass and nearly as brittle. * * * *

"Besides these two constituents of prime importance, there are three others of moment:

"1. Graphite—unimportant in steel, but important in gray cast iron.

"2. Slag—present in wrought iron.

"3. Austenite—hardened steel: steel hardened by sudden cooling from a red heat consists essentially of austenite, a solid solution of carbon in iron of varying degrees of concentration."

Steel is usually divided into four general classes; namely, Converted or Cemented Steel, Crucible Cast Steel, Bessemer (acid or basic) Cast Steel, and Open-Hearth (acid or basic) Cast Steel. Our troubles and complaints come from structural (Bessemer and Open-Hearth) steel. To know some of the causes for them, it is well occasionally to visit works where steel is made, to investigate modern methods of handling and treating it, and to talk with those whose lives have made them familiar with the ethics and practice of steel producers.

It is not easy to-day for the uninformed to get sound, homogeneous, inert structural steel—that is, metal that is free from pipes, seams, water-cracks, blow-holes, discoloration, etc., or excess of oxygen or nitrogen, or that is of fairly fine, even grain, elasticity, and hardness; and when it may be had few are willing to pay for it. It is probably wise to apply a cheap paint or a tar preparation to a surface of structural steel that is covered with scale, rust, grease, and dirt, as it frequently happens to be when taken from the works or from the field to-day. Coatings of worthy paint upon such an unstable foundation are bound either to be decomposed or soon forced off the surface by the moisture, scale, or grease under them.

Up to the present time no physical or chemical tests have been discovered that can distinguish between Bessemer and Open-Hearth Steel, or between acid and basic, provided the same materials have been used in making them. This fact is "so well known that some of the best and most careful engineers in the country, including those who are most stringent in their demands concerning physical and chemical qualities, do not make any surface inspection," and yet flaws, flash, rust, grease, and dirt in the surface are things that may destroy the work of the painters. No surface of structural steel ought to be coated with paint unless it shows the grayish-white, natural color of the metal.

Now, it may be noted at times immediately after the removal of the scale from the surface of steel by means of a sand-blast, that the parts are soon covered with rust. In reply to a direct question of the author, Prof. Henry M. Howe recently wrote: "The reason for this is that the sand-blast roughens the surface, and that on a rough surface of iron, as we all know, rust forms much more rapidly than on a smooth one. You can leave a razor lying in a drawer for years without its rusting at all, because it is so highly polished, whereas a piece of rough, unpolished steel lying beside it will rust very rapidly.

"There is no doubt that the scale itself is in one sense a preventive against rusting; that is, it adheres pretty closely to the skin of the metal and mechanically excludes the air. The scale itself is in most cases unoxidizable; it consists approximately of magnetic oxide, which is extremely stable. It is true that if part of the surface be covered with scale and the rest be naked, the naked part will rust more rapidly because of the presence of that scale on the neighboring parts, the scale acting 'by difference of potential' to produce corrosion by electrolytic action. But so long as the scale is intact, it acts similarly to paint, excluding the air." The writer adds: "I do not know that I can fully suggest a remedy—the only thing that occurs to me as worth trying is to modify the sand-blast so as to reduce to a minimum its roughening effect, as, for instance, by using sand the grains of which are *round* instead of *sharp* (and such sand can be found), or by using *fine* sand."

"The durability of a steel structure will depend upon the quality of the metal, upon its mass, and the measures taken to prevent its deterioration; and its strength, measured either by the stress it will bear or by its resistance to corrosion, is only the strength of its weakest member."

Steel differs from wood, brick, etc., in that there is much less absorption of the paint into its body, so that the adhesion of the first or foundation coating of paint upon steel is necessarily almost wholly restricted to its surface, and the adhesion of subsequent coats is restricted to the surface of the dried paint already in position. "The better adhesion of paint to puddled iron than to steel can readily be accounted for by the greater roughness of the puddled iron, due to its containing a small quantity of cinder widely scattered throughout it in minute particles, whereas steel contains none."

Steel is perhaps the most tenacious of all known substances—that is, tough—having great cohesive force between its particles, so that they resist any effort to pull or force them apart; and as we fancy all matter to be in a state of motion at all times, the difficulty in preserving it by use of a paint is at once apparent. The defects in modern structural steel are largely due to its mechanical working—that is, it is run out too hot and too quick, and afterward not properly housed and cared for. " The enormous increase of late in its use in building and engineering construction in various forms, demands increasing and vigilant attention to its maintenance and present condition, wherever it has been placed, as either from corrosion, fatigue, vibration, or general deterioration, the metal may become so impaired as to be unfit to do that for which it was designed."

RUST

"Sloth, like rust, consumes faster than labor wears; while the used key is always bright."

Rust is iron plus air and water, plus nature. Attention has been directed to the rusting of iron the past few years as never before. The increasing use of iron, and especially of steel, in buildings, bridges, cars, and fences is a sufficient reason for this greater public interest. Besides, there is a strong suspicion in the minds of many users of steel, amounting to a conviction with some, that modern-made steel rusts faster than the old-fashioned product of the iron mills.

Rusting was once so obvious and simple a matter that everybody understood it.

Now there is great doubt whether anybody really knows how rust comes to be. The chemist long ago analyzed it and pronounced it a hydrated oxide of iron. So, since the atmosphere contains an abundance of free oxygen and water, what more natural and reasonable than to suppose that these components of the air combine directly with iron. Growing chemical knowledge, however, has discredited the explanation of simple combination; iron, in fact, cannot unite directly with oxygen except at a very high temperature.

Two or three theories of importance have been proposed to account for the phenomenon of rusting.

In the order in which they have been suggested and defended they are the carbonic-acid theory, the hydrogen-peroxide theory, and the electrolytic theory.

The advocates of the carbonic-acid theory hold that carbonic acid attacks iron, converting it into a ferrous carbonate. The hydrogen thereby released combines with oxygen of the air, or other sources, which in turn decomposes the ferrous carbonate to ferrous hydroxide, or rust, releasing in the latter reaction the same amount of carbonic acid as was originally present. This attacks a new portion of iron and forms a second particle of rust. A moderate supply of oxygen would render this process indefinitely continuous on the initial small supply of carbonic acid. The theory is logical, but too great importance seems to be attached to it by those who assume it to be the only method, or even principal method of rusting.

The claim of the hydrogen-peroxide theory is that iron, oxygen, and water react to produce ferric oxide and hydrogen peroxide. In the combination of these three substances rust is produced, and also the initial portion of hydrogen peroxide which attacks a new particle of iron, and thus, as under the preceding theory, the process is continuous, or cyclic.

The weakness of this theory lies in the impossibility of detecting hydrogen peroxide during rusting under experimental conditions. It has few advocates.

The electrolytic theory, which no doubt has the strongest support, is based upon the recognized tendency of metals to go into solution, even in pure water. The act is accompanied by the release of hydrogen positively charged with electricity, leaving on the metal a corresponding charge of negative electricity. If oxygen is at hand to combine with the hydrogen, the electrical tension is relieved in an infinitely small current and new portions of the metal pass into solution; otherwise the action is arrested by the non-conducting quality of the thin film of hydrogen.

The presence of minute particles of suitable impurities in or on the iron, whose solution tension differs from the iron, or the presence of acids in the water, facilitates the discharge of the electric tension, and hence, the continuous removal of particles of iron. On the other hand, the presence of alkalies, and a few other substances that decrease hydrogen ion concentration, will diminish or even stop iron solution and rusting altogether.

This, in brief, is the substance of the electrolytic theory of rusting, the more complete explanation of which would involve the details and language of the ionic theory of chemical action. Corrosion of iron, in the sense in which that term has been used in this section, has nothing whatever to do with electrolysis by stray electrical currents from outside sources. The currents involved in rusting under the theory of electrolytic action are almost infinitely short and minute, and originate in or on the metal itself.

The theory is valuable to the extent that it suggests reasonable and practical remedy of the defects either of the metal or its proposed covering, or both. As in the treatment of diseased animal and plant tissues, so in this case, intelligent diagnosis must precede the application of preventives of rust. Experimental work following the lines of the electrolytic theory in seeking, first, to prevent, or "inhibit" corrosion by a priming coat, and, secondly, to diminish the penetration of water by suitable overcoats, is promising good results, and a final solution of the problem is confidently looked for.

The tendency of rust to grow and spread out from a centre has an adequate explanation in the electrolytic theory. This phenomenon is especially pernicious, as it results in pitting, or, under a paint coat, in a growth which finally flakes off the paint and exposes large areas of the iron.

Some agencies that have been observed greatly to hasten corrosion are:

1. Alternate exposure to air and water.
2. "Constant or alternately occurring heavy rains with drying winds, hot sun, frost, or snow."
3. "Collection of soot, dust, or anything that will retain moisture in sheltered places."

4. Heating apparatus in buildings causing damp places in walls.
5. Salt-water drippings from refrigerator cars.
6. Brackish soil and sewage.
7. Smoke and heated vapors issuing from locomotives.
8. Exposure to acid gases, vapors, or liquids.
9. Electrolytic action.
10. Electrolysis by stray currents from street railways and other electrical lines.
11. Decaying animal and vegetable matter.
12. Damp, vitiated air in tunnels, subways, covered and confined places of all kinds.

CLEANING

"I require a menial to clean it now and then."

The cleaning of structural steel is a problem for engineers, and yet common sense tells us, as paint-makers, that heat of sufficient degree to evaporate any moisture that may be in contact with the metal, or to burn up any grease that may rest upon it, is, perhaps, the best method of preparing the surface of structural steel properly to receive a covering of paint. In repainting old structures, all dirt, loose scale, and dead paint should be removed with wire brushes, or chisels made of old files, then all rusty places soaked with benzine, and a hot-blast blow-torch flame applied to burn out all the benzine, and to change the yellow (hydrated) oxide of iron to the red (anhydrous) oxide, which is inert and harmless. Objection is made to this method of cleaning steel because of the expense of it.

The sand-blast seems to offer the most rapid and economical means of preparing structural steel to receive a coating of paint. It leaves the metal not only clean, but fairly dry—an important and essential condition if a receptive surface is to be secured. The painting of the metal should follow immediately after the cleaning is done, as cleaned metal will corrode under ordinary atmospheric conditions much more rapidly than uncleaned metal. It is argued that "aside from the chemical or scientific value of sand-blasting there is a very serious question of its effect upon the eyes and lungs of the operator." It is further argued that the sand-blast should not be used to clean new metal because it will remove the black oxide, or mill scale, which in itself, like paint, is a protection against rust formation so long as it remains. The sand-blast certainly offers the best means of cleaning old structures which are very rusty, and now that portable air compressors are available, it is fair to presume that metal coatings will have better opportunities in the future to prove the life that is in them than they have had in the past. For an interesting paper on sand-blast cleaning of steel, with discussions by prominent engineers, the reader is referred to the " Transactions of the American Society of Civil Engineers," Vol. L., Paper No. 948.

It is said that a thousand times as much iron and steel is cleaned by pickling as is cleaned by the sand-blast; for example, all work that is to be electro-plated and all work to which a vitreous enamel is to be applied, such as granite ware, etc. Why more structural steel is not cleaned in this way we do not know, but it is well to remember that pickling with hot dilute sulphuric acid or with hot muriatic acid should be avoided, unless one is well prepared to neutralize thoroughly and remove all traces of the acid from the metal immediately after it is taken from its bath.

LIQUIDS AND SOLIDS

Eligible for Use in Designing Metal Coverings

LIQUIDS

> "How many fondly waste the studious hour,
> To seek in process what they want in power;
> Till all in gums engross'd, macgilps, and oils,
> The painter sinks amid the chemist's toils."
>
> —*Shee.*

Linseed Oil.—First amongst the liquids used for paint-making stands a worthy quality of linseed oil, the best available binder, because its great affinity for oxygen makes it the best drying oil known.

There are many kinds of pure linseed oil made and sold to-day, and a guarantee of an oil's purity is no evidence of its quality or commercial value. One might classify the "pure" linseed oil marketed as follows: praiseworthy, fair, and unsatisfactory.

A praiseworthy linseed oil is of a pale yellow color, brilliant, limpid, drying well, with a rich luster, and having a pleasant, nutty taste.

A fair linseed oil is a yellowish oil, with a brown hue; clear, drying fairly; not very pleasant to the taste, but somewhat bitter.

An unsatisfactory linseed oil is of a greenish or dark color, uncertain taste, cloudy, and drying poorly.

If all the liquid matter pressed out of flaxseed were painter's oil, and it were common to get a uniformly fair quality of it, substitutes for linseed oil could not be sold. Forty years ago, one and one-half gallons of oil were considered a fair yield from a bushel of flaxseed; to-day, with steam and hot pressure, two and one-half gallons are not enough to satisfy the sellers of the "strictly pure."

The quality of linseed oil depends as much upon the quality of the seeds from which it is made, as upon the manner in which the oil is expressed from the seeds, and upon the way in which it is afterward stored and cared for. The seed of the flax plant is a laboratory in which we find working:

1. Albumen (plant flesh), the growing principle.
2. Mucilage, starch, and sugar as elements for nourishment of the embryo flax plant.
3. Oil, "which may be changed into sugar and starch and used as plant food."

Space does not permit us to go into the effects of climate and soil upon the quality of the flaxseed; the ill effects of frost and excess of rain upon it; the good effects of age upon it (old seed better than new seed); nor into the quantities of foreign seeds, like those of the wild mustard, rape, and pigeon weeds, generally found associated with those of the flax plant. But to give an idea of the many kinds of flaxseed used by crushers, we would refer to "the regulations for the inspection of flaxseed, adopted by the Board of Directors and approved by the Board of Trade of the city of Chicago, to be in full force and effect on and after July 1st, A.D. 1899," and to this day operative.

Boiled Linseed Oil.—The author first boiled linseed oil in 1869. It was boiled in bulk in open kettles, holding 1,000 gallons each, over an open fire, the pigment used as an oxidizing agent being either litharge or red lead. The heat was kept on the oil until it was hot enough to scorch a feather or melt a piece of tin (good thermometers or pyrometers were not to be had then as now). Such boiled oil sold then for six cents per gallon over the price of raw linseed oil, and it would be worth at least that difference to-day for some purposes if it could be had. We know of no one that sells it, but we know of some old painters who have their own kettles and cook it. Boiled oil of this kind is rich in luster and body (a kind of varnish).

The temperature of the boiling oil and the length of time the given temperature is sustained are important factors in the quality of the product. Oil boiled at 400°–450° differs from that at 575°–600°. The one cannot be substituted indiscriminately for the other with assurance of getting the results expected.

Commercial boiled oil is an uncertain quantity. We know of no satisfactory chemical or mechanical tests that determine its quality. Experiment and observation have taught us that no treatment of flaxseed oil improves it like storage and repose in tanks under favorable conditions. Under unfavorable atmospheric conditions, raw oil in paint may be made to dry better and more rapidly than boiled oil. When blended with a japan or siccative of the right kind, well-settled raw oil dries simultaneously throughout. Boiled oil dries on the surface first, and therefore is more apt to crack. A fair quality of boiled oil is preferable to raw oil made from unripe or impure flaxseed, or to raw oil improperly treated.

Linseed Oil Substitutes.—None of the standard literature upon oils recognizes any animal, vegetable, or mineral oil as the equal of linseed oil for painter's use. Some of them are valuable as thinners or extenders of it, improving both its working and drying properties, especially if the linseed used be viscous. The base of the best substitutes for linseed oil is linseed oil itself. Various petroleum products of greater density than benzine are sometimes added to linseed oil, with or without other ingredients, to form paint oils. These are merely mechanical mixtures, the unworthiness of which increases as the percentage of linseed oil decreases. The non-drying and non-sticking properties of petroleum are so pronounced as to offset any virtue it may possess in offering resistance to atmospheric influences.

Spirits of Turpentine is miscible with linseed oil in any proportion. As a thinner, it ranks high; if of good quality, it has a refreshing smell and will, we think, entirely evaporate; it improves the working and wearing property of paint under many circumstances, but diminishes its lustre. Good spirits of turpentine is not difficult to obtain; when it has deteriorated by age its quality may be restored by redistillation.

Petroleum Naphtha ("benzine") is very volatile and readily ignited; if free from impurities, like paraffine, glue, and water, its limited use, under certain conditions, is not objectionable but often advantageous on account of its volatility. It also permits of the formation of a higher gloss in the dry paint coating than can be obtained when turpentine is used; and when old paint is to be covered, benzine in the coat applied will impart to it better cementing properties than will be imparted by spirits of turpentine.

However, paints containing benzine tend to thicken up when allowed to stand open, due to evaporation of the light thinner. Other drawbacks to its use are its inflammable nature, and the fact that its low price may in many instances lead to its excessive use, in which case it is an injury to paint.

Painters' Japans and Siccatives, or Driers.—Paints dry by evaporation and by oxidation. The function of driers of any kind is to increase the rate; they are usually made from lead or manganese oxides cooked in oil, and then reduced with some solvent like spirits of turpentine or naphtha. Resin is frequently added to harden the oil. Resin causes the japan itself to dry more rapidly, but reduces its power to dry oil paint. Present conditions often demand quick-drying paint; in such cases use the best japan you can get, so that you will not shorten the life of your paint. The quality of a japan depends as much upon its cooking as upon the quality of the materials used in making it; too much heat or too long a heat frequently spoils it. It is not easy to enumerate all the possible ways in which a given number of things, like the ingredients of a painters' japan, may be mixed and combined together, nor the changes that may result from an excess of this or that component part, nor the degree or period of heat to which it is subjected. The only simple way that we can suggest to test the quality of a japan is to have a standard sample, whose efficiency has been proven, for comparison. A good japan is a painter's best friend, but it takes some little time and skill to determine its durability, drying, and binding properties. Concentrated driers are obtained by heating linseed oil with excessive weights of lead and manganese oxides until the product becomes viscous, like sticking-plaster. Liquid driers are concentrated driers thinned out while hot with naphtha or spirits of turpentine; sometimes rosin or better resins are added to give viscosity. The function of painters' japans, etc., should be to "hurry up" the drying of the binder, yet the lower grades are often used as extenders or cheapeners.

Metallic Soap.—The principal constituents of linseed oil (about 85 per cent.) are the glycerides linolein, linolenin, and isolinolenin. They are "esters of glycerine and linolic, linolenic, and isolinolenic acids"; and it is to them that the drying of linseed oil is due. These glycerides are very easily saponified. The soaps formed from them with potash, soda, or ammonia readily dissolve in water, but those containing lead, calcium, iron, zinc, or manganese as the base are more or less insoluble, and are usually known as metallic soaps.

Japans embody the soap principle; and, although the production of a lead soap by grinding white lead with oil is denied by some investigators, we believe it is the soap principle in well-made linseed oil paint that gives to it two of its most valuable properties; namely, rapid drying and easy flow. We claim that to-day a satisfactory paint, for outdoor use, cannot be made unless it embodies the soap principle. The saponification will result either from the pigment proper or from one or more of the elements of a pigment forced into the binder by heat.

SOLIDS

"Their time in envious search of colors lose,
Which, when they find, they lack the skill to use."
—*Shee.*

The solids applied as paint to iron may be classified as (1) stimulators of corrosion, (2) preventives, or inhibitives of corrosion, and (3) inerts. Stimulators embrace some natural pigments that are either slightly soluble themselves, like gypsum, or that contain soluble impurities. Many manufactured pigments also must be included on account of the presence of traces, at least, of stimulative acids and salts employed in the process of manufacture, or resulting therefrom. Inhibitives include chromates of the alkaline earths, and a few other pigments not so certainly determined. Zinc yellow, which is a double chromate of zinc and potassium, is a conspicuous member of this group.

Inerts, or indeterminates, are pigments that have been observed to exert neither stimulative nor inhibitive influence sufficient to classify them in either of the foregoing groups.

In view of the very brief time that has elapsed since the investigation of the relation of pigments to corrosion began it would be unwise, if not unfair, to make a classification of pigments at all comprehensive upon the basis of stimulating and inhibiting qualities. It appears to be pretty well established, however, by numerous tests that some pigments that have heretofore been confidently used on steel are unsafe for protective covering of exposed iron work. As complete information as it is possible to secure along this line may be found in a report prepared this year (1909) by Allerton S. Cushman, of the Office of Public Roads, United States Department of Agriculture.

The classification followed in this section is the usual one of chemical constitution.

CARBONS

The prominent paint pigments of the carbon group are graphite and lamp-black, or soot. They depend for their coloring principle upon the carbon contained in them, and, if well made, have no chemical action upon the liquid with which they are used. But, with the possible exception of wood charcoal, it is not recommended to use carbon paint as primers on steel.

Graphite exists in two forms—amorphous and crystalline, or fibrous. The crystalline form, 80–95 per cent. carbon, includes kinds called globular, granular, foliated, scaly, flake, etc. Any of these kinds is to a limited extent eligible for paint-making, but the amorphous 80–90 per cent. carbon is generally conceded the best on account of its susceptibility to finer division. Much of the stuff sold as graphite is but a carbonaceous schist—that is, a kind of coal or slate. Genuine amorphous or crystalline graphites do not make good paints; they are soft, unctuous, and greasy, and serve better as lubricators, but if compounded with a pigment or pigments that have affinity for oil, like red lead, white lead, zinc oxide, etc., good results may be obtained from their use as an important component of paint.

Electric graphite is now in use at times as a carbon pigment. It is made by heating anthracite coal to a very high temperature (as high as 6,000° F.) in an electric furnace. A graphite of uniform and superior quality is obtained. It contains about 90 per cent. of carbon, and the remaining 10 per cent. consists of matter as inert as the graphite itself.

Lamp-black—that is, soot or the black of smoke—represents almost pure carbon when prepared with proper care. The raw materials for its manufacture are numerous, including rosin, naphtha, coal-tar products, tallow, or any oily substance which will burn with a smoky flame, provided its use is not prohibited by considerations of cost.

These materials are burned according to their nature either in burners or heated kettles in such a manner as to produce a very smoky flame. This smoke is then collected in bags or chambers.

Lamp-blacks are not changed by air or

sunlight, and when well made are excellent pigments

Gas-black is the soot from the partial combustion of a hydrocarbon gas; the pigment must be an impact black, free from grit and dirt. It is not suitable for mixing with white lead or zinc for making tints. The particles of gas-black are said to be in form of little stars, while those of lamp-black have that of filaments.

Bone-black.—A black made by burning bones in retorts or furnaces without air, just as charcoal is made from wood. The mineral matter of the bones is, of course, all retained in the finished product.

OXIDES OF IRON

Oxide of iron pigments are obtained from natural and artificial sources; they vary largely in their characteristics, and in their chemical composition. Pigments of this class suitable for making paint may range from 98 per cent. down to as low as 10 per cent. of ferric oxide, their value as pigments depending less upon the amount of iron present than upon their physical properties, and the composition of the material which is not oxide of iron.

Roasted iron ores often yield excellent pigments, the quality depending upon the character of the ore, the construction of the furnace, the uniformity of the heat, and the care and attention given to the milling and grinding.

Natural ores or mineral earths seldom yield pigments that are good for making metal coatings, for the reason that they contain more or less water, and are apt to contain sulphur or other unstable elements, one exception to this being the rich hematite ore from the Lake Superior district. It yields a heavy pigment of value. One reason paint compounded from it wears so well is because of its specific gravity. It is almost a pure ferric oxide, and requires a small proportion of oil to prepare it for application in a paint.

Artificial oxides of iron are sold under a variety of names, such as Indian, Turkey, Venetian red, etc. If properly made, some are stable pigments. They are made under a variety of processes, but usually by calcining copperas. Years ago, Venetian reds were burnt ochres, and, therefore, produced more durable paints than the copperas reds of the present day, which latter are apt to contain traces of sulphuric acid, and frequently excesses of land-plaster and powdered limestone.

LEAD PIGMENTS

Litharge is a heavy yellow powder frequently containing metallic lead and dirt. It is prepared by heating metallic lead or the dross from molten lead in an oven, through which is passed a current of air.

Its value as a pigment is restricted, for unless used in proper combination with other pigments, its action on the oil may be so great as to shorten the life of the paint.

Red Lead is formed by the continued heating of litharge in the air at 575°–750° F. Its quality depends on the care and skill employed in its manufacture; much of the commercial article contains metallic lead, vitrified particles, and excessive amounts of litharge.

Red lead contains more oxygen than does litharge, but for chemical reasons its action on linseed oil should be much less than that of litharge, when used with it in paint. Experience has shown this to be a fact, and has also demonstrated that a high grade of red lead is a valuable pigment.

Such a grade of red lead, when properly mixed for use, and applied to a smooth, vertical surface, should neither run, separate, nor sag. Red lead should be used as a plaster upon steel, not as a paint. We know of no first coating equal to it, for it forms a tough, adhesive, and unyielding cement, that not only dries well, but does not retard the drying of any paint spread over it. It is claimed that the fact that red lead sometimes hastens the drying of any paint spread over it is a reason for its condemnation. It is true that if the red-lead coat is not dry when it is painted over, it will quickly oxidize or burn up the paint or varnish covering it; but, if the red-lead priming coat is made to dry right (if hurried work is to be done), or if a mixture of it and raw linseed oil are allowed ample time to dry, then the paint topping it will be permitted to live out its natural life. Red-lead plaster should always be protected by elastic coatings, the pigments largely composing which should have no chemical action on the binder, and should be repellent of water.

Orange mineral results from the calcination of white lead; in the finished product the carbonic principle remains. It closely resembles red lead in composition and in its properties, but is more bulky and works better. Its use will probably increase.

White Lead.—White Lead is the best white pigment with one base known to-day. It is popular with painters because of its working and drying properties, and because of its covering or hiding power. At best it is a soft, sensitive, and unstable compound, and often, as sold, it is but a mechanical mixture of White Lead and other salts of lead that are white. Corroded lead is not amorphous, but more or less crystalline in form.

White Lead is a mixture or compound of lead carbonate and lead hydrate. A perfectly finished White Lead contains two parts of lead carbonate and one part of lead hydrate (and nothing else), the former giving whiteness and the latter only hardening the oil; but without it there is no paint, only a wash. Excess of lead hydrate lessens the opacity of the paint, too little lead hydrate lessens its binding power and working quality. One who has had much experience with White Lead writes: "The

'Strictly Pure,' as found in the market today, ground in oil, is a mechanical mixture of White Lead, acetate of lead, chemically pure carbonate of lead, partially corroded lead (in all stages of corrosion), rotten metallic lead, rotten tan-bark, and excess of water."

"The Dutch Process of corroding lead is a 'happy-go-lucky' one."—(*Terry.*) Under it a uniform product cannot be obtained, unless the pigment, after being taken from the stacks, is ripened and finished by alternate washings and aërations until it is relieved from harmful ingredients and excesses; for example, excess of water, lead acetate, lead carbonate, etc. Time and money only can accomplish this result. "The time is probably quickly coming when, except for indoor or the commonest purposes, White Lead Oil Paint, that is, White Lead ground in oil, with perhaps some linseed oil, turpentine, and little driers, will cease to be used for any engineering structure except of the meanest kind." —(*Newman*).

ZINC WHITE

Zinc white, or the oxide of zinc, has been attracting attention in the past few years. The action of the French Government in requiring its use upon all public structures in preference to White Lead has doubtless, in a large measure, brought this about. However, it is a dangerous pigment to use, because, when mulled with linseed oil (especially oil containing much free fatty acid), brittle soap seems to be formed, which causes a paint made from it to lack adhesiveness, and peel or scale off. Then, again, if a dried film of paint made from it is exposed to the action of carbonic acid and water, more or less of the zinc oxide is converted in time into zinc carbonate, which is more obviously crystalline and more bulky than the oxide; therefore, such a paint would lose its hiding power, and increase in volume, causing motion in the dried paint. The remedy for the defects in zinc oxide is to combine it with other pigments that will improve it.

The varieties of zinc oxide sold are of two essential kinds: First, that from the oxidation of metallic zinc; second, that obtained from the sublimation of zinc ores. The former are more dense and better paint pigments than the latter. (Occluded gases.)

The particles of zinc oxide are "needle-formed," like snow. The objectionable features in oxide of zinc may be largely overcome by tempering and combining it with lead products, oxides of iron, carbon, or any hard, indifferent powder.

ZINC CHROMATE

The only use made of this pigment in structural iron paints is as an inhibitive of corrosion. Being a double chromate of zinc and potassium, and somewhat soluble, it acts, when pure, like potassium chromate in preventing rust. Some other chromates, such as calcium and barium chromates, have the same power.

The use of inhibitive chromates is yet very small, partly, no doubt, because their actual utility has not been proved by endurance tests, and partly because the use of any quality short of chemically pure is worse than useless, since the impurities may be stronger stimulators of corrosion than the zinc chromate is an inhibitor.

REINFORCING MATERIAL

An important function of the solids in paint is to protect the dried binder from destructive influences. Some substances, by virtue of their stable nature, possess this property in a high degree. They do not act chemically upon the oil, and are not easily changed. They are classed as inert pigments, and should be used simply as a means of improving and increasing the durability of the paint.

PIGMENTS ALLOYS

" How many metals make the bronze of Corinth ? "

Regardless of color, there is no one pigment that will " answer all the requirements, fill all the offices," of a perfect pigment to mix with linseed oil for paint-making; not a single pigment that will do what pigment must do, until a better medium is found for paint-making than linseed oil; namely, "take and retain the binder, cover and obscure the surface," prolong the life of the oil, and make it dry fast enough for practical use. Certain solids, under certain conditions and in certain proportions, have mutual action upon each other; they interchange elements and combine to form new substances, just as metals alloy and form new metals. Now, applying this truth to pigments: In order that chemical combination may follow, or that that which is bad in one pigment may be linked with that which is bad in another, to produce a new pigment that is good, it is necessary that the solids under consideration be very finely divided, very closely intermingled; and that the affinity between them be great enough to excite the desired interchanges and to form the new substance.

It is upon this sound theory that some combination paints are unwittingly made. If such paints are scientifically and honestly made, they are worthy of the utmost confidence, and we think they will ultimately displace all others.

TESTS

"Prove all things, hold fast that which is good."

Paint tests may be of three kinds; namely, Chemical, Mechanical, and Physical tests.

Chemical Tests.—In the selection of solids and liquids for paint-making, it is well to know that they contain no deleterious matter, such as soluble solids or destructive liquids, nor useless substances either to make weight or to make bulk. Chemistry can tell these things, but it cannot foretell the quality of the finished paint from a knowledge of the materials used.

"Chemistry is physics applied to atoms and molecules."—(*Tyndall.*) A chemical analysis applies to very small quantities of the substances used, and the accuracy of the results obtained from it depend entirely upon the method of sampling. When one considers that about all pigments are allotropic, that no two lots of paint liquids are exactly alike, and that any prepared paint changes more or less, in one way or another, with age, the chemist's test is proved to be of value in so far as it relates to the matter subject to his analysis and determinations, and no further.

The popular idea of a chemist is that of one who can analyze material substances and determine their composition—that is, take them apart; the main study of the progressive paint-maker of to-day is synthetic chemistry—that is, combining separate substances into new forms. Chemistry can tell things that may have been used in making a paint; it can foretell some phenomena that it may develop, but it cannot at all surely predict its "vis viva"—that is, what the stuff will do, and what it will do is the only true measure of its value or worth. "Chemistry is the science of affinity." —(*Simon.*) "Essentially heterogeneous bodies excite chemical affinity." Do you fancy that a chemist can probably know the affinities that exist in the kinds of gross matter used by the paint-maker as well as the paint-maker can? The solids and liquids used to secure a worthy paint must have a liking for one another, else you cannot get a fairly homogeneous liquid mass;

if you do not get that, you have a poor paint. Further, the quality of paint depends quite as much upon its physical as it does upon its chemical properties.

Mechanical Tests.—By this is meant tests made by a skilful painter. No one can determine the working qualities of paint as well as the man whose eye and hand and arm are trained through practice. The importance of the proper application of paint receives less attention than it deserves; *e.g.*, air bubbles may be worked out of paint by means of thorough brushing with good tools, and then again a poor painter may use 25 per cent. more material upon a given surface than a good painter will use, and get poorer results with it. Engineers and architects should demand the employment of competent artisans to do their painting, for results are often more dependent upon the intelligence and good will of the painter than upon the quality of the material used.

It is worthy of mention that, in all the years the company, with which the author has been connected, has been making tests of oil paints upon roofs, bridges, and test-plates of wood, iron, steel, and glass, we have never had the paint blister, scale, or peel off, although, of course, results have often been non-concordant and we have noted great difference in durability, covering, working, and drying properties. Why? Because each coat has been applied by an expert painter with thought and care, to a surface in fit condition to receive it, and the paint was, in each instance, protected when drying.

Physical Tests.—By this is meant weather tests or the exposure of the dried paint, on metallic or other surfaces, to the destructive forces of nature, such as sunshine, rainfall, frost, dew, heat, cold, light, darkness, etc., or to those agencies which are frequently present in atmospheric air, that shorten the life of dried paint, such as acid or alkaline gases and vapors. Comparative tests on limited surfaces—that is, small panels of steel, iron, or glass—may be misleading because the painter, unless experienced in making such tests, cannot gauge his work with unfamiliar material, and because his brush may not be in condition to give the paints an impartial trial.

However, given a properly equipped testing-room, a thoughtful painter trained by long and constant practice in making comparative tests on small panels, and a systematic method faithfully pursued of examining and recording conditions and results; we believe tests of an unfamiliar paint or paint material made against one of similar nature and use and of known properties, will give on exposure to the weather more reliable information regarding the value of the new material than any other method now in common use. In this way it is possible to control carefully the variable factors always present in each painting job, such as condition of surfaces, character of paint, state of weather, and method of application, each of which has far-reaching effect on the durability of the paint coating.

Actual service tests under normal conditions give the most conclusive data to guide us, but so long as it takes years to make them, common sense dictates that consumers should hold fast to materials that universal experience has proven trustworthy, until better are found. Accelerated tests under "abnormally severe conditions" have little value unless "the results obtained by the method selected will be in harmony with long-time service tests." It is easy to test the water-proofing quality of a dried coating of paint, but such a test determines nothing more than the ability of the paint to exclude water from the surface underneath it. It is easy to test the effect of artificial heat upon dried paint, but this does not determine the power of the paint to withstand sunshine. We have found no quick test to determine the probable life of paint, under given conditions, but are led to conclude that one intimately acquainted with the properties of the subject-matter, and with the forces of nature, may reasonably predict its life, if he knows the method of application, the conditions under which it is to be exposed, and the condition of the surface upon which it is to be applied.

CONCLUSION

> "Facts are nothing, but the ideas they signify, the analogies that they evoke, are everything."
>
> —*Jean Moréas.*

Guided by study of the phenomena pertaining to the subject-matter—that is, oil paint—and reasoning by analogy and inference from practice and experiments, at the present time, the following conclusions have been reached in regard to structural steel coatings:

1. That the surface of steel must be in fit condition to receive paint, provided a worthy paint is used; otherwise, it is better to use a cheap paint or tar preparation.

2. That to know the probable results to be obtained from the use of any paint ma-

terials, one must know the following things about them; namely:

A—Their history and mode of preparation.

B—Their physical properties.

C—Their chemical properties.

3. That a competent paint-maker can design a paint to meet any reasonable conditions of location, atmosphere, temperature, surface, application, drying, and wear, but that in order to do so he must know the conditions; that these being known he should be entrusted with the manufacture of a coating to accomplish the results desired.

4. That the priming, or first coat of paint, upon any surface, is the most important one, and that it should form an inhibitive, firm, unyielding, and receptive foundation for those to follow it.

5. That under-coats should dry harder and more quickly than those above them, and that the difference in drying between adjoining coats should not be very great.

6. That the quality of the binder is equally as important as the quality of the pigment.

7. That the quantity or weight of pigment used is equally as important as its quality or volume.

8. That the time and method of application are equally as important as the quality of the paint.

9. That no accelerated tests can be the equivalent of a long-time service test.

PAINT {
Theory is practice applied to atoms and molecules.
Practice is theory applied to masses.

REFERENCE TO BOOKS

"Books should follow the sciences, not the sciences books."

The following list of books, while by no means exhaustive, includes some of the most reliable treatises on the subjects briefly considered in this little manual:

"Iron, Steel, and Other Alloys." Henry M. Howe.

"Steel, A Manual for Steel Users." William Metcalf.

"Manufacture and Properties of Structural Steel." Henry Huse Campbell.

"Iron Corrosion and Anti-Corrosive Paints." Louis E. Andés.

"The Corrosion and Protection of Metals." A. H. Sexton.

"Rustless Coatings, Corrosion and Electrolysis of Iron and Steel." M. P. Wood.

"The Corrosion of Iron" (Pamphlet). Allerton S. Cushman.

"Corrosion of Fence Wire" (Pamphlet). Allerton S. Cushman.

"The Corrosion of Iron and Steel" (Pamphlet). Alfred Sang.

"Protective Coatings for Conservation of Iron and Steel" (Pamphlet). Robert S. Perry.

"Linseed Oil" (Pamphlet). Otto Eisenschimel.

"Handbook on Petroleum. A Treatise on the Industrial Uses of its Products." Thompson Redwood.

"A Treatise on Color Manufacture." Zerr and Rubencamp.

"The Chemistry of Pigments." E. J. Parry.

"The Manufacture of Paint." J. Cruickshank Smith.

"Manufacture of Varnishes, Oil Crushing, Refining, etc." Livache and McIntosh.

"Technology of Paint and Varnish." Alvah Horton Sabin.

"Chemistry and Technology of Mixed Paints." Maximilian Toch.

"Analysis of Mixed Paints, Color Pigments, and Varnishes." Holley and Ladd.

"The Chemistry of Paints and Painting." A. H. Church.

"Painting and Painters' Materials." Condit.

"Science of Painting." J. G. Vibert.

"Protective Coverings for Iron." J. Spennrath.

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