The Prevention of Corrosion

These notes set out briefly the lessons that can be drawn from the researches during the last quarter of a century of the Corrosion Committee of the British Iron and Steel Research Association. The intention has been to state plainly what is known about the various choices that face engineers and others concerned with anti-corrosion measures in various groups of circumstances, so that the lessons of experience and research may be readily available. It is obvious that such notes cannot be exhaustive and the references given to authoritative sources of information on the various aspects of the subject have been selected similarly with the needs of the practical engineer in view.

INTRODUCTION

Corrosion may take place in air, in water or in the soil. In all environments the effects of corrosion may be alleviated by one or more of four methods:—

(*a*) Alterations in the corrosive medium;
(*b*) Modifications in the design of plant or apparatus exposed to corrosion;
(*c*) Changes in the composition of the iron or steel;
(*d*) Efficient protective measures.

The relative usefulness of the various methods varies with the different environments.

CORROSION IN AIR

In terms of sheer bulk this presents the biggest problem. Almost all structural steel is exposed to corrosion by air, and the cost of protecting it represents a heavy overhead charge.

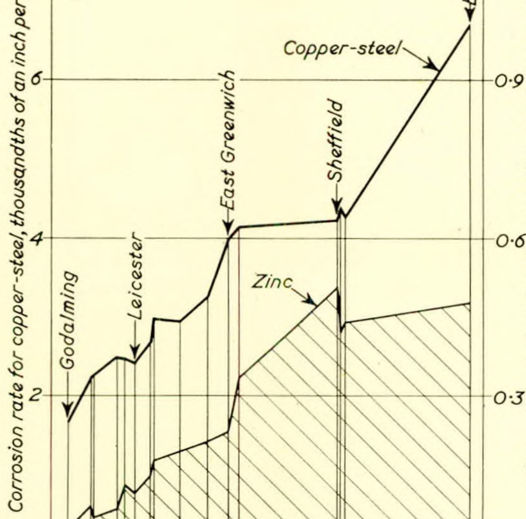


FIG. 1—*Correlation between the sulphur pollution of the air and the atmospheric corrosion of copper-steel and zinc*

Alterations in the Medium

It has been clearly shown that corrosion will not take place in an atmosphere with a relative humidity of less than 70 per cent and that where the relative humidity is conducive to corrosion the degree of atmospheric pollution is the governing factor. In the few circumstances where the engineer can control either or both of these conditions, virtually complete protection can be achieved. Examples are the air conditioning of some factories making polished steel parts such as needles, and some ships' holds. The remedy of reducing atmospheric pollution, however, is not normally within the control of the engineer concerned with corrosion prevention.

Modifications in Design

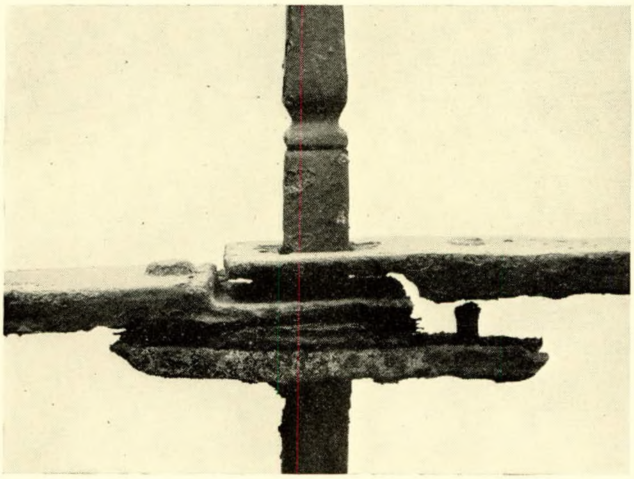
One of the simplest means of reducing the risk of corrosion is to avoid any detail of design that may facilitate the lodgement of moisture and atmospheric grime; for rust begets rust by keeping the underlying steel wet long after the rest of the structure has dried. Again, it is not uncommon for structures to be designed with "back-to-back" angles or similar features that render certain parts inaccessible for repainting. This mistake is surprisingly frequent. In a fairly recent case, for example, about 50-ft. run of twin 10-in. by 6-in. joists supporting the floor of a cold store had to be replaced because they had been set too closely together to permit repainting their inner surfaces. Consequently, condensation of atmospheric moisture had caused dangerous rusting.

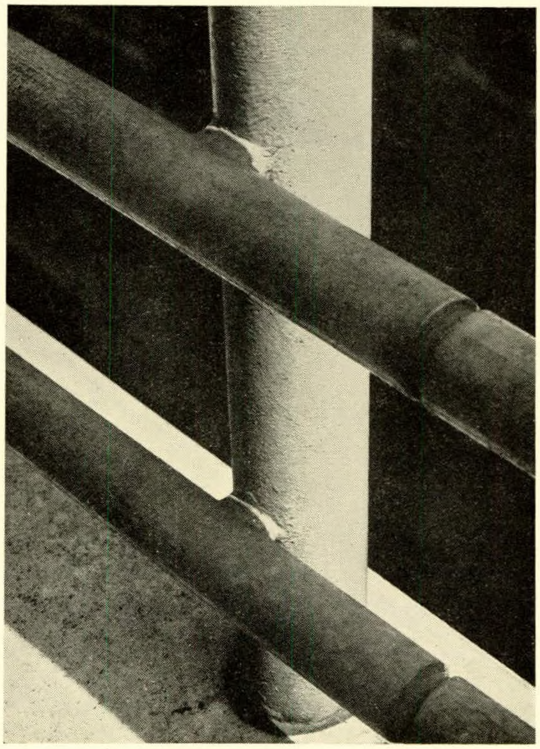
It is, fortunately, now generally recognized that contact between dissimilar metals in the presence of an electrolyte should be avoided, particularly when they lie far apart in the electrochemical series. This is because of the danger of setting up a corrosion cell.

Changes in the Composition of the Iron or Steel

The extreme application of this method of prevention is the use of stainless or rust resisting steels, with 18 per cent chromium and 8 per cent nickel, or their many derivatives with special heat resisting and other properties. The great value of these steels in special engineering applications is well known to those who use them, and need not be dwelt on here. The general application of highly alloyed rust resisting steels for general structural purposes is limited by cost and the availability of alloying elements, and these limitations are not likely to be overcome in the foreseeable future.

Such limitations do not apply to the group of corrosion resistant low-alloy steels, which generally contain small amounts of chromium, copper or nickel. These steels are not "rustless", but the rust formed on them is more compact than that formed on ordinary steel and retards the progress of rusting on the steel beneath. Exposure tests have shown that steel containing about 0·3 per cent of copper is roughly 50 per cent more resistant to atmospheric corrosion than ordinary mild steel, and that low-alloy steels containing about 1 per cent of chromium in addition to the copper are three times more resistant; i.e. it would take three times as long for rusting to destroy a plate of given thickness if it were made in 1 per cent chromium steel instead of ordinary mild steel. Other low-alloy steels are claimed to give as good or even better results.





FIGS. 2 *(left)* and 3 *(right)*—*The importance of good design. Railings at Westminster Abbey (left) and on Waterloo Bridge (right)*

Where mild steel can be maintained in such good condition that rusting never starts, the slower corrosion rate of low-alloy steels clearly offers no advantage. This property is very valuable, however, where structures are exposed to severely corrosive conditions or where efficient paint maintenance cannot be guaranteed. Where it is wholly impracticable to paint steel exposed to atmospheric corrosion, corrosion resistant low-alloy steels will show to even greater advantage. A good example is the steel floor of a railway wagon. Service tests on coal wagons made by the Corrosion Committee have indicated that the life of low-alloy steel plates will probably prove at least double that of similar plates of ordinary steel. Or again, the durability of the plates of steel railway sleepers will be appreciably prolonged by making them of copper-bearing steel, with about 0·3 per cent copper, instead of ordinary steel. Similar considerations apply to fencing wires and other thin steel sections that cannot conveniently be repainted after erection.

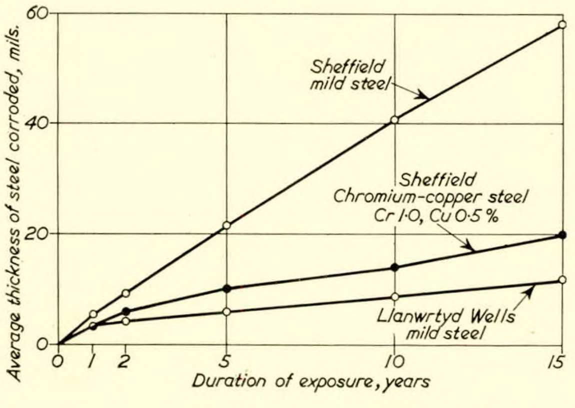


FIG. 4—*Corrosion/time curves for mild steel and chromium-copper steel*

It is the opinion of the Corrosion Committee that the increased use of low-alloy structural steels provides one of the best means of minimizing the effects of corrosion of structural steel.

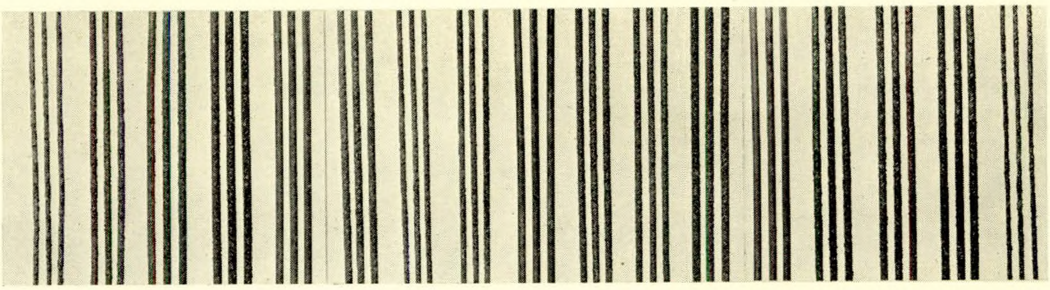
Efficient Protective Measures

Applications of effective coatings by painting or other means are the protective measures that can be applied to iron and steel in air.

Painting

Contrary to what might be expected, protection of steel by painting does not depend solely or even mainly on the exclusion of water and/or oxygen from the metal. Most paint films are, in fact, pervious. They operate by slowing down the movements of ions, and therefore the electrochemical processes which cause corrosion, and only to a lesser extent by excluding air and oxygen from the metal surface. An effective painting scheme must, therefore, be based on a primer containing inhibitive substances, and must be applied to a surface prepared in such a way that its inhibitive action can take effect. If this is done, and if there are two or more robust outer coats to prevent mechanical damage and chemical alteration to the inner coat, corrosion can be virtually stopped. Three-coat paint combinations based on this principle have given complete protection during seven years outdoor exposure in London. Even two-coat systems, properly chosen, give fairly good protection if all scale and rust is removed so as to bring the inhibitive substances into direct contact with the steel.

Authoritative opinions have been expressed that the best inhibitive paint contains mixed red lead and white lead in linseed oil. The formulation may be varied within reasonable limits, but in trials conducted by the British Iron and Steel Research Association, a paint pigmented with 40 per cent by weight each of red lead and white lead and 20 per cent of asbestine has shown up well. The medium is a blend of linseed stand oil (30-poise) with alkali-refined linseed oil in the pro-



STEEL No.	36	40	43	46	BLANK	19	6	11	BLANK	18	8	24	BLANK	26	28	31	27
COMPOSITION %	MILD STEEL	Mo 0·5	Mo 0·5 Ni 2·0	Cr 3·1 Mo 0·4 Ni 0·1		Cr 2·0	MILD STEEL	Si 0·8		Cu 0·5 Si 0·8	Cu 0·5	Cr 1·9 Cu 0·5		Al 1·6	Cr 2·6	Ni 3·1	MILD STEEL
FINAL DIAMETER-IN.	0·08″	0·10″	0·11″	0·12″	0·12″	0·11″	0·08″	0·09″	0·12″	0·10″	0·09″	0·12″	0·12″	0·11″	0·11″	0·11″	0·06″

FIG. 5—*10 S.W.G. (0·18 inch) low alloy steel wires after five years' outdoor exposure at Sheffield*

portion of two parts to three by weight. There are, of course, numerous good alternatives such as red lead paint, as specified in B.S. 1011, or paints containing chromates.

"Zinc rich" paints, containing 92 per cent to 96 per cent of metallic zinc by weight in a polystyrene or other suitable medium show interesting possibilities, as they possess inhibitive properties based on their electrochemical properties.

Given a good inhibitive priming paint, the type of finishing paint used is not critical and there is a wide field of choice. Probably, red oxide of iron in a weather-resistant medium is as good as any for practical purposes, where appearance is not an important consideration. Otherwise paints pigmented with titanium oxide or aluminium powder, each bound with suitable synthetic media, generally give good results. In tests by the British Iron and Steel Research Association, made in many different climates, a painting scheme consisting of two coats of red lead in linseed oil paint on a surface freed of millscale by pickling or sand-blasting, followed by two coats of red oxide in linseed oil paint was observed to protect steel adequately for periods of ten years or more.

However carefully selected the protective paints may be, they cannot fulfill their purpose if they are applied to an ineffectively prepared surface, nor if the paint film is not thick enough. These points cannot be over emphasized. It is a sure way of wasting time and money to preface expensive painting schemes with inadequate surface preparation or to apply them at an inadequate film thickness. These are perhaps two of the most outstanding sources of false economy in modern industry.

The worst surfaces for painting are those carrying dirt, grease, rust or millscale. Dirt and grease can be removed by cleaning with suitable solvents, but chemical or mechanical treatments, e.g. pickling or grit-blasting, are needed to remove rust and millscale. The benefits resulting from good surface treatment are shown by Table I. These data were originally obtained in 1951, but the relative proportions still obtain. Table II shows some experimental results, giving average figures for many specimens of different structural irons and steels painted with two coats of red lead paint followed by two coats of red oxide paint, and exposed at Sheffield. The "intact millscale" surface represents a surface that could not be achieved over a large structure under practical conditions. The effective life of the painting scheme was more than quadrupled by being applied to pickled or sand-blasted steel, instead of to weathered and wire-brushed steel, as in common industrial practice.

TABLE I.—SUMMARY OF THE RELATIVE COSTS OF VARIOUS SURFACE TREATMENTS

Process	Period between successive repaintings, years	Relative total* cost over a period of fifty years
(1) Weathered and wirebrushed	3	2·5
(2) Flame cleaned and primed at works	5	1·75
(3) Pickled and phosphoric acid dipped and immediately primed	5½	1·25
(4) Grit blasted and metal sprayed (3 mils.)	7	1·0

$$\text{*Total cost} = \left\{\begin{array}{l}\text{Initial cost of}\\ \text{surface preparation and}\\ \text{painting}\end{array}\right\} + \left\{\begin{array}{l}\text{Costs of repainting}\\ \text{over a period of}\\ \text{fifty years}\end{array}\right\}$$

TABLE II.—EFFECT OF SURFACE PREPARATION ON PAINT DURABILITY

Surface preparation	Durability, years
Weathered and wire-brushed	2·3
Intact millscale	8·2
Pickled	9·5
Sand-blasted	10·4

The American Steel Structures Painting Council has recently issued a valuable set of surface preparations specifications for steel.

Phosphating processes should also be considered. In these the steel is immersed in solutions of phosphates near the boiling point, and acquires an excellent surface for painting. They are more readily applicable to light-gauge steel, as used, for instance, in the motor-car industry, but there is no reason why they should not be employed for structural steel. Phosphoric acid washes, rubbed or brushed on cold, are of value in preparing clean unrusted steel for painting, but no wash used in this way will nullify the bad effects of serious rusting or restore a steel surface carrying rust and millscale to a satisfactory condition for painting. For this, only a descaling process or immersion in a hot-phosphating bath will suffice. An effective process in current use consists of pickling steel plates and sections in hot dilute sulphuric acid, rinsing them in hot water, and then transferring them for a few minutes to a tank of hot dilute phosphoric acid. The steel is allowed to dry under its own heat after removal from the last bath and is then prime-painted whilst still warm.

The most recent development in chemical surface treatments as a preparation for painting metal is the use of the so-called "etch primers", originally on ships' hulls, but later for other purposes as well. They were developed in the U.S.A. during the second World War, and consist of an alcoholic solution of phosphoric acid to which a synthetic resin polyvinylbutyral, and zinc chromate pigment are added. In broad terms, the phosphoric acid component of the etch primer reacts on the steel base, thus ensuring good adhesion. It forms an impermeable phospho-chromo-organic complex with the other constituents, to which the primary coat of paint keys well.

It should be noted that an etch primer forms a film much thinner than a single coat paint film, and should be used as a supplement to the priming coat of paint, not as a substitute.

A paint film thickness of at least 5 mils (0·005 inch), should be applied to any important steel structure, except for those erected in particularly non-corrosive conditions. The thickness of a good coat of oil paint is about 1½ to 2 mils, so that at least three coats are applied in good practice. Whenever possible the thickness of the final paint film should be checked at representative parts of the structure. Suitable non-destructive measuring instruments for this purpose are on the market. This close attention to testing the thickness of paint films was the main feature of American practice noted by the Productivity Team on Metal Finishing which visited the United States in 1950.

When considering the repainting of steel structures, the most important point to bear in mind is that repainting should be carried out while the old paint film remains effective, so that a minimum of surface preparation is needed before the new paint is applied. After cleaning down to remove dust and dirt, any bare places should be wire-brushed and primed; then one or two coats of finishing paint should be put on over the whole surface. The British Iron and Steel Research Association has prepared a photographic chart showing increasing degrees of rusting of a painted steel surface and recommends that repainting should be carried out after not more than 0·5 per cent of surface rusting has developed.

Metallic Coatings

Zinc and aluminium coatings on steel provide effective means of protection against its corrosion.

Zinc can be applied by any of several processes; hot-dipping, electro-deposition, metal-spraying and sherardizing. Except that the weight of zinc that can be applied by sherardizing is limited to a maximum of about ¾ oz. per sq. ft., the protective value of these processes is substantially the same, the life of any given coating being determined by the weight of zinc applied. An unpainted zinc coating weighing 2 oz. per sq. ft. or about three mils* thick, should prevent serious rusting of steel for six years in an industrial atmosphere, and for much longer periods in mildly corrosive rural atmospheres. The British Electricity Authority have observed that their steel transmission towers, erected after the steelwork has been hot-galvanized with 2 oz. of zinc per sq. ft., but without painting, require painting after five-ten years in industrial districts, ten-twelve years in coastal districts and fifteen-twenty years in country districts.

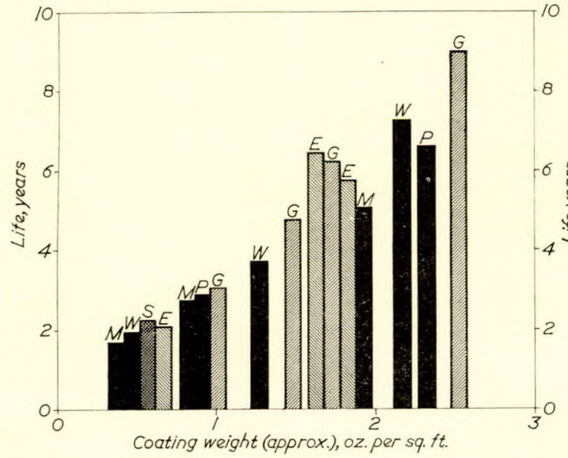


FIG. 6—*Effect of coating weight and method of application on the life of zinc coatings*

Aluminium can be applied to structural steel only by spraying, though recent research developments indicate that a hot-dip method may soon become feasible. A recent application of aluminium spraying to a large building was at the Abbey Works of the Steel Company of Wales, where 15,000 tons of structural steelwork has been shot-blasted and given a sprayed coating of aluminium, 4 mils thick, followed by a single coat of paint. The cost of this scheme has been given as "not more than two-and-a-quarter times" that of the more usual procedure of weathering and wire-brushing before the application of red lead primer and finishing paints, as was specified for the remainder of the steelwork. The life of the "normally" treated paintwork is expected to be five years; that of the aluminium coating may be "up to twenty years", and the single coat on top of it will be renewed every seven years after simply washing down the old paint. On this basis the total cost of anti-corrosive treatment at Margam over fifty years for the metal-sprayed work is expected to be just under half that for the ordinary painting treatment.

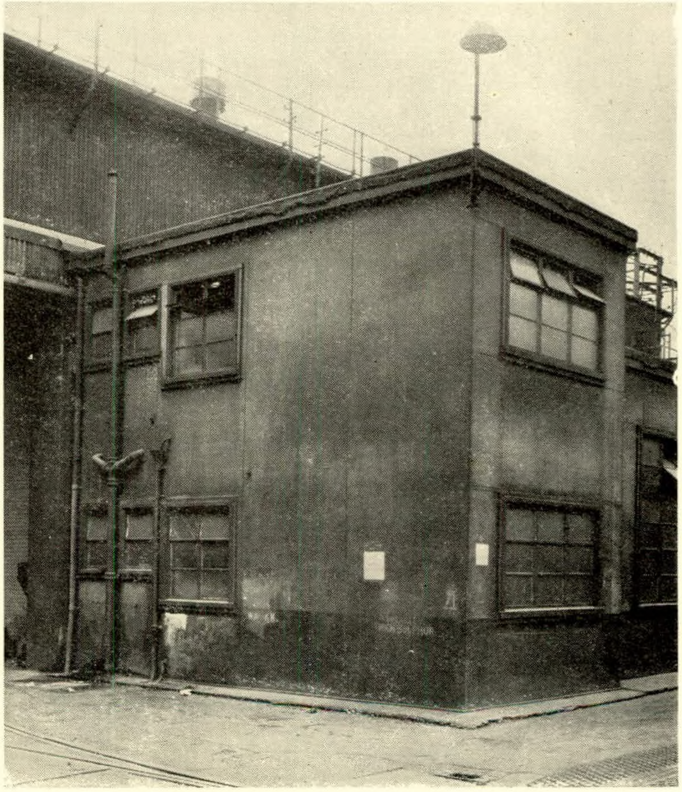


FIG. 7—*A good record in Sheffield*

March 1938: Grit blasted and aluminium sprayed; bituminous paint and lacquer on 3-ft. dado only.
1939-46: Encased with sand revetment to about 10 feet.
1946: Revetment removed, bituminous paint put on dado, aluminium paint above.
1952: Sprayed aluminium coating still in very good condition.

Although non-ferrous metal coatings are more resistant to corrosion than mild steel, they are not incorrodible and sooner or later it becomes necessary to paint the steel structures on which they have been used; in some cases, as at Margam, it may be preferable to do this immediately after erection. Metal coatings and paints are, therefore, to be regarded as complementary rather than competitive. It may be said that for general use over metal coatings, paints containing chromate pigments, say, in conjunction with red oxide, prove suitable.

No reference has been made here to "enveloping" coatings, which prevent corrosion purely by excluding the corrosive medium. Certain plastics, vitreous enamel, and various greases, for example, come into this category. Although these are only employed to a limited extent at the present time, each

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* 1 mil = 0·001in. (0·025 mm.).

has a specific and valuable field of usefulness well known to its practitioners.

CORROSION IN WATER

This aspect of the subject will be considered in two sections: —

(*i*) Marine corrosion, ships' hulls and superstructure.
(*ii*) Marine corrosion; shore installation.

The important subject of corrosion by industrial water is not dealt with here, as it has been fully but concisely covered in Special Report No. 41 of the Iron and Steel Institute; "Corrosion of Iron and Steel by Industrial Waters and its Prevention". It is sufficient to remark here that the main preventive measures in this connexion are concerned with alterations in the corrosive medium by such means as water treatment and the addition of inhibitors.

Marine Corrosion: Ships

(*a*) *Alteration of the medium.* This does not apply to the exterior of ships, though consideration must be given to the conditions in which they will be operating when selecting the best means of protection against corrosion. Holds, as mentioned above, may sometimes be dehumidified so that the relative humidity of the air inside them is less than about 70 per cent of the critical value above which rusting may occur.

(*b*) *Modification of design.* Below the water line this consideration does not apply. Between wind and water, and above the water line, however, the same points should be observed as with structural steels. Details must be avoided that facilitate the lodgement of moisture and atmospheric grime.

(*c*) *Changes in the composition of the steel.* Trials of sixty different low-alloy steels, which were immersed in sea water for periods of up to five years showed that the only alloying element with a marked influence on the corrosion rate in such circumstances is chromium, a 3 per cent addition of which halves the corrosion rate. Copper bearing steel is, unfortunately, no better at sea than mild steel, though evidence from the (then) Inland Waterways Executive has shown that copper bearing steel may show to advantage where immersion is intermittent, as when used for the sides of narrow boats or barges. In general it appears that mild steel will continue as the principal shipbuilding material for many years to come, except where considerations of strength may lead to the use of a low-alloy steel.

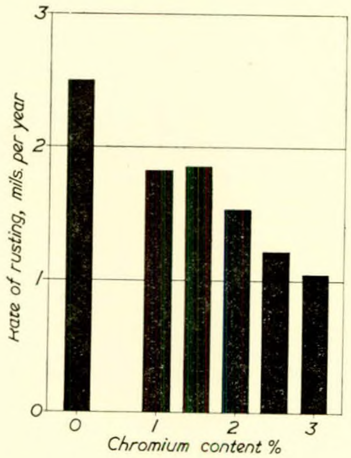

FIG. 8—*Effect of chromium content on the rate of corrosion in water*

(*d*) *Effective protective measures.* The usual protective coating on a ship's bottom is two coats of anti-corrosive composition (paint), with one coat of anti-fouling paint. An anti-corrosion paint resulting from the Corrosion Committee's researches was adopted several years ago by the Admiralty as the standard for painting all new construction. A later composition showing even better performance is being widely used in the Merchant Marine fleet. This composition (known as No. 185) is pigmented with basic lead sulphate, aluminium powder, Burntisland red, and barytes in the proportions by weight of two parts of basic lead sulphate to one part of each of the other constituents; it is bound in a medium of the phenol-formaldehyde/stand-oil type. It is impossible to be strictly quantitative about the results of an operation which is affected by so many varying factors, but an indication is given by the experience of the Cunard Steam-Ship Co., Ltd.

Anti-corrosive composition No. 185 has been in continuous use on the two *Queens* since 1949, except that on the *Queen Mary* a proprietary composition of substantially the same formulation was substituted for it from 1952 onwards. The procedure is to apply two coats of the composition over the old paint when the liners are drydocked in December and January for their overhaul; a final coat of anti-fouling composition is applied over the anti-corrosive paint on the sides but is omitted on the flats of the bottom where it is unnecessary on this route. Because of the good condition of the old paint, little surface preparation is needed other than cleaning down with water and brushes but a number of plates are "sliced" annually in rotation so as to break the head of any small blisters that may have formed. At the annual inspections the paint has been found to be perfectly intact and the amount of rusting negligible, except over small local areas where mechanical damage, e.g. chafing, has occurred. Indeed, the performance of the paint has been such that it has proved possible to omit the summer application of anti-corrosive paint which used to be customary, i.e. the protective painting in the winter now lasts for the full twelve months. The Cunard Company is perfectly satisfied with the behaviour of the paint, which has now been in service for five years.

The effect on corrosion rate of pre-painting surface preparation is not so clearly established for marine corrosion as it is for structural steels, though there is evidence to show that it is considerable.

There is no doubt that the best results are obtained when the millscale is completely removed from the plates, but some anti-corrosion compositions do not adhere well to freshly descaled steel immersed in sea water after painting. Experience has shown that a slight superficial rusting of the descaled plates is an advantage; alternatively, one of the so-called etch primers can be used, as described above.

Both in surface preparation and in paint film thicknesses there are indications that closer control over painting conditions would yield profitable results.

An extreme case of failure was that of H.M.S. *Niger.* Within two months of launching (1936) pits nearly 1/10th inch deep had developed on some of her underwater plates. Their positions were found to correspond with places where the hull had been in contact with the wooden supports used for launching. Either these supports had made it impossible to paint the plates at these places or the paint had been removed by friction during launching. It seemed probable, too, that the corrosion already concentrated on the area denuded of paint had been abnormally increased by stray electrical currents resulting from welding aboard ship during the fitting-out.

Marine Corrosion: Shore Installations

(*a*) Alterations in the corrosive medium
(*b*) Modifications in design
(*c*) Changes in composition.

The remarks made under these three headings in the section on corrosion by air apply to structural installations, such as piers and jetties, exposed to the risk of corrosion in marine atmospheres. Under immersed conditions low-alloy structural steels containing some 3 per cent of chromium appear from raft tests to resist marine corrosion twice as well as mild steel. Copper-bearing structural steels do not maintain their advantage in corrosion resistance when immersed but may be useful for members immersed intermittently. In general the corrosive effects of salt and fresh water do not appear to differ widely.

(*d*) Effective protective measures, including cathode protection.

Paints

Although a mixed red lead and white lead in linseed oil paint will give reasonably good results on steel that is to be immersed in fresh or salt water, particularly if it is allowed a long drying time before immersion, it is not the best for the purpose. Unless the protection yielded by the paint film is perfect and remains so, corrosion of the steel is liable to occur, particularly in waters of good electrical conductivity, such as sea water. Linseed oil is inferior for the purpose under discussion to synthetic media, which are more chemically inert. Some of the best types of such media are the chlorinated rubbers and media based on unmodified or modified phenol-formaldehyde resins.

The anti-corrosive paints formulated with one or other of these media referred to should protect steel immersed in sea water satisfactorily for twelve months, if applied at adequate coating thickness. For immersed steelwork this may be taken as at least 7 mils. It should be maintained by repainting; it is often a mistake merely to touch up an anti-corrosive coat, rather than to give a full coat because it appears to be in good condition.

Within practical limits every endeavour should be made to choose good weather conditions for painting.

Metal Coatings

For underwater use, zinc is superior to other metals normally used for coating heavy steel, and in particular to aluminium and cadmium. Tests have shown that a coating of zinc weighing 3 oz. per sq. ft. will protect steel against rusting for about six years when it is immersed in the sea.

Cathodic Protection

The reasoning on which cathodic protection is based is simple and may be expressed thus: "Corrosion is an electrochemical process involving an anode, which is corroded and a cathode which is not. Let us, therefore, so arrange matters that the metal that we wish to protect acts as a cathode, i.e. is the uncorroded member of the electrolytic cell".

In essentials, therefore, cathodic protection consists in making the steel the protected part of a suitable electric circuit so as to throw the corrosion from it on to a "sacrificial anode". This anode may be of some metal less noble than iron; the most suitable for the purpose is magnesium lightly alloyed with nickel. In this type of assembly the circuit generates its own current. Alternatively, the protective current needed may be supplied from an external source of electrical energy; in this case anodes of scrap iron or steel or of other materials, such as graphite are used.

Cathodic protection can be effective only when the system to be protected is in contact with a good electrical conductor. This condition is amply satisfied when steel is immersed in sea water or buried in most types of soil.

Cathodic protection should, therefore, prove extremely useful to engineers interested in docks and harbours, where ample opportunities exist for its application, and in fact it is being effectually used to an increasing extent for preventing the corrosion of immersed structure. It has been successfully applied, for example, to the lock gates of the Panama Canal. Each practical case is a study in itself and it is advisable to consult experts with previous experience in the subject.

Many examples of successful application of cathodic protection were described at a recent symposium organized by the Corrosion Group of the Society for Chemical Industry.

CORROSION IN THE SOIL

Corrosion in the soil is concerned almost entirely with buried pipe lines. Whereas pipes that have lasted in the soil for seventy or eighty years (and longer) are by no means uncommon, there have been cases where up to twenty miles of line have had to be replaced after only ten years, and some where perforation has occurred within a year. The most common form of corrosion in cast iron pipes is graphitization, the disappearance of the iron matrix of the pipe, leaving a brittle skeleton consisting mainly of carbon. This takes place in anærobic conditions, that is, in conditions (such as burial in impervious clay) where the access of oxygen is denied, and where bacteria provide, as an alternative to atmospheric oxygen, a mechanism for the removal of cathodic hydrogen. The second most common type of underground corrosion is that caused by burial in ashes, cinder and clinker in made-up ground. Other types of corrosion do occur, but their incidence is probably insignificant.

Alterations in the Corrosive Medium

Avoidance rather than alteration of the corrosive medium is sometimes possible by the use of route surveys to show where hostile conditions are likely to be met. It is not usually possible, however, to avoid corrosive areas. Non-aggressive surroundings can be supplied in these areas where it is economic to do so, by using sand, gravel and chalk, usually to a thickness of about 9 inches all round the pipe. They all have the effect of ensuring ærobic conditions, though special drainage may sometimes be necessary.

Modifications in Design

This is not applicable in soil corrosion. Buried pipes are almost always of standardized cast iron or steel units.

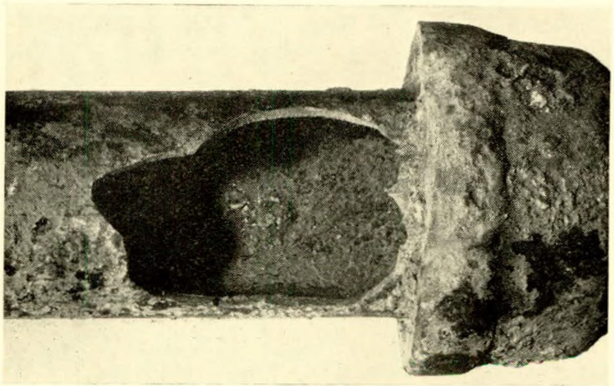

FIG. 9—*Water pipe corrosion after seven years' service at Southend*

Changes in Composition

Alterations in composition do not contribute to a solution of the problem. In the soil low-alloy steels are no more resistant than ordinary steel. It has been remarked on one or two occasions that older cast iron pipes, cast in stationary moulds, appeared to withstand anærobic conditions better than more modern spun cast iron pipes. It does not appear, however, that the difference is more than can be explained by the thinner walls of spun pipes, though other factors may have an influence.

Efficient Protective Measures

The general practice in this country is to apply to spun iron pipes a hot-dip thin tar coating, some 5 mils thick, or 0·5 oz. per. sq. ft. of surface. Examination of pipes that have been stored for any length of time in the open air will show this coating to have an extremely limited life even in the atmosphere.

To improve the performance of coatings on such pipes the first requirement would appear to be an increase in thickness. American investigations have shown that the pitting of pipes over the early stages of exposure is inversely proportional to the thickness of the protective coating on them. The materials most commonly used for protective coatings are concrete and bitumen, but other compositions are being investigated. Concrete coatings are generally permeable to water (also, it should be noted, to stray currents) and their protective value depends on their alkalinity. A rich mix (1:2:4, cement, sand, coarse aggregate) should be used and the coating should be about 3 inches thick. Portland cement is attacked by high concentrations of sulphate and in these conditions aluminous cement should be used.

To be effective, bitumen coatings must be fairly thick, say, ⅛ inch to ¼ inch. To stiffen the coating and to render it mechanically more resistant the bitumen is reinforced with an inert material like short-fibre asbestos or latex or, more commonly, by incorporating a wrapping material inside and/or outside the bitumen. Cellulosic wrapping such as hessian, has been widely applied for the latter purpose in the past, but it is really unsuitable because cellulose is decomposed into organic substances by certain types of soil bacteria. These substances are corrosive and injurious to the mechanical properties of the bitumen; they also favour the growth of sulphate-reducing bacteria. Recently, glass fabrics have been introduced for wrapping pipes, and plastic wrappings are a possibility. They should prove permanent in the soil, and if they prove to have the necessary mechanical strength should help bitumen coatings to give a better performance.

The Dutch Corrosion Committee has published specifications for coatings of blown bitumen with particular reference to their application to steel pipes of 3 inches or less internal diameter. The latest version of this specification calls for a composite coat consisting of (*i*) a priming coat not exceeding 20 mils in thickness; (*ii*) a covering coat bringing up the total coating thickness to 100 mils; (*iii*) a wrapping of impregnated material, such as asbestos, glass wool or hessian; and (*iv*) a final coat of bitumen at least 80 mils thick. This treatment gives a maximum total thickness, including the wrapping, of 180 mils. The quality of the bitumen is defined by reference to its softening point (ring and ball method) and its resistance to penetration; in addition, other tests are made on the bitumen, fillers and the wrapping materials. Even a slight increase of thickness to, say, 20 mils would give substantially better protection than a hot-dipped coal tar coating about 5 mils thick, which is all that is frequently applied.

Buried sheet pilings are sometimes exposed on one side to sea water and on the other to corrosion by soil. Here the same types of protective coatings as are used for buried pipes are appropriate. Cathodic protection is a particularly valuable defence when the water has a sufficiently high conductivity to make its use possible.

Protective coatings of buried metals may often be reinforced with advantage by "cathodic protection", a note on which was included in the remarks on marine corrosion of structural installations.

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