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THE PAINTING OF STRUCTURAL METAL (STEEL, GALVANIZED METAL, TIN PLATE AND COPPER)

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Contents

GENERAL CONSIDERATIONS

The fundamental requisite of a priming-coat paint for any metal surface is that it adhere permanently to the surface. In preparing the surface and selecting the primer, this important fact should be kept constantly in mind. All paint should be applied in bright, warm weather, and all surfaces when painted should be clean and dry. Painting should not be done early in the morning when the structure is damp from dew. Ample time should be allowed for each coat of paint to dry before applying another coat.

It is generally believed by most competent paint technologists that good linseed oil paints made with heavy or medium weight pigments (sp.gr 2.5) should contain more than 28 percent by volume of pigment in the dry film. The paint formulas given in this paper are based upon experience with average pigments of good quality and raw or boiled linseed oil. If a given lot of pigment is coarser than the average good grade, it may be necessary to increase the proportion of pigment to get a paint of good working properties. On the other hand, if a given lot of pigment is much finer than the average good grade, it may be necessary to decrease the proportion of pigment to keep the paint from being too thick for proper brushing.

The federal specifications referred to are believed to represent satisfactory materials for the purposes indicated. "Federal Standard Stock Catalog," section IV. Federal Specifications, part I, Index, lists all federal specifications with information as to how they may be obtained. This index can be purchased for ten cents (stamps not accepted) from the Superintendent of Documents, Washington, D. C.

STRUCTURAL STEEL

The steel should be thoroughly cleaned by sandblasting, scraping, or wire brushing. While the color of the priming coat is in itself of little importance, provided the work is properly done, inspection during application is much easier if the color of the paint is distinctly different from that of the iron or steel. Each additional coat should differ sufficiently from the coat on which it is applied to make inspection easy.

The steel must be protected by the paint in contact with it, and since it is difficult to be sure that every part of the structure is covered by the priming coat, it is best to have the second coat like the priming coat except for a slight difference in color. The succeeding coats should protect the underlying paint and furnish the desired color. White and slightly tinted paints are less durable and more expensive than dark-colored paints. For this reason they are seldom used on structural steel.

Priming Paint

Various exposure tests made at the National Bureau of Standards and similar work done by other observers indicate that in general the nonvolatile portion of priming coats for steel should contain at least 29 percent by volume of pigment, and that two pigments stand out, bulk for bulk, as superior to all other pigments for priming coats for iron and steel. These are basic lead chromate and red lead.

The variety of basic lead chromate used as a priming pigment, and found somewhat superior to red lead for this purpose, is that known as scarlet lead chromate, American vermilion, or chrome red, and is a crystalline pigment which tends to settle badly in a paint. The more valuable variety of basic lead chromate, known as chrome orange, deep shade, has a finer grain and does not settle as badly in a paint and therefore would probably be even better than the scarlet lead chromate. (See final coats). All pure basic lead chromate is much more expensive than red lead, which doubtless explains why it is not used more extensively for priming. Could it be sold at a price not more than 1.2 times that of red lead, it might be a serious competitor of that widely used pigment.

Basic lead chromate.- Basic lead chromate paints should be made by grinding the basic lead chromate to a paste with part of the oil, and then thoroughly mixing this with the remaining vehicle by running again through the mill. While our tests have generally been made with basic lead chromate paints containing about 75 percent by weight of pigment and 25 per cent by weight of linseed oil without volatile thinner of any kind, it is believed that the addition of some volatile thinner would make the paint flow more readily into cracks, porous iron, and the irregularities of a steel structure. The paints should therefore be made to approximate the following composition:

Dry basic lead chromate --	15 1/2 pounds
Raw linseed oil --	5 pints
Turpentine --	2 gills
Liquid drier --	2 gills
Yield about	1.02 gallon

or

Dry basic lead chromate --	15 1/2 pounds
Boiled linseed oil --	5 pints
Turpentine --	1 pint
Yield about	1.02 gallon

These paints weigh about 21 pounds per gallon and the non-volatile portion contains about 30 percent by volume of pigment.

Red lead[1]. For many years, unadulterated red lead-

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[1] A booklet entitled "Structural Metal Painting" by A. H. Sabin and F. M. Hartley, Jr., issued by the National Lead Company, 111 Broadway, New York City, while obviously written to promote the use of red lead, contains so much valuable information that any one concerned with painting steel will profit by reading it.

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linseed oil paints have been considered the best paints for priming structural steel. This opinion is held by an overwhelming majority of unbiased engineers, as well as by other observers, and has prevailed ever since structural steel came into use. Formerly, such paints were made without any liquid drier or volatile thinner, but now it is generally admitted that some liquid drier and volatile thinner improve the quality of the red lead-linseed oil mixtures.

Exposure tests on red-lead paints indicate that a high proportion of pigment gives the best results. The exact upper limit of pigment has not been determined, but we believe that red-lead paints properly mixed and made according to either of the following formulas (Fed. Spec. TT-R-191) can be considered "standard" red lead priming paints for structural steel.

Dry red lead	20 pounds
Raw linseed oil	5 pints
Turpentine	2 gills
Liquid drier	2 gills
Yield about	1.02 gallon

Red lead paste in oil . .	20 pounds
Raw linseed oil.	3 pints
Turpentine	2 gills
Liquid drier	2 gills
Yield about	0.94 gallon

These paints weigh about 25 pounds per gallon, and the non-volatile portion contains about 30 percent by volume of pigment. For second coats with either basic lead chromate or red lead paints it is advisable to add about 1/2 gill (2 ounces) of lampblack in oil to the above formulas. This will change the color so as to facilitate inspection.

Blue lead (Basic lead sulphate blue).- One of the two American manufacturers of this pigment does not recommend it for use on steel; the other manufacturer recommends it most highly as a protective paint for steel. For first and intermediate coats, a good mixing formula using blue lead as paste in oil, is:

Blue lead, paste in oil . . .	100 lb (about 2 7/8 gal)
Raw linseed oil	2 3/8 gal (about 18 7/16 lb)
Turpentine or mineral spirits .	1 3/4 gal (about 11 1/3 lb)
Drier	1/4 gal (about 1 3/4 lb)

Weight per gallon -- about 18 lb
Volume percent of pigment in dry film -- about 30.

Our observation is that this paint does not equal the above described red lead paint and that it is somewhat inferior to a properly formulated, deeply tinted lead-zinc paint as a priming and second coat on structural steel.

Lead-zinc.- Deeply tinted lead-zinc semipaste (Fed. Spec. TT-P-36), raw linseed oil (Fed. Spec. JJJ-O-336), turpentine (Fed. Spec. LLL-T-791a), and drier (Fed. Spec. TT-D-651) mixed in the proportions of

Lead-zinc semi-paste in oil	100 lb	(about 4 1/4 gal)
Raw linseed oil	1 gal	(about 7 3/4 lb)
Turpentine	1 gal	(about 7 1/2 lb)
Drier	1/2 gal	(about 3 1/2 lb)

will yield a lead-zinc paint weighing about 17.5 lb to the gallon and containing about 31 percent by volume of pigment in the dry film. To facilitate inspection during application, it is advisable to have the semi-paste tinted red or brown rather than gray. For the second coat, add about 1 pint (1 lb) of lampblack in oil to the above mixture, or about 1/2 gill (2 oz) to each gallon. This should change the color sufficiently to facilitate inspection during application.

Both the lead-zinc and the blue lead paints have excellent working properties and are easier to apply than the red lead paints. The lead-zinc paint gives somewhat better protection than the basic lead sulphate blue, but the difference is small and the two paints may be considered competitive.

Cheap priming paints.- Dull red and brown iron oxide paints meeting Fed. Spec. TT-P-31 and black paint meeting Fed. Spec. TT-P-61 are typical of many low-priced paints often used for painting structural steel. They are excellent as finishing coats, and while they are inferior to all of the paints mentioned above for direct application to the metal, they do give considerable protection. A very cheap painting job can be obtained by applying iron oxide paint meeting Fed. Spec. TT-P-31 as a priming paint. (The addition of 15 to 20 percent of red lead, zinc or lead chromate or zinc oxide pigments to the pigment in this paint distinctly improves the paint.) For the second coat, a small amount of black paint meeting Fed. Spec. TT-P-61 can be added to change the colorto facilitate inspection.

Mixed primers.- Various commercial linseed oil priming paints for structural steel contain basic lead chromate, zinc chromate, red lead, or a mixture of these pigments, along with cheaper pigments or extenders of lighter weight. One such mixture of pigments, said to give good service, is

Chrome orange -- 40 percent by weight
Blue lead -- 40 percent by weight
Silica and asbestine -- 20 percent by weight

A properly formulated linseed oil paint made with this pigment has a color which makes inspection easier than is the case with a straight blue lead paint. It is doubtful whether it is any better as a rust preventive coat than the blue lead paint. The 20 percent by weight of silica and asbestine in the pigment actually amounts to 38 percent by volume. This volume relation is the important point to remember. In this connection, so called "extended" or "reinforced" red lead paints (pigment being a mixture of about 60 percent by weight (about 32 percent by volume) of red lead and 40 percent by weight (about 68 percent by volume) of silica or asbestine) may brush easier than the heavy, unadulterated red lead paints, but they are distinctly inferior to the latter as priming coats for structural steel.

The addition of some red lead, chrome orange, other lead pigments or other basic pigments, such as zinc oxide, to iron oxide paints will improve them, but the simultaneous introduction of an equal or greater volume of extending pigment will probably more than neutralize the beneficial effect of the addition of the good pigment.

Quick-drying primers.- Quick-drying metal primers for automobiles and machinery are generally highly pigmented iron oxide primers in which the vehicle is a thin varnish (long-oil spar or the new synthetic resin type). They dry to smooth (self-leveling) velvety flat to eggshell finishes, which give excellent foundations for the decorative coats. Some dry overnight while others dry within one or two hours. Some of the pigment combinations are, by weight, 1/3 zinc chromate or basic lead chromate and 2/3 iron oxide; others are equal parts of these pigments. At least one primer consists of pure red lead and synthetic resin varnish.

Final Coats

The function of the final coat on structural steel is to protect the underlying coats, which in turn protect the steel from rust, and to give the desired color. Since black and dark-colored paints are more durable than light-colored paints, dark colors are commonly used. Red lead paint should not be used as/final coat. It is not only too expensive, but it does not retain its color, and on long exposure to sun and weather develops small checks to a greater extent than many of the much cheaper dark paints. Blue lead does not hold its color on exposure. Chrome orange is suitable for both priming and finish coats. For a finish coat the addition of some varnish to the vehicle is recommended. The "international orange" paint used on airway signal towers contains this pigment. One good formula for this paint, which of course should be mill-ground and not just hand-mixed, is

Pigment	C.P. chrome orange of approved color -- 90 percent by weight Magnesium silicate -- 10 percent by weight
Vehicle	Raw linseed oil -- 80 percent by weight Spar varnish (TT-V-121) -- 10 percent by weight Liquid paint drier -- 10 percent by weight
Paint	Above pigment -- 70 percent by weight Above vehicle -- 30 percent by weight

For finish coats of other colors, paints meeting the following federal specifications may be used: black, Fed. Spec. TT-P-61; dull red or brown, Fed. Spec. TT-P-31; olive drab, Fed. Spec. TT-P-81; gray and various tints, Fed. Spec. TT-P-36; green, Fed. Spec. TT-P-71.

The retention of color and gloss and general appearance of all dark-colored, linseed oil paints, such as those just mentiondd, can be improved by adding a small amount of spar varnish to the paint. The amount of varnish (Fed. Spec. TT-V-81 or TT-V-121) added should be quite small -- from one-half pint to a pint per gallon of paint, and care should be taken to select a varnish which will mix properly with the particular paint.

One of the best finish coats is an aluminum paint made by mixing about 2 lb of aluminum powder, TT-A-476, with one gallon of varnish, TT-V-81.

GALVANIZED IRON

Since the zinc coating on galvanized metal offers a better protection from rusting than any paint coating, it is not necessary or advisable to apply as many or as thick coats of paint to galvanized metal as to ordinary iron and steel. It is well known that it is difficult to get paint to adhere to galvanized metal. The safest, easiest, and cheapest method of preparing galvanized metal for painting is to let it weather. Nelson and Jamieson[2] recommend two

2 "The Painting of Galvanized Iron and Sheet Zinc", Research Bulletin, The New Jersey Zinc Company, 160 Front St., New York City.

to six months. We would recommend at least six months. While stating that properly executed sandblasting is the best quick method of preparing such surfaces, Nelson and Jamieson recomment several etching solutions, as follows:

(a) 60 volumes denatured alcohol
30 " toluol
5 " carbon tetrachloride
5 " commercial concentrated hydrochloric acid

(b) 6 oz copper acetate in 1 gal water

(c) 2 oz copper nitrate crystals
2 oz copper chloride crystals
2 oz ammonium chloride crystals
1/6 pint commercial concentrated hydrochloric acid
1 gal water

Solution (a) will cut grease as well as etch. If the metal is not free from grease, solutions (b) and (c) must be preceded by a grease-removing operation.

The U. S. Navy Department[3] prescribes weathering before

3 "Instructions for Painting and Cementing Vessels of the U. S. Navy", Edition of 1931

painting galvanized metal. Before painting galvanized work that has not been weathered, the Navy Department recommends cleaning the new galvanized iron with ammonia or vinegar or by using a priming solution similar to (c) above, except that the hydrochloric acid is omitted.

Directions for using solutions of copper salts vary. Some, for example the Navy Department, allow the solution to dry and then dust off. Nelson and Jamieson recommend washing with clean water after the solution has dried. The latter method seems preferable.

Numerous other etching solutions have been used successfully. A man of wide experience in railroad work has recommended to us the use of a water solution of zinc sulphate for roughening galvanized metal. Since the plating out of copper by the etching solutions containing copper salts may promote electrolysis, the solutions that do not contain copper are probably safer.

A proprietary product that is extensively used for etching various metals preparatory to painting is an alcoholic solution of phosphoric acid. This solution seems to be one of the most logical materials for this purpose. Ordinary syrupy phosphoric acid is soluble in alcohol and the solution will readily wet practically all metallic surfaces. The phosphates of the metals are insoluble, hence the etching may be, and probably is, accompanied by the deposition of a film of phosphate, which may serve well as a protective coating if it adheres closely. <u>Like the other etching solutions it should be followed by thorough washing with clean water and careful drying before painting.</u>

Even when every precaution has been taken to prepare the surface, paint scaling and peeling on galvanized iron are all too common. Peeling has been observed after two or three years on parts of galvanized iron structures which had been weathered for six months, then primed with good red lead paint (formula taken from Fed. Spec. TT-R-191), followed by a gray tinted white lead-linseed oil paint.

While it has been rather general practice to recommend the same expensive, highly pigmented priming paints for galvanized metal as for ungalvanized steel, it is doubtful whether this is really good practice. A nationally known corporation that turns out exceptionally well painted equipment has adopted the following procedure. After sandblasting (using low pressure) just enough to dull the spangle and leave a matte surface, but with a negligible loss of zinc, a coat of primer and a finishing coat (both coats rich in oil) are applied. The following is a quotation from a letter written by the testing engineer of that corporation. "First: We have a substantial protection from the zinc in the galvanized coating and consequently do not need a full body paint. Second: The following coatings are very thin and flow down into the minute cavities occasioned by the sandblasting, giving good anchorage and sealing pin holes. Red lead assists in a little etching action, and carbon black is used as the finish coating in order to have the finish color black.

"<u>Galvanized roof primer</u>

Dry red lead	10 lb
Boiled linseed oil	9 1/2 gal
Turpentine	1 7/8 gal
Drier	1/8 gal

"<u>Galvanized roof finish</u>

Dry red lead	5 lb
Carbon black paste	31 lb
Boiled linseed oil	6 1/4 gal
Turpentine	1 7/8 gal
Drier	1/8 gal

The carbon black paste referred to in this formula is 18.0 percent carbon black and 82 percent boiled oil.

It is interesting to note that while the priming and other coats on ungalvanized steel contain more than 28 percent by volume of pigment, the above primer for galvanized metal contains less than 1 1/2 percent, and the finish coat contains only about 4 1/2 percent by volume of pigment in the dry film. It should be remarked that over 5/6 by volume of the pigment in the above finish coat is carbon black, which probably has the finest grain and is the most opaque commercial pigment, and therefore offers the greatest protection from the destructive action of light on the organic binder.

The writers have had no first-hand experience with the above described system of painting galvanized iron, but believe it to be sound and practical. They have had some very good results with aluminum paint as a primer for galvanized iron. This paint is made from 1 1/2 to 2 pounds of aluminum powder to one gallon of good exterior spar varnish. Using 2 pounds of aluminum to one gallon of varnish will result in about 17 percent by volume of pigment in the dry film. It is interesting to remember that the flaky particles of aluminum powder are many times larger than particles of carbon black, and tend to rise to the surface of the paint film. The dry film is therefore much richer in organic binder next to the metal, and the greater content of opaque aluminum flakes in the upper portion of the film protects it from the light. A single coat of aluminum paint, therefore, consists of a layer at the bottom that is mainly organic binder, with a pigmented layer near the top. This structure is somewhat similar to the structure of the two-coat system mentioned above.

Finishing coats.- Since paint fails on galvanized metal by flaking off, it is advisable to use as few and as thin coats as will give the desired appearance. The building up of thick layers of paint should be avoided.

TIN PLATE

The usual red or brown iron oxide paint (TT-P-31) (preferably modified as suggested under cheap priming paints, p. 6) is an economical as well as an excellent paint for tin (terne) plate, such as is used on roofs. Care should be taken to see that the new tin, before painting, is wiped with a cloth saturated with gasoline or turpentine to remove any oil or grease. The paint should be well brushed out. This is especially true on nearly flat tin roofs, as thick coats will crack later on. Repainting should not be done too frequently, or cracking of thick coats may result. On the other hand, tin-coated steel is rapidly destroyed once rusting starts. For this reason, it should not be allowed to rust before painting.

COPPER

Copper, bronze, or brass gutters and flashings, as well as copper or bronze screening, are apt to cause bad yellowish-green stains on light- or white-painted houses, owing to the washing off of corrosion products. Exposure tests at this Bureau indicate that one of the best ways to paint copper or bronze surfaces is to wash off any grease, using gasoline or turpentine. The surface should be roughened slightly with sandpaper, and a priming coat composed of 1 1/2 to 2 pounds of aluminum powder to 1 gallon of aluminum mixing varnish (TT-V-81) applied, followed by the desired color coat. Weathered copper or bronze screening should be thoroughly dusted, and then given two coats of a thin black paint (1 gallon of TT-P-61 ready-mixed paint thinned with 1 quart of turpentine, or a thin black enamel (1 gallon TT-E-521 enamel thinned with 1 pint to 1 quart of turpentine). Some of the best grades of black auto top dressings, which are free from asphalt, but are essentially thin, water-resistant, carbon black enamels, make excellent screen enamel.