An Engineering Approach to Improved Protection of Structural Steel

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•THE problems relating to the successful painting of structural steel have been considered in many papers presented by technical paint people for consumption within their own industry. However, the subject has not, by any means, received sufficient consideration in the forum of the ultimate user—in this case, the bridge engineer who is charged with the responsibility of providing a durable bridge structure as free of maintenance as possible and yet aesthetically acceptable.

To contribute to the general knowledge and to offer some ideas which might be useful to others concerned with the problem of protecting their bridges, we have prepared information based on the experience of the New York State Department of Public Works, Division of Construction, over the past few years.

BACKGROUND

From the organization in 1926 of the New York State Department of Public Works, Division of Construction through 1957, there were few changes in the paint formulations designed for the protection of bridge structures.

Primer

During this period, the requirements for a shop primer changed only slightly. The paint specified in 1926 had the following composition:

One grade of pigment known as ninety-five (95) percent is required.

Dry Pigment. The pigment shall consist entirely of oxides of lead free from all adulterants and shall meet the following requirements:

	Percent
True red lead (Pb_3O_4), not less than	95
Total impurities, including moisture, soluble matter in water, and matter insoluble in a mixture of nitric acid and hydrogen peroxide, not more than	1
Coarse particles retained on a standard 325-mesh sieve, not more than	1
The red lead, ready mixed paint, shall consist of:	
Red Lead	74 to 76
Vehicle	24 to 26

The vehicle shall consist of a mixture of raw and boiled linseed oil in the proportion of one-third ($^1/_3$) to one-half ($^1/_2$) boiled oil, the balance being raw oil.

In 1929 the specification was modified as follows:

One grade of pigment known as ninety-five (95) percent is required.

Dry Pigment. The pigment shall consist entirely of oxides of lead free from all adulterants and shall meet the following requirements:

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	Percent
True red lead (Pb_3O_4), not less than	95
Total impurities, including moisture, soluble matter in water, and matter insoluble in a mixture of nitric acid and hydrogen peroxide, not more than	1
Coarse particles retained on a standard 325-mesh sieve, not more than	1
The red lead, ready mixed paint, shall consist of:	
Red Lead	78 to 81
Vehicle	19 to 22

The vehicle shall consist of a mixture of raw and boiled linseed oil in the proportion of one-third to one-half boiled oil, the balance being raw oil.

This specification for red lead primer was continued through 1958. In other words, no improvement was made in the red lead primer through this period when to overcome some of the disadvantages complained about by steel fabricators as well as shop and field painters, these paints were up-graded through research in the industry to reduce gloss and improve drying characteristics.

First and Second Field Coats. —In 1926 the specification for intermediate and finish coats was based upon a pigmentation of the Department standard white paint. The specification reads as follows:

Gray Paints

The gray paints will be ordered in the form of ready mixed paint and they shall meet the requirements as to composition as called for under White Paint but having substituted for the extending pigments sufficient suitable pigment color in order to furnish the required color and hiding power.

The Department specification for White Paint was as follows:

White Paint

The paint shall be well ground, shall not settle badly or cake in the container, shall be readily broken up with a paddle to a smooth, uniform paint of good brushing consistency, and shall dry within eighteen (18) hours to a full oil gloss without streaking, running or sagging. The color and hiding power shall be equal to that which may be specified.

Pigment. The pigment shall be composed of:

	Min. Percent	Max. Percent
White lead (Basic carbonate, basic sulphate, or a mixture thereof)	45	70
Zinc oxide (ZnO)	30	55
Silica, magnesium silicate, aluminum silicate, barium sulphate, or any mixture thereof	0	15

In no case shall the sum of the basic lead carbonate, basic lead sulphate, and zinc oxide be less than eighty-five (85) percent. The lead and zinc pigments may be introduced in the form of any mixture preferred of basic carbonate white lead, basic sulphate white lead, zinc oxide, or leaded zinc, provided the above requirements as to composition are met.

Liquid. The liquid in the paint shall consist of not less than ninety (90) percent of pure raw linseed oil previously specified, the balance to be combined drier and thinner.

The paint shall consist of:

	Min. Percent	Max. Percent
Pigment	62	66
Liquid (containing at least 90 percent linseed oil)	34	38
Water	—	0.5
Coarse particles and "skins" (total residue retained on No. 200 sieve based on pigment)	—	0.5

From 1929 to 1935 the specification for intermediate and finish coats was modified to read as follows:

Gray Paints

The gray paints will be ordered in the form of ready mixed paint and they shall meet the requirements as to composition as called for under White Paint but having substituted for the extending pigments sufficient suitable pigment color in order to furnish the required color and hiding power. The color of the gray paint shall be what is known as Battleship Gray. The paint for the first coat shall be lighter in color than the second coat.

White Paint

The paint shall be well ground, shall not settle badly or cake in the container, shall be readily broken up with a paddle to a smooth, uniform paint of good brushing consistency, and shall dry within eighteen hours to a full oil gloss without streaking, running or sagging. The color and hiding power shall be equal to that which may be specified.

Pigment. The pigment shall be composed of:

	Min. Percent	Max. Percent
White lead (Basic carbonate)	45	70
Zinc oxide (ZnO)	30	55
Silica, magnesium silicate, aluminum silicate, barium sulphate or any mixture thereof	0	15

In no case shall the sum of the basic lead carbonate and zinc oxide be less than eighty-five percent.

Liquid. The liquid in the paint shall consist of not less than ninety percent of pure raw linseed oil previously specified. The balance to be combined drier and thinner.

The paint shall consist of:

	Min. Percent	Max. Percent
Pigment	62	66
Liquid (containing at least 90 percent linseed oil)	34	38
Water	—	0.5
Coarse particles and "skins" (total residue retained on No. 200 sieve based on pigments)	—	0.5

From 1935 to 1957 minor modifications in the standard white paint specification consisted of the following:

	Min. Percent	Max. Percent
1935—White lead (Basic carbonate)	50	70
Zinc oxide (ZnO)	30	40
Silica, magnesium silicate, aluminum silicate, barium sulphate or any mixture thereof	0	10

1939—Sum of basic lead (carbonate) and zinc oxide was increased from a minimum of 88% to a minimum of 90%.

1942—The second field coat was designated as Gray-Green Paint and specification follows:

Gray-Green Paint

The gray-green paint shall be ordered in the form of ready mixed paint. It shall meet the requirements as to composition as called for under White Paint, except that the color of the paint shall be the same as indicated in a panel on file in the Assistant Chief Engineer's office. The color shall be obtained by substituting for the inert pigments and a portion of the zinc oxide, if necessary, chromium oxide or pure chrome green and other suitable pigments necessary to procure the desired color.

The chromium oxide shall conform to the A.S.T.M. specifications D-263-40 for chrome oxide green.

The pure chrome green shall conform to the A.S.T.M. specifications D-212-40 for pure chrome green.

1957—The gray-green paint specification was modified to require the use of chromium oxide and other suitable pigments necessary to procure the desired color, eliminating the permissive use of pure chrome green as a tinting pigment.

The selection of a gray-green paint to blend in with the landscape was an innovation that a number of States adopted about 1942. Due to the war it was impossible to procure chrome oxide green for civilian purposes which resulted in the use of pure chrome green for tinting. As with the primer there had been no basic changes in the composition requirements from those existing in 1926. None of the newer technology of the paint industry had been adopted thus by comparison with the more modern formulations of the period the gray-green paint faded rapidly and ununiformly. This resulted, in many instances, in unattractive structures in as short a time as five years.

In 1926 specifications for linseed oil, thinner and drier were as follows:

Linseed Oil

The raw linseed oil must be strictly pure, well settled linseed oil, perfectly clear, and not show any sediment or loss of more than two-tenths (0.2) percent when heated for one-half ($\frac{1}{2}$) hour at a temperature between 105° and 110° C. (221° and 230° F.) Raw and boiled linseed oil shall conform to the requirements of U.S. Bureau of Standards Circular No. 82 as adopted by the Federal Specifications Board. These are as follows:

	Raw Oil		Boiled Oil	
	Max.	Min.	Max.	Min.
Loss on heating at 105°-110° C. (221° to 230° F.) (percent)	0.2	—	0.2	—
Foots by volume (percent)	2.0	—	—	—
Specific Gravity, 15.5°/15.5° C. (60°/60° F.)	0.936	0.932	0.945	0.937
Acid number	6.0	—	8.0	—
Saponification number	195.0	189.0	195.0	189.0
Unsaponifiable matter (percent)	1.5	—	1.50	—
Iodine number (Hanus)*	—	170.0	—	168.0
Ash (percent)	—	—	0.7	0.2
Manganese (percent)	—	—	—	0.03
Lead (percent)	—	—	—	0.1
Time of drying on glass (hours)	—	—	20.0	—
Color	Not darker than a freshly prepared solution of 1.0 gm. potassium bichromate in 100 cc. pure strong (1.84 sp. gr.) sulphuric acid.			

*When oil from North American seed is specified by the purchaser, the iodine number must be not less than 180 in the case of raw oil and 178 in the case of boiled oil and the oil shall conform to all the other requirements as above.

Thinner

a. Turpentine. The turpentine used shall either be the distillate commonly known as "Gum Turpentine" or "Spirits Turpentine" which is distilled from pine oleoresins or the product secured from resinous wood by extraction with volatile solvents, by steam, or by destructive distillation, and shall meet the following requirements:

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

The color shall be "standard" or better.

The specific gravity shall be not less than 0.862 nor more than 0.875 at 15.5°/15.5° C. (60°/60° F).

The refractive index at 20° C. (68° F.) shall be not less than 1.465 nor more than 1.478.

The initial boiling point shall be not less than 150° C. (302° F) nor more than 160° C. (320° F.) at 760 mm. pressure.

Ninety (90) percent of the turpentine shall distill below 170° C. (338 F.) at 760 mm. pressure.

The polymerization residue shall not exceed two (2) percent, and its refractive index at 20° C. (68 F.) shall not be less than 1.500.

b. Mineral Spirits. The mineral spirits shall be clear and free from suspended matter and water.

The color shall be "water white".

Spot Test: The mineral spirits shall evaporate completely from filter paper.

The flash point shall be not lower than 30° C. (86° F.) when tested in a closed cup tester.

Sulphur shall be absent as determined by the white lead test.

The distillate below 130° C. (266° F.) shall not exceed five (5) percent.

Drier

The drier shall be composed of lead, manganese, or cobalt, or a mixture of any of these elements combined with a suitable fatty oil, with or without resins or "gums" and mineral spirits or turpentine, or a mixture of these solvents. It shall be free from sediment and suspended matter. The drier when flowed on metal and baked for two (2) hours at 100° C. (212° F.) shall leave an elastic film. The flash point shall be not lower than 30° C. (86° F.) when tested in a closed cup tester. It shall mix with pure raw linseed oil in the proportion of one (1) volume of drier to nineteen (19) volumes of oil without curdling, and the resulting mixture when flowed on glass shall dry in not more than eighteen (18) hours. When mixed with pure raw linseed oil in the proportion of one volume of drier to eight (8) of oil, the resulting mixture shall be no darker than a solution of 6 g. of potassium dichromate in 100 c.c. of pure sulphuric acid of specific gravity 1.84.

From 1935 to 1947 the specifications for linseed oil and thinner required compliance with ASTM Standards. There was no change in the drier requirements. From 1947 to 1957 no requirements for the vehicle were indicated in the specifications.

Throughout the period from 1926 to 1957 the specifications contained no indication of a desired minimum film thickness for the three coats of paint required. This resulted in a variable performance of the system depending on the care in application exhibited on a particular job. This was magnified further by the environment a particular structure was subjected to; in New York State this ranges from rural to marine as well as industrial both heavy and chemical.

INVESTIGATION

In 1954, Deputy Chief Engineer (Bridges) E. W. Wendell initiated an investigation which culminated in the adoption of our current paint systems. This preliminary investigation included extensive studies by department personnel with regard to the problems involved. These studies were followed by consultations with personnel of the technical departments of raw material suppliers to obtain all available information relative to the substantiation of our findings and to lay the groundwork for upgrading our paint systems. The result of this preliminary work indicated the reason for unsatisfactory performance of existing paint systems.

Primer

Because of its excellent hiding power there was a tendency to spread the primer too far, thus insufficient dry films were obtained to protect the steel from its environment. In addition red lead paint possessed the inherent characteristic of settling heavy which often made it impossible to remix the paint properly. This resulted in the application of a paint low in pigment content. The oily gloss of the full oil type red lead paint made it difficult for painters to obtain adequate adhesion when applying overcoats. In addition, slow drying created a hardship in scheduling movement of the steel and repainting.

Another practical problem with the primer was that it did not weather well. Often with large structures many months elapse between shop priming and the application of the field coats. Carbonation of the red lead with its known tendency to chalk and erode left insufficient film thickness of the paint to protect the steel.

First and Second Field Coats

Intermediate and finish coats provided little, if any, anti-corrosive properties and also presented problems with regard to the general appearance of the finished structure. While color was good initially, appearance fell off rapidly. This was particularly true during that period when pure chrome green was used as a tinting pigment in the finish coat. When the color stable green pigment (chromium oxide) was required, conditions of the finish coat improved but it was noted that these finishes acquired an irregular washed-out, unpleasant yellow cast after five or six years. This could have been due, for one thing, to the unauthorized use of some pure chrome green in order to match the required color. Another reason could be the high white lead content. White lead coatings, while producing durable films, are inclined to fade ununiformly giving a mottled appearance. The straight oil vehicle with its rather limited durability also contributed to the failure.

It became evident that by modernizing our paint requirements that savings in initial cost could be realized, but more important the life expectancy of the paint systems could be extended resulting in the ever important maintenance cost savings to be gained, that is, cost per square foot per year.

With these points in mind, in 1956 the Division of Construction in cooperation with a major pigment supplier began an investigation in an effort to solve our problems. The pigment company had a relatively new anti-corrosive pigment, basic lead silico chromate, which had been evaluated at their test stations for seven years as well as on several small structures throughout the country. It had been demonstrated through these tests that in addition to providing anti-corrosive properties at least as good as red lead, it weathered far better and because of its unique low tinting strength could be incorporated into finishes to enhance color retention.

Over the years the original test panels protected with coatings containing basic lead silico chromate as well as control red lead films, were observed and pictures taken at intervals for the record. In one set, on sandblasted steel, comparing the two pigments as single pigments formulated into linseed oil primers at 31 PVC (90% oil - 10% volatile) and exposed at 45° South on Long Island, it became apparent within 16 months that basic lead silico chromate imparted superior weathering characteristics. In addition, where multi-coats were used forming a typical paint system, improved corrosion protection became evident with time. It should be noted that all paint films were applied by brush at a spreading rate calculated to give dried film thicknesses of 1.5 mils. Table 1 (1) gives corrosion ratings for the different test areas of the specimens.

TABLE 1

CORROSION[a]

Months Exposure	9	16	21	28	36	49	58	65	75	86	96	101
(a) Basic Lead Silico Chromate in Linseed Oil												
One coat primer	10	10	8	6	4	2	1					
Two coats primer							10	9	9	7	7	7
One primer and 1 topcoat									10	10	10	10
(b) 97% Grade Red Lead in Linseed Oil												
One coat primer	10	6	3	1								
Two coats primer					10	9	3	1				
One primer and 1 topcoat						10	9	9	8	7	7	7

[a] Corrosion ratings are based on "10" as perfect, down to "1", which represents total failure.

Another series exposed under the same conditions using the single pigments in paints formulated with a long oil alkyd resin vehicle at 30 PVC but applied to cold-rolled steel gave similar results. The corrosion ratings are presented in Table 2 (1). In addition to improved protection, it was noted here that the exposed basic lead silico chromate primer retained its color with little drift from what it was originally. It was this that indicated the potential use of the pigment for color stable, anti-corrosive finishes.

Figure 1 shows the comparison of the basic lead silico chromate and red lead alkyd resin paints described in Table 2. On each panel, one coat of primer was applied overall, a second coat over the upper half, and a finish coat over the mid-section.

TABLE 2

CORROSION

Months Exposure	34	40	54	62	74	80	90	99	105
(a) Basic Lead Silico Chromate with Alkyd Resin									
One coat primer					10	9	9	8	7
Two coats primer					10	10	10	10	10
One primer and 1 topcoat					10	10	10	10	10
(b) 97% Grade Red Lead with Alkyd Resin									
One coat primer	10	9	5	3	1				
Two coats primer					10	10	10	9	9
One primer and 1 topcoat					10	9	9	8	6

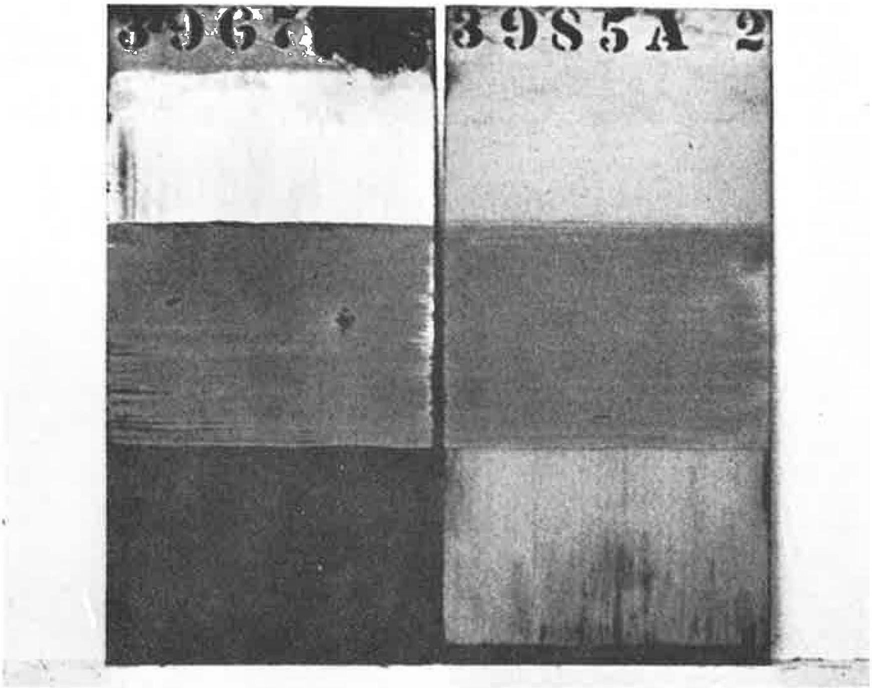

Figure 1. Comparison of red lead (left) and basic lead silico chromate (right) in a long oil alkyd after 110 months exposure at 45° South on Long Island.

The first cooperative test started with the exposure at 45° South on Long Island, using small angle specimens. New York's standard three coat system, previously described, and one based on this new pigment formulated to be present in all coats of paint were selected and laboratory batches prepared. To derive specific information uncluttered by many variables, all coatings were applied to similar surfaces (both sandblasted and lightly rusted mill scale carrying angles) at rates designed to give equal dried film thicknesses (1. 5 mils).

The basic lead silico chromate experimental system was composed of:

1. Primer—Basic lead silico chromate in 80/20 raw linseed oil/long oil alkyd (current TT-P-61 5b, Type I).
2. Gray intermediate—Basic lead silico chromate, titanium dioxide, zinc oxide, extender and tinting pigments in 2/1 raw linseed oil/long oil alkyd.
3. Gray-green finish—Basic lead silico chromate, titanium dioxide, chromium oxide, toning colors in 5/3 raw linseed oil/long oil alkyd.

The test angle specimens were painted in the following manner. One coat of primer was applied overall. The intermediate was applied over the upper half (both faces). The finish coat was applied to one face—the right side. This then gave an angle having exposed primer on the lower left segment, primer and intermediate coat applied to the upper left segment, primer and finish coat applied to the lower right segment, and the complete three coat system applied to the upper right segment.

Because of adequate controlled thicknesses, corrosion did not develop with the comparative primers for several years. However, to make a point, when failure had developed just shy of requiring touch-up, the control was three years old. The modification required five years to reach that point. Of more significance, the control primer started chalking or wearing away within 12 months, while the modified primer showed no indication of chalking after 25 months. This point would be of still more significance to an engineer charged with the responsibility of protecting steel at the site in southern climates.

This was substantiated by a subsequent exposure designed to demonstrate erosion characteristics. A basic lead silico chromate primer containing a vehicle composed of 80 percent linseed oil and 20 percent alkyd resin was compared with New York State's existing M20 red lead-linseed oil paint and also Federal Specification TT-P-86c, Type I. The red lead primers lost 15 percent of their film in 15 months and 20 percent within 22 months, while the basic lead silico chromate primer lost only 4 percent over a 32-month period.

The difference in general appearance of the comparative finish coats was most striking. Within 18 months the control New York State gray-green had faded badly and nonuniformly. The basic lead silico chromate gray-green by comparison, still maintained an appearance rated as good after 8 years.

Pictures were taken of this series at intervals, which demonstrated the weathering characteristics experienced.

Figure 2 shows the condition of the control and experimental systems after 19 months exposure. The development of chalking as well as severe fading of the control finish is apparent. The typical carbonation of red lead after extended exposure is evident.

Figure 3 taken after 66 months shows the same paint systems. It is apparent that the control finish (right side of left angle) has completely weathered away. In addition, the excellent weather and corrosion resistance of the basic lead silico chromate experimental primer as compared with the red lead primer should be noted (comparing films on lower left quarters of the two angles).

Thus within two years it became evident that the experimental system had potential advantages. To coincide with this laboratory work, it was decided early in 1957 to give this same system a practical trial on a large structure. A bridge on the outskirts of Albany (Southern Boulevard Bridge) was selected to evaluate the system. It was considered a typical condition to which bridge coatings would be subjected in New York State. Considerable repair and widening, using freshly fabricated steel, was scheduled along with touching up and refinishing of the existing steel.

Figure 2. Comparison of control New York State system (left) and experimental basic lead silico chromate system (right) after 19 months exposure at 45° South on Long Island.

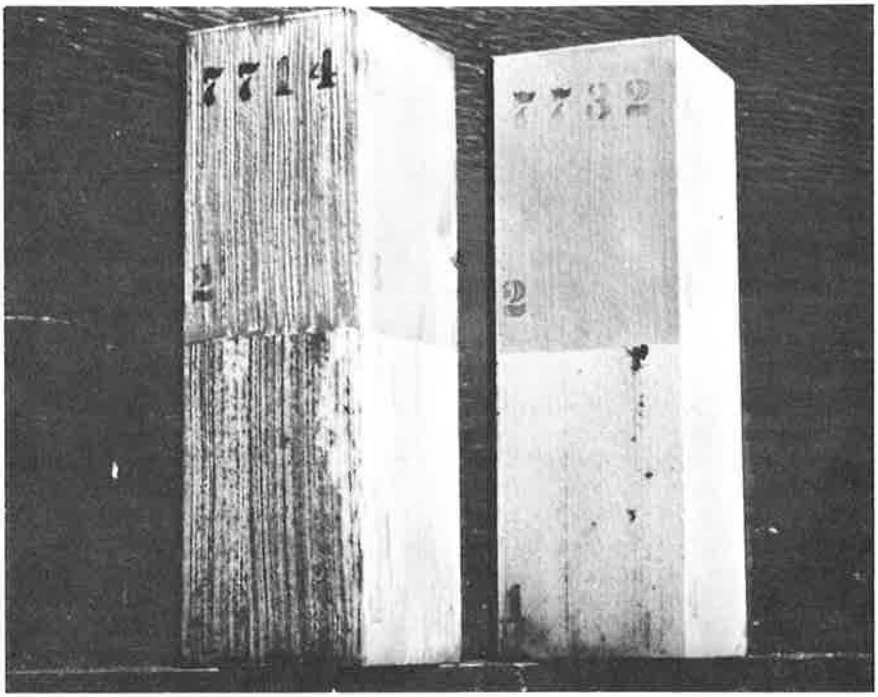

Figure 3. Comparison of control New York State system (left) and experimental basic lead silico chromate system (right) after 66 months exposure at 45° South on Long Island.

The environment at Albany is that expected over much of the state. Cold winters prevail with much snow and, accordingly, any number of corrosive de-icing applications. The summers are hot with ample humidity, aided by a river running through the ravine which the bridge spans.

Special specifications were written and commercial quantities of paints were prepared and applied following normal practices required by the Department.

This work was completed in 1957. Since that time, or 8 years, no maintenance repainting has been found necessary. The pleasing initial appearance of the gray-green finish has held throughout the exposure. It is our opinion that this system, with the possible exception of localized spots, will not require refinishing for at least another four years. It is interesting how well this large test run under normal field conditions has correlated with the laboratory test put out under controlled conditions.

IMPLEMENTATION

Based on the performance of the system on the Southern Boulevard Bridge as well as the continued high ratings of the laboratory field tests, an interim specification following the original experimental composition was adopted by the Department in the fall of 1958, which made the new system mandatory for new construction In 1962, when the Division of Construction specifications were revised, these paint formulations were included. *

Since there was a requirement in our specifications which called for three coats of primer for surfaces not in contact, which after fabrication, would be inaccessible, a maroon primer was added to the list of paints.

In addition to this basic bridge painting system, other modifications were made in the specifications. The black finish, available for use on structures maintained by railroads, was changed from a simple decorative black pigmented linseed oil paint to one containing some basic lead silico chromate in the pigmentation and alkyd resin to reinforce the oil vehicle. Thus this coating has been upgraded to provide positive anti-corrosive properties, augmenting those of the undercoats.

The white paint for use on curb protection plates and guide railing was upgraded to provide a stain resisting system. This paint calls for the use of fungicides and was formulated so that it could be used on steel, concrete or wood surfaces.

The Department modernized its infrequently used aluminum paint specification. To get away from the practice of tinting the aluminum finish with blue, to provide a contrasting undercoat for the finish, non-leafing aluminum was adopted. Adequate contrast

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*The original paper contained the following sections of documents from the State of New York Department of Public Works which are not reproduced here:

Public Works Specifications of January 2, 1962
Section M 18 A Paints and Painting Materials
Section M 18 B Maroon Primer
Section M 18 D Black Paint
Section M 18 E Stain Resistant White Paint
Section M 18 G Gray Paint
Section M 18 J Ready-Mixed Aluminum Paint
Section M 18 K Zinc Chromate Primer

Part II Section 8a—Painting—General Specifications Painting of Metal Structures
Addenda No. 19 to Public Works Specifications of January 2, 1962
Section M 18 C A Dull Orange Primer
Section M 18 H A Gray-Green Paint

Materials Method N.Y. 6. June 25, 1962 "Sampling of Paint for Field Application"
Materials Method N.Y. 6.1.—November 1, 1962 "Sampling and Control of Paints for Shop Application"
Materials Method N.Y. 6.11.-"Shop Paint Application Samples"

to the leafing aluminum finish was obtained. Perhaps more importantly with this new undercoat-finish system, the unsightly appearance of a structure when the finish erodes away, exposing an irregular blue color, now becomes a thing of the past.

For the protection on the bottom areas of aluminum railing posts which would come in contact with freshly placed concrete, a zinc chromate primer was added to the specifications.

To substantiate the validity of this approach for providing paint systems to improve protection of structural steel, due consideration should be given to the facilities placed at one's disposal and the intimate contact with eminently qualified technical personnel, together with the results obtained.

From the beginning a program of investigation and research was developed whereby we could take advantage of any advances made in the paint industry.

As an illustration, tests were run on the Skyway Bridge in Buffalo. This is an elevated structure providing 135 ft of under-clearance for the Buffalo Ship Canal. It is located at the eastern-most end of Lake Erie and is subjected to abnormally high winds as well as a full range of climatic conditions. Its industrial environment is made up of steel mills, cement mills, flour mills and a variety of chemical plants.

In September 1958, nine complete and different paint systems were applied to a portion of the railing of the Skyway Bridge. In October 1959, ten complete and different paint systems were applied to another portion of the railing of this same structure, and three complete and different paint systems were applied to the beam-type guide railing fastened to the metal protection plate for curbs.

The September 1958 series consisted of the following:

Area	Composition
1	M20A—M23A—M22A
2	M20A—M19A—M23A—M22A
3	M20A—M23A—Epitex T. C.
4	M20A—M19A—M23A—Epitex T. C.
5	M20A—M23A in alkyd—Parlon T. C.
6	M20A—M19A—M23A in alkyd—Parlon T. C.
7A	M20—M23—M24
7B	M20—M23—M24A
8	M20—M23—M23—M22
	Old paint removed essentially to metal.

Paint Description

M19A—Basic lead silico chromate maroon intermediate
M20A—Basic lead silico chromate orange primer
M22A—Basic silicate white lead—basic carbonate white lead—TiO_2—oil-alkyd white top coat
M23A—Basic lead silico chromate—TiO_2—gray—oil-alkyd undercoat
M24A—Basic lead silico chromate—gray green top coat
M20—Red lead primer
M22—White lead—zinc oxide white top coat
M23—White lead—zinc oxide gray undercoat
M24—White lead—zinc oxide gray green top coat
Epitex T. C. —T-8397 M22A with epoxy ester vehicle
M23A in alkyd—T-9044 M23A pigmentation—untinted in straight alkyd vehicle
Parlon T. C. —T-9904—TiO_2—dyphos—oil-alkyd—Parlon

The October 1959 series consisted of the following:

Area	Composition
1	M19A—M23A—M22A
2	M19A—M23A—MIL-P-1264
3	M19A—M23A—M24A in alkyd

Area	Composition
4	M19A—M23A—Lt. green in alkyd
5	M19A—M23A—Lt. green in epoxy ester
6	M19A—M23A—M25A + M-50
7	M19A—M23A—M25A
8	M19A—M22A—M22A
9	M19A—MIL-P-1264—MIL-P-1264
10	M20A—M23A—Acrylic (double coat)

Guide Rail Test

1. M19A—M22A—M22A
2. M19A—M22A + sand—M22A
3. M19A—M22A + pumice—M22A + pumice

Old paint removed essentially to metal

Paint Description

M19A—Basic lead silico chromate maroon intermediate
M20A—Basic lead silico chromate orange primer
M22A—Basic silicate white lead—basic carbonate white lead—TiO_2 oil-alkyd
M23A—Basic lead silico chromate—TiO_2—gray—oil-alkyd undercoat
MIL-P-1264—T-9720—TiO_2—ZnO—alkyd
M24A in alkyd—T-8356—M24A in straight alkyd vehicle
Lt. green in alkyd—T-9729—basic lead silico chromate—TiO_2—epoxy ester
M25A N. Y. S. aluminum top coat
M25A + M50—1 lb basic lead silico chromate paste (75% pigment in oil) mixed into 1 gallon M25A
Acrylic—T-9808—TiO_2—inert in acrylic emulsion
M22A + sand—sand thrown onto wet film of M22A before it sets
M22A + pumice—½ lb pumice mixed into 1 gallon M22A

For the purpose of correlating the results of this test, these same series of paint systems were also applied to prepared structural angles and steel plates, and exposed at the pigment supplier's test stands, under rural, marine (salt and fresh water) and industrial environments.

These test areas were inspected at regular intervals but tests had to be concluded in July 1962 since a contract was being prepared to repaint this structure in the Fall.

The following is a summation of the observations made at the time of inspection:

1958 Test

Overall, all systems are giving good protection, due in part to the reasonably careful paint application. The best systems, from the standpoint of protection, appearance and visibility are:

1—M20A—M23A—M22A
2—M20A—M19A—M23A—M22A
6—M20A—M19A—M23A in alkyd—Parlon T. C.
7A—(except visibility) M20—M23—M24

1959 Test

All systems are giving good protection, visibility is best with M22A or MIL-P-1264 as a finish. Except for high visibility requirements, Test 4 with a light green alkyd finish is very satisfactory. Acrylic finish did not cure properly under cool weather conditions prevailing during painting, therefore, is not considered practical for all-purpose use.

1959 Guide Rail Test

Visibility of these systems is excellent considering their location on the structure. Those systems containing sand or pumice exhibited remarkable resistance to removal by scraping when compared with the conventional paint system used on the rest of the structure.

The late Elmer G. H. Youngmann, District Engineer with headquarters in Buffalo, New York, requested a design of a white paint system for use on railings, guide rails and the metal protection plate for curbs on this structure, for the purpose of providing better visibility, thereby reducing the potential mental hazard. Sand was applied to the intermediate coat of paint used on guide rails and the metal protection plate for curbs. At the same time the wet film thickness was increased on intermediate and finish coat from 3.2-4 to 5.3 mils.

In 1959 drying difficulties were encountered with the gray-green finish. Without a careful selection of drier catalysts the paint skin-dried, producing wrinkling. It was found necessary to modify the specification to require the use of a particular drier combination which would insure relative freedom from this defect.

In 1960 it was observed that the new gray-green finish had a tendency to dry with an irregular gloss and have poor color uniformity under unfavorable, drying conditions (hot humid air). While initially this was objectionable, the weathered film fortunately dulled down uniformly to produce a lasting attractive finish.

Figure 4 shows the flashing or irregular gloss defect on certain structures. This effect usually developed at laps or where the coating had been applied unevenly.

To overcome this defect the alkyd resin was increased considerably while retaining some linseed oil for ease of applying the paint. The pigmentation, containing basic lead silico chromate, was maintained essentially the same. Two independent investigations were made in order to arrive at the proper ratio of alkyd to oil. This work was undertaken in 1961.

Figure 4. A demonstration of irregular gloss experienced with gray-green finish coat paint.

The first, which involved application of test paints to small specimens exposed to 45° South weathering, comprised a vehicle ladder wherein the percentage of resin (long oil alkyd) in the vehicle ranged from 35 percent (as specified) up to 100 percent at the expense of raw linseed oil. It was obvious from the beginning that high concentrations of alkyd resin (80% to 100%) offered problems in practical application. Inspection within two years showed a definite break in gloss retention and uniformity where the ratio of resin to oil was 65 to 35. Here and above, appearance was better.

To check this out practically, field tests were made on State structures on Long Island and upstate in the Rochester area in 1962, using four vehicle compositions: 35:65 long oil alkyd resin to raw linseed oil, 65:35, 80:20, and finally 100 percent resin. The paints were applied by State maintenance crews directly to scraped, wirebrushed and dusted surfaces at normal spreading rates under the following preselected environmental conditions.

Application*	Temp. Limits Steel Surface	Humidity Limits
Brush	40- 48 F	80-90
Brush	40- 48 F	25-40
Brush	110-125 F	80-90
Brush	110-125 F	25-40

*Paints are to be applied over a solid intact previously painted surface or a properly undercoated surface.

Thus four extreme conditions, which could be met in practice, were used to evaluate paint modifications. The observations of the painters were noted and, in addition, the weathering characteristics were recorded at frequent intervals thereafter.

The standard formulation initially showed, as it had in field use, the flashing phenomenon. The 65:35 resin:oil combination showed excellent uniformity regardless of the environmental conditions. The higher resin content coatings (80% and 100%) were inclined to retain high gloss points where overlapped, although were satisfactory when properly spread out. The disadvantage of these latter paints, particularly the 100 percent resin, was difficulty in handling. This is of particular importance from a practical point of view. In the protection of steel, the development of an anti-corrosive system using coatings of highest durability is essential. Unfortunately in field practice such coatings often are difficult to apply properly by brush, as required by the State. Therefore, some compromise must be made to ease the handling characteristics so that useful films can be uniformly applied. This is best accomplished by the inclusion of some linseed oil rather than permitting the use of high solvent additives. Another result of this compromise is to obtain a higher vehicle solids content which will, in turn, result in a higher paint film build. With these points in mind, a new specification for the gray-green using 65:35 long oil alkyd:raw linseed oil was adopted in 1964.

The fabricators experienced difficulty in handling the orange primer since they were not familiar with its lean hiding compared with the previously used red lead. Their painters had the tendency to over-apply un-uniformly to obtain hiding, which resulted in excessively thick films. Being high in linseed oil these films skin dried and wrinkled and in cold weather dried slowly, making them susceptible to damage in the course of handling the structural members.

With the aid of interested fabricators and the research laboratory staff of the cooperating pigment company, modifications in the primer specification were fully investigated. As a result of this work, a revision was made and adopted in 1964. Specifically, the drier catalyst requirements were changed, the alkyd resin content was raised to improve winter drying without adversely affecting steel surface wetting characteristics, and a small amount of pure iron oxide tinting pigment was included to upgrade the hiding. The hiding was increased just enough so that the applicator would not tend to load on the paint excessively, would be satisfied in his own mind that he was hiding well, and at the same time would not spread it too far to obtain inadequate film thickness. For reference, this paint coincides with Federal Specification TT-P-0061 5c, Type V, except for the requirement that pure iron oxide be used.

QUALITY CONTROL OF PAINT

With the adoption of our new paint systems we introduced a new method of control in order to assure delivery of material conforming to the required specifications. This consisted of requiring the use of an approved lever-type ring seal on the containers and the employment of tamper-proof tags installed on the ring seal. Paint manufacturers installed the tamper-proof tags which were furnished by the office of the Deputy Chief Engineer (Bridges).

The paint manufacturer's request for the tamper-proof tags indicated the project for which the paint was made, together with the gallonage of each type and the size of container. Based upon this information the required number of tamper-proof tags would be supplied the manufacturer.

Tags broken by the Department inspectors for purpose of sampling paint for submission to the Department laboratory for analysis were replaced by him with a tag of the same type but a different color. By this method of control we were able to compile a record of the amount of paint supplied to any given contract. Any unauthorized tampering with, or breaking of the tags would be cause for rejection of the paint at the Contractor's expense.

As a result of the experience gained by this method of control, a far more comprehensive and orderly program was developed by the personnel of the Bureau of Materials in the office of George W. McAlpin, Deputy Chief Engineer (Research). *

PRACTICES AND INSPECTION

While paint compositions, as the example, have been changed to keep abreast of progress—and will continue to be—painting practices in the main have remained static. Fabricators are required to clean the steel of foreign matter and to remove by mechanical or manual means loose scale and rust. Removal of rust and scale can at times be rather haphazard, depending on the size of the project and the number of inspectors available. The inspectors may be from outside testing laboratories or Department employees.

Two other causes of potential paint failure are poor caulking of lap joints and insufficient film thickness of paint applied to sharp edges (bolt and rivet heads, edges of flanges, welds, etc.). The shop inspectors watch these carefully because our specifications are explicit in spelling out preventive procedures. For example, with sharp edges these critical points must be striped with the shop primer prior to general application of the prime coat to the steel when those areas are again coated to build film thickness. There would be a definite advantage to continuing that practice with each succeeding paint coat, and in fact, such an interpretation can be made from the wording of our specification, but unfortunately it is not required.

In order to obtain adequate film thickness for the bridge paint system, the inspectors—from fabrication to completion—must now insure that certain prescribed wet film thicknesses of each coat be applied. It is the intent of the Department that a minimum of 7 mils dry of the three coat paint system be obtained. There are several wet paint film thickness gages to utilize during application as well as two or three acceptable dried film gages to check the finished job. The inspectors are expected to use these frequently.

We are conscious of the fact that our surface preparation requirements for new construction have not kept abreast of the times as they have in some States. We still require only mechanical and hand scraping and wirebrushing to remove loose rust and scale. Blasting methods are now available which would make complete stripping of the steel to virgin metal economically feasible. The problem is that few fabricators in the Northeast have been equipped to undertake this work. When they become so, the Department will likely upgrade its requirements. This, it is recognized, will noticeably lengthen paint film life and result in further maintenance cost savings—particularly in the more severe environmental areas of the State.

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*See footnote p. 32.

SUMMARY

From the foregoing it can be concluded that our approach to improve protection of structural steel was valid and that we have benefited through a liaison that has accorded us the results of the continuing experience and research of technically qualified personnel in the paint industry.

With our improved paints, and in spite of our limited requirements for surface preparation, we anticipate:

1. Twelve years attractive, protective performance from the three coat system.
2. Minor amount of required scraping and spot priming followed by a full coat of finish on the 12-year cycle.

For the future, it is to be expected that the protection of our structures could be further enhanced by:

1. Adoption of improved cleaning methods.
2. Improved control of paint application through more stringent inspection.
3. The testing and possible adoption of coatings containing still more durable vehicles—a goal not now possible with limited surface preparation and the lack of practical knowledge in our field to properly apply these more difficult to handle materials.

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