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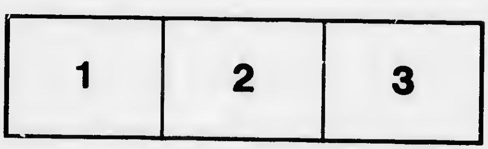

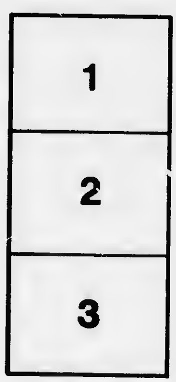

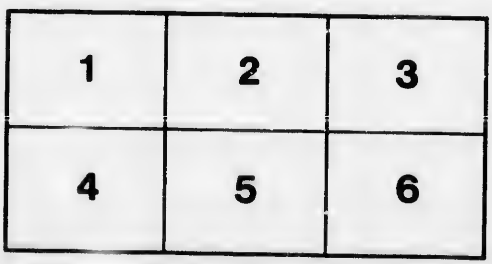

PAINTING METAL BRIDGES

BY

WILLIAM B. MACKENZIE

MEM. CAN. SOC. C.E., MEM. AM. SOC. C.E., ASSISTANT ENGINEER INTERCOLONIAL RAILWAY

MONCTON, CANADA.

REPRINTED FROM THE CANADIAN ENGINEER

1897.

PRICE, TWENTY-FIVE CENTS.

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Painting Metal Bridges.

In the early part of 1895 I began to investigate the subject of painting metal bridges. After reading what literature I could obtain, I determined to make a few experiments for myself, the results of which are here presented. I do not feel at liberty to give manufacturers' names in a communication of this kind, particularly as my tests are so few; but I have no objection to giving, in a less public way, such facts as I have, to persons interested in the subject.

Twenty-four new wrought-iron plates, one foot square and three-eighths of an inch thick each, were painted two coats of different kinds of paint, under precisely similar conditions, the boiled linseed oil being the same in all, excepting those samples obtained ready-mixed from the manufacturers. These plates were provided with hooks on the back, and hung on the lower chord eye-bars of a steel railroad bridge 1,900 feet long, across a strait or arm of the sea, in latitude 45° 56′ N., longitude 60° 59′ W. They stood vertically at a height of nine feet above the water surface, and were exposed to the sun and salt air at all times, and also to salt spray in rough weather. They faced the prevailing wind from the north-east.

This strait, or arm of the sea, is situated about 35 miles from the Atlantic Ocean, lies north-east and south-west, and forms a narrow passage five miles long and 1,900 feet wide, between two large inland basins. The strait is bounded by high land on both sides, the bridge crossing it in an east and west direction. The wind usually comes from the north-east, and a light breeze causes spray to be dashed against the floor. In storms, the spray is thrown over the floor and across the bridge. The rise of tide in the open sea, 35 miles distant, is five feet, but here the rise is only six inches.

Metal corrodes here very rapidly. The bridge itself was erected in 1890. One coat of iron oxide paint was applied in the shop and another coat given after erection. In 1892, it was considerably rusted, and two coats of iron oxide paint were put on the lower chords and floor system; but without proper inspection or scraping. In 1894, scales one-eighth of an inch thick were removed from the end stiffeners of the floor-beams on the north side. Pieces of this scale were trimmed to exact dimensions and the cubic contents calculated. On being weighed, the scale was found to weigh slightly more than one-half that of new steel.

A chemical analysis of iron-rust scale from the outside of the Conway Tubular Bridge, in England, is as follows:

Sesquioxide of iron	92.9	per cent.
Protoxide of iron	6.177	"
Carbonate of iron	0.617	"
Carbonate of lime	0.295	"
Silica	0.121	"
Ammonia	trace.	
	100.000	"

In August, 1895, our bridge was thoroughly scraped and painted with two coats of iron oxide paint, the analysis of which is as follows:

Color	Indian red.	
Fineness	80 00	
Body	85.00	
Strength	70.00	
Iron oxide	48.16	per cent.
Insoluble matter	51.84	"

Adulterated slightly with clay.

It is now in good condition; but will require constant attention to remedy defects in the painted surface as they appear.

It will be seen by the record of the experimental plates (see table) that the asphalt paints, the carbon

RECORD OF TWENTY-FOUR PAINTED PLATES.

EXPOSED ON A STEEL RAILROAD BRIDGE OVER AN ARM OF THE SEA, LAT. 45° 56′ N., LONG. 60° 59′ W.

Mark on Plate.	Kind of Paint.	How Mixed.	No. of Coats	When Painted.	When exposed on Bridge.	Length of time Exposed.	State when examined by W. B. McK. on Nov. 30th, 1896.
I	Oxide of iron	Boiled linseed oil	2	March, 1895	April 24, '95	1 year & 7 ms.	In good condition.
II	Red lead	Raw linseed oil	2	do	do	do	Discolored and slightly rusted.
III	Graphite paint	Boiled linseed oil (?)	2	do	do	do	Small patches of rust all over.
IV	Oxide of iron	Boiled linseed oil	2	do	do	do	Rusted all over.
V	Anti-corrosion paint	$\frac{1}{3}$ raw oil, $\frac{1}{3}$ boiled linseed, $\frac{1}{3}$ turps	2	do	do	do	In good condition.
VI	Black anti-rust paint	Mixed by the manufacturer	2	do	do	do	Very much rusted.
VII	White lead	Half raw and half boiled linseed oil	2	do	do	do	Half the plate rusted and discolored.
VIII	Tar and asphalt coating applied hot	......	1	do	do	do	Considerably rusted.
IX	Red lead 1 lb. and lampblack 1 oz.	Raw linseed oil (no drier)	2	do	do	do	In fair condition.
X	Oxide of iron	Mixed by the manufacturer	2	do	do	do	Very much rusted.
XI	This painted plate was supplied by a painter for test. The composition of the paint is unknown to me	......	......	......	do	do	Considerably rusted.
XII	Black bridge paint	Mixed by the manufacturer	2	......	do	do	Very much rusted.
XIII	This painted plate was supplied by a painter for test. The composition of the paint is unknown to me	......	......	......	do	do	In good condition,
XIV	Asphalt paint	Mixed by the manufacturer	2	......	do	do	Rusted all over.
XV	Carbon paint	Mixed by the manufacturer	2	......	Oct. 31, 1895	1 year & 1 mth	Rusted in large patches.
XVI	Oxide of iron	Mixed by the manufacturer	2	July 17 1895	do	do	Fairly good condition; a few rust spots.
XVII	Oxide of iron	Mixed by the manufacturer	2	do	do	do	Covered with rust; paint all gone.
XVIII	Graphite paint	Mixed by the manufacturer	2	do	do	do	Fairly good.
XIX	Coal tar coating; plate heated and dipped in hot tar	......	1	do	do	do	Rust spots all over.
XX	Oxide of iron	Mixed by the manufacturer	2	do	do	do	Fairly good; a few rust spots.
XXI	2 lbs. 7 ozs. yellow ochre and 1 oz. lampblack	Raw linseed oil and Japan	2	do	do	do	Good; a few rust spots on back.
XXVIII	Paint for ironwork (secret process), said to be furnace slag, linseed oil and gum	Mixed by the manufacturer	2	March, 1896	April 4, 1896	8 months	Very good.
XXIX	Oxide of iron	Mixed by the manufacturer	2	April 1, 1896	April 9, 1896	do	Small rust spots scattered over.

REFERENCES:

III. The manufacturers say that the pigment is mixed in pure kettle-boiled linseed oil, and direct that in dry weather it be thinned with raw linseed oil, and in damp weather with boiled linseed oil.

XII. The manufacturers say that the pigment is mixed in linseed oil and turpentine and that it also contains asphaltum and Kauri gum.

XIV. The manufacturers say that this paint contains no coal tar, and direct that it be thinned with 62 per cent. benzine.

XVI. The manufacturers say that the mixture of this paint is a secret process and that it contains no oil. It sets too quickly and is difficult to apply for this reason.

XX. The manufacturers say that the pigment is mixed in pure clarified linseed oil.

paints, the coal-tar coatings, and some of the oxide of iron paints are already out of the race, and that neither the lead nor the graphite paints are holding out quite as well as might have been expected.

A chemical analysis of the water beneath the bridge was arrived at as follows:

The average density of ocean water is 1.026, and the composition is as follows:

Water	96.5 per cent.
Salts	3.5 "

The composition of the salts is as follows:—

Chloride of sodium	77.758
Chloride of magnesium	10.878
Sulphate of magnesium	4.737
Sulphate of lime	3.600
Sulphate of potash	2.465
Bromide of magnesium	0.217
Carbonate of lime	0.345
Total salts	100.000

The density of the water under the bridge was determined roughly by weighing a certain volume and comparing it with the weight of a like volume of fresh water. This gave a density of 1.00813, which would make the composition as follows:—

Water	98.215 per cent.
Salts	1.785 "
	100.000 per cent.

The composition of the salts would be the same as that given above for ocean water.

The highest summer temperature of the air in 1895 was 82° F., and the lowest temperature in winter of 1895-6 was—2° F. The highest summer temperature of the air in 1896 was 72° F., and the lowest temperature in winter of 1896-7 was—7°. The summer temperature of the sea-water under the bridge is 60° F. to 63° F., and the winter temperature 30° F. to 35° F. Total precipitation in 1895 was probably about 70 inches. Total precipitation in 1896 was 69.86 inches. Snow lies on the ground, more or less, in depths from three inches to three feet, between the middle of December and the middle of April. The greatest velocity of the wind during north-east autumn and winter storms is about 60 miles per hour.

CORROSION.

Corrosion is most active in autumn and winter, because there is then more moisture deposited upon the metal, and the water contains a larger proportion of oxygen and carbonic acid.

At 32° F. water will absorb	4.9%	of its own	bulk	of	oxygen.
At 50°F. "	3.8%	"	"		"
At 68°F. "	3.1%	"	"		"

Snow water contains more oxygen than rain or river water and will rust metal quicker. Cold water dissolves more carbon dioxide than warmer water. At 32° F. water will dissolve 1.8 volumes of carbon dioxide, and at 60° F. only one-half as much. Pure rain-water contains 2½ volumes of air in 100 volumes of water. If water is freed from oxygen by boiling, iron will not rust in it, nor will it rust in perfectly dry air. Rust consists of iron, oxygen and water and it requires a simultaneous action of oxygen and water to produce it. Damp oxygen and damp carbon dioxide in combination produce rust quickly. Neither will do so when dry either together or separately, and only to a very slight extent when damp, separately. It requires the combination of both, damp, to rust quickly.

Steel, when unprotected and exposed to the weather and sea-water, corrodes at the rate of $\frac{1}{82}$ of an inch per year .... or 1 inch in 82 years.

Wrought-iron, under same conditions, corrodes at the rate of $\frac{1}{190}$ of an inch per year.................. or 1 inch in 190 years.

Steel, unprotected and exposed to the weather and fresh water, corrodes at the rate of $\frac{1}{170}$ of an inch per year .... or 1 inch in 170 years.

Wrought-iron, under same conditions, corrodes at the rate of $\frac{1}{430}$ of an inch per year............	or 1 inch in 430 years.
Steel, unprotected and submerged in sea-water, corrodes at the rate of $\frac{1}{130}$ of an inch per year,	or 1 inch in 130 years.
Wrought-iron, under same conditions, corrodes at the rate of $\frac{1}{310}$ of an inch per year..................	or 1 inch in 310 years.
Steel, unprotected and submerged in fresh water, corrodes at the rate of $\frac{1}{600}$ of an inch per year.	or 1 inch in 600 years.
Wrought-iron, under same conditions, corrodes at the rate of $\frac{1}{700}$ of an inch per year..................	or 1 inch in 700 years.

Wrought-iron in an overhead bridge, subjected to coal-smoke from locomotives, corroded in 25 years from 39.5 per cent. or 1.8 per cent. per year to 100 per cent., or 4 per cent. per year, some of the members being entirely eaten away.

Unstrained members corrode more quickly than strained members. Shaded parts will corrode more slowly than parts exposed directly to the sun's rays.

Real iron-rust does not promote further rusting because of any chemical influence on the iron, but being a spongy mass, it retains in its pores 24 per cent. of water deposited as rain or dew. It does not, therefore, prevent, but rather encourages rusting, and in this way has a physically injurious effect upon iron. Corrosion accelerates with time, the second year's being 50 per cent. greater than the first.

LINSEED OIL.

In paint, oil is king; any finely ground pigment, inert toward the metal and oil, will last until the oil decays and wastes away, and against this decay and waste there is no remedy. The raw oil is obtained by both cold and hot pressure from linseed, or the seed of the flax plant, *Linum* *usitatissimum.* When cold-drawn, the color of the oil is golden-yellow, and when hot-pressed, brown-yellow The specific gravity is:

At	50° F.	= 0.9385
"	53½° F.	= 0.9364
"	59° F.	= 0.9350
"	68° F.	= 0.9325
"	77° F.	= 0.9300
"	266° F.	= Boiling-point.
"	—16½° F.,	the oil congeals to a solid yellow mass.

It is sold under different forms: Raw, refined, boiled and artist's oil. The seed should be ripe, and from two to six months old. The quality of the oil is affected by the quality of the seed, which is in turn ruled by the soil and climate in which it is grown. Boiled oil is heated to a temperature of from 266° to 600° F., and agitated mechanically for five or six hours. Water evaporates, and the scum and froth is removed from the surface with ladles; this scum is afterwards used in making putty. Equal quantities of litharge and red lead are added by slow degrees as dryers, to the extent of three per cent. of the oil, a small proportion of umber being also thrown in. The heat is continued for two or three hours, when the fire is suddenly withdrawn and the oil left covered over for ten hours longer. It is now known as "boiled oil," and is stored in settling-tanks for a few weeks, during which time the uncombined driers settle to the bottom as "foots." The heating process darkens the color and causes the oil to dry quickly, producing a hard firm surface. Pure, unadulterated linseed oil is not a common article. Driers are not infrequently added through the bunghole without boiling. Cotton-seed oil, Niger oil, hemp-seed oil, poppy-seed oil, colza oil, rape-seed oil, Lucca oil, resin oil, turpentine oil, benzine, fish oil, animal oil and water are often mixed with it, all or any of which shortens the life of the paint. There are about 17 vegetable drying oils which may be used in paint, and over 30 vegetable non-drying oils, which may be used as adulterants. The greater number of these oils are cheaper than linseed oil.

In addition, there are the fish and animal oils, so that the rarity of pure linseed oil is not to be wondered at.

The purity of linseed oil may be roughly tested by shaking it well; if iridescent bubbles appear on the surface, it is adulterated with benzine or mineral oil; if sulphuric acid is present, the paint when shaken and then allowed to stand will thicken into a brown paste. Other rough tests are: Brush it upon brown paper, and expose to the sun's rays; the water, benzine, etc., will evaporate and leave the oil. Dip a sheet of well-sized paper into the oil, and hang it up to dry; when dry the whole of the sheet should show a well-varnished coating; if only the bottom of the paper is varnished, the oil is insufficiently boiled. Brush the oil on a smooth wood surface; if it turns white, "blooms" in drying, it is adulterated with resin.

Oil, when spread out thinly, dries by absorbing oxygen from the air; the water and vapor passing out create multitudes of very minute holes in the oil cover, where water may enter; these holes are partly filled up by the second coat of paint. While the oil is absorbing oxygen, it adds 13 to 14 per cent. to its weight.

PIGMENTS.

After reading what the different manufacturers say about the price, covering capacity, and durability of their own particular paints, and the folly of using anything else, a person is inclined to believe fully in David's hasty assertion that "all men are liars."

The following comparative statement of the cost of painting a 100-foot span steel bridge, with a number of kinds of good paint, is taken from a statement published by C. E. Fowler, C.E., in the *Engineering News* of Feb. 6th, 1896. The cost of painting spans from 20 feet to 300 feet was accurately determined, and it will be seen that, after all, there is very little difference in the first cost between good qualities of the usual kinds of paint used for general railroad work; there being only $9.25 difference between oxide of iron and red lead for a span of 100 feet.

Cost of painting a 100-foot railway bridge (clean new iron) with different kinds of pigments and linseed oil:

Oxide of iron—14 gals. 1st coat, at 50c; 10 gals. 2nd coat, at 50c.
Labor, $68.00 = $80.00

Red lead—10 gals. 1st coat, at $1.25; 7 gals. 2nd coat, at $1.25.
Labor, $68.00 = $89.25

White Lead—14 gals. 1st coat, at 85c.; 10 gals. 2nd coat, at 85c.
Labor, $68.00 = $88.40

Graphite—14 gals. 1st coat, at 70c.; 10 gals. 2nd coat, at 70c.
Labor, $68.00 = $84.80

Asphalt—23 gals. 1st coat, at 40c.; 14 gals. 2nd coat, at 40c.
Labor, $68.00 = $82.80

Carbonizing coating—7 gals. 1st coat, $1.50; 5 gals. 2nd coat, $1 50.
Labor, $68.00 = $86.00

SCRAPING.

The labor of scraping the metal and applying the paint is from four to eight times the cost of the pigment and oil; so that there can be no economy in using cheap paint. To remove scale, loose rust, oil, dirt and cinders, use benzine, chisels and hammers, wire brushes and scrapers, as may be necessary. Unless the metal is perfectly clean and dry, no paint can be successful. Scraping should not proceed far ahead of the painting. Should salt spray touch the scraped metal, it should be scraped again before painting.

KIND OF PAINT AND ITS APPLICATION.

It is absolutely necessary that the first coat should contain a large quantity of pigment, and should dry quickly with a dense, firm surface, to receive the second coat in from 48 to 72 hours. If not dry and firm, the paint will blister, because of the separation of the first coat from the metal. To secure this, a pigment of high specific gravity must be used in boiled linseed oil, with a considerable quantity of turpentine, and we cannot do better than use a heavy, finely ground oxide of iron pigment, inert toward both metal and oil, and which has already been tested for durability, such as No. 1 of my experimental plates. Iron oxides often contain acids, lime, sulphur, clay, etc., so that there is much room for choice. Red-lead has been largely used for first-coat work, because it dries quickly, with a hard surface ; but if the air, from local causes, contains obnoxious gases, such as sulphuretted hydrogen gas, produced by the passage of trains, the red-lead will be quickly destroyed. J. Newman, author of "Corrosion and Fouling," says by letter of 21st January, 1897: "Probably the *worst* paint you can use for either iron or steel is ordinary lead and oil paint." Oil alone should not be used for priming in the shop ; it collects dirt and cinders ; besides, the pure oil dries, but never hardens. As it contains no pigment, it is quite porous and pervious to water ; the surface will consequently expand and present a shrivelled appearance and blisters will eventually appear.

For second-coat work, an elastic but firm surface is required to follow the expansion and contraction of the metal and resist the mechanical impact of strong dust or cinder-laden winds and rain, spray, hail and snow. In this coat more boiled oil, a less weighty pigment, and a less quantity of turpentine is required, so that it will dry more slowly and for a longer time resist the sun's influence, which is ever tending to harden and crack the surface and allow the entrance of water to the metal. A pigment, then, of low specific gravity must be used. Crude graphite ore powder has a specific gravity of about 0.7, and as graphite cannot be affected by chemical influences, it would seem to offer a suitable material for second-coat work. I have tested it for a period of one-and-a-half years, and so far it has done fairly well. Objections have been urged against it as follows :

1st. It is expensive to grind to a high degree of fineness, because of its oily and flaky character.

2nd. Because of its lightness, no great body of it can be got into the oil.

3rd. It settles out of the oil.

Some of these objections may be more imaginary than real.

A prominent manufacturer says that the composition of the best graphite now mined, ground and used for paint, is as follows :

ANALYSIS OF THE CRUDE ORE.

Moisture	0.15	per cent.
Graphite	33.48	"
Silica	37.54	"
Oxide of iron	14.25	"
Pyrites of iron	1.27	"
Oxide of alumina	12.35	"
Lime	0.54	"
Magnesia	0.48	"
	100.00	

On referring to the statement of cost, it is seen that for a 100-foot span bridge, the cost of graphite is $4.80 greater than iron oxide.

There exists in Canada, in large quantities, a cheap natural product, the specific gravity of which, compared with No. 1 iron oxide powder, is as 0.31 to 1. This material, after an inexpensive treatment, can be mixed with the iron ore powder to reduce the weight and increase the bulk, and on adding oil, a paint will be produced affording an elastic silicious surface which will resist cracking, peeling and blistering for a much longer time than the iron oxide alone.

On a clean, dry surface, paint applied at a temperature of 70° F., will last longest. Painting should not be done in damp, wet or freezing weather, and on summer mornings time must be given for the dew to evaporate before work begins, as oil paint will not adhere to wet metal. Painting should never be done by contract, but by day work, under a competent foreman. In painting it is best to begin at the top and work down. Buy paint in powder form when possible; next best in paste form. Light colors quickly become covered with a layer of dust, which absorbs as much heat as dark surfaces. The greater the number of pigments mixed together, the shorter the life of the paint.

LIFE OF METAL BRIDGES.

Heretofore, owing to increases in train loads, flimsy construction and neglect, the average life of iron bridges has not been over 25 years, and it is now generally believed among well-informed engineers that the average existence of such properly designed metal bridges as have lately been constructed throughout the country will not greatly exceed fifty years. Where corrosion is particularly active, as at the bridge of which I have spoken, the life of the structure must be much shorter, probably not over 35 years.

An English oxide of iron paint much used in this country contains 48 per cent. of iron oxide and 52 per cent. of insoluble material, and some American oxide of iron paints contain as little as 33 per cent. of iron oxide and 60 per cent. of silica. We have in Canada unlimited quantities of iron ore, which requires no preparation except grinding. Why should we then continue to import that with which nature has so liberally endowed us, and why should we continue to use unsuitable paints on locomotives, stationary engines, cars, roofs, bridges, freight and store-houses, when good iron oxide paints are cheaper and more lasting?

The company which will produce iron oxide paint from Canadian ore, as good as the best, push its sale, and show the people its advantages for works of this kind, will benefit both themselves and those to whom they sell. Hundreds of iron ore deposits exist in Canada, some affording 72.4 per cent. metallic iron, and several extensive graphite deposits, some of which produce 50 per cent. of pure black lead, while the natural product of low specific gravity for mixing with the iron ore powder can be supplied pure in any desired quantity.

For part of the information contained in the foregoing article, I am indebted to Prof. J. Spennrath's prize essay on "Protective Coverings for Iron," 1896; J. Newman's "Corrosion and Fouling," 1896, and to several articles in engineering periodicals by such high authorities as W. P. Wood, E. Gerber, W. G. Berg, A. H. Sabin, Samuel Wallis, J. H. Stanwood, and J. E. Greiner.