Indian Standard

CODE OF PRACTICE FOR PROTECTION OF IRON AND STEEL STRUCTURES FROM ATMOSPHERIC CORROSION

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0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 30 September 1977, after the draft finalized by the Corrosion Protection Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 This standard has been prepared to assist engineers, architects, builders and others who are responsible for the choice or application of measures to protect iron and steel structures from atmospheric corrosion. The treatments suggested in this code represent the minimum acceptable standard of good practice for important structures. However, there may be some other usages for which lower standards of protection are acceptable or are necessary for reducing the initial cost even though higher maintenance cost may ensue. The recommendations made in this code are not intended to discourage the use of other improved or newly developed methods and materials which may prove to be satisfactory in service.

0.3 An appreciation of the scientific principles of corrosion and its prevention is essential for efficient use of modern protective schemes. This standard, therefore, gives an outline of the basic principles of corrosion and its prevention. It also includes data on the relative corrosivities at different places in India, a knowledge of which is essential in selecting a suitable protective scheme.

0.4 In the preparation of this standard, assistance has been derived from the following publications:

CP 2008 :1966 Protection of iron and steel structures from corrosion. British Standards Institution.

RAO (KNP) and LAHIRI (AK), Ed. Corrosion Map of India, Corrosion Advisory Bureau, Council of Scientific and Industrial Research, Jamshedpur.

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PART I GENERAL PRINCIPLES OF CORROSION AND ITS PREVENTION

1. SCOPE

1.1 This standard (Part I) covers the general principles of corrosion and its prevention. It also includes data on the relative corrositivities at different places in India.

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions given in IS : 3531-1960* and IS : 1303-1963† shall apply.

3. MECHANISM OF CORROSION

3.1 Iron and steel corrode in presence of moisture. The nature of this corrosion is electrochemical. At certain spots, known as 'anodic points', iron enters the electrolyte as 'ions', this entry being called the 'anodic reaction'. The anodic points may be breaks in the millscale or an oxide film on the metal, or perhaps, places where because of heterogeneities in the crystal structure the atoms require less energy to break away than elsewhere. However, since the passage of ions into the electrolyte leaves electrons behind, it may continue only if elsewhere a 'cathodic reaction' has been established to use up electrons. A corrosion cell is thus set up. The cathodic reaction may be the reduction of oxygen to hydroxylion, although in acidic electrolytes, it may be liberation of hydrogen gas.

3.1.1 The flow of current in the corrosion cell thus formed results in attack on the metal at the anode, but the cathode is not corroded.

4. ATMOSPHERIC CORROSION

4.1 Atmospheric corrosion may be classified into three categories, namely:

a) dry oxidation or dry atmospheric corrosion,
b) damp atmospheric corrosion, and
c) wet atmospheric corrosion.

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*Glossary of terms relating to protection of metals.

†Glossary of terms relating to paints (*revised*).

4.1.1 In dry oxidation all metals develop oxide films and remain free from corrosion. Certain metals for example copper, silver, brass etc, are however, tarnished if sulphur compounds are present in the atmosphere.

4.1.2 In case of damp atmospheric corrosion the atmosphere contains large amounts of water vapour and the corrosion has a close resemblance to immersed condition. Water vapour is present in concentrations above a certain minimum value (the 'critical humidity' *see* **5.4**), and gaseous and solid polluants are also present in traces.

4.1.3 In wet atmospheric corrosion, the metal surface are wetted by rain and dew. In these conditions, although approaching those of immersed conditions, corrosion is much more aggravated due to alternate wetting and drying and better replenishment of oxygen than under immersed condition, where the limited amounts of dissolved oxygen is not so easily replenished.

5. FACTORS GOVERNING THE CORROSION RATE

5.1 The severity of corrosion is controlled by a number of determining factors, such as condensation, moisture, atmospheric pollution (both industrial and marine), deposition of solid particles and surface condition of metals.

5.2 Effect of Condensation and Moisture — At atmospheric temperatures, the metals used in engineering are generally resistant to direct oxidation and suffer rapid attack only when electrochemical action takes place. Usually an electrolyte is provided by a film or pocket of condensed moisture on metal surface or by wetting due to exposure to rain. It may also be provided by absorption of moisture from the atmosphere by hygroscopic substances like dust or other contaminants deposited on metal surface. Products of corrosion, such as rust are themselves hygroscopic. Although pure water is only a weak electrolyte, natural waters may be quite strong electrolytes. In industrial areas, the atmosphere is polluted with substances, such as sulphurous products of combustion which render atmospheric water much more corrosive. Near the sea and even at considerable distances inland, the atmosphere also contains chlorides, which again increases the corrosiveness of atmospheric water.

5.3 On exposure to air, almost all metals become covered with a surface film of oxide. Such films are very thin. The films, which are continuous and firmly adherent and occupy substantially the same volume as the metal from which they are formed, are protective. In dry air, the metal remains uncorroded. However, where the metal is exposed to damp atmosphere, the metal surface is liable to acquire a film of condensed natural water, so that the immediate environment is, instead of dry air, an electrolyte solution. Under such conditions a thin air-formed film of oxide generally affords little protection. Although it may be impervious to molecular oxygen, it is usually incapable of preventing access of ions to the metal.

5.4 Critical Humidity — The critical humidity represent the relative humidity above which corrosion of metal becomes substantial. Below critical humidity, there is practically no corrosion although air-formed oxide film grows which causes some increase in mass of specimens. The critical value of relative humidity above which corrosion of iron becomes rapid is about 70 percent.

5.4.1 In presence of polluants, the value of critical humidity is generally reduced. For example, in the presence of traces of sulphur dioxide, the critical humidity of iron is 50 percent relative humidity. Above this value, there is pronounced increase in the rate of attack and the specimen becomes rapidly covered with rust. Similarly in the presence of sodium chloride nuclei on its surface, the critical humidity of iron is reduced to 45 percent relative humidity.

5.5 Atmospheric Pollution — Corrosion is greatly stimulated when the air contains sulphur dioxide and corrosive salts, such as certain sulphates and chlorides. The main sources of those types of atmospheric pollution are the combustion of coal and other fuels, exhaust gases of automobile, and marine spray. The amount of sulphur in coal varies, about 11·5 percent being fairly average. The normal sulphur dioxide content in air varies between 10^{-5} to 10^{-2} percent. Table 1 gives the data of salinity and sulphur dioxide pollution at various sites in India. Sulphur dioxide content varies between negligible to 1 mg of $SO_3/dm^2/day$. Sulphur dioxide contamination varies with season, being higher in winter due to higher fuel consumption.

5.5.1 The action of electrolytes on atmospheric corrosion is of considerable importance in dust and salt laden atmosphere of industrial and marine sites. In marine atmospheres the corrodant is sea salt, which may be dispersed either as liquid aerosols or dry particles. The presence of electrolytes in the air is responsible for high rates of corrosion near the sea where metals are directly exposed to sea surface or wind from the sea. Table 2 shows corrosion rates at some of the marine sites in India and the effects of distance from the sea.

5.6 Effect of Different Climates — The corrosion rate is profoundly effected by the microclimate and to a lesser degree by the mass, size and shape of the metal, and by angle of exposure. For mild steel specimens exposed at an angle of 45°, the corrosion suffered in one month's exposure and one year's exposure varies widely with the climates (*see* Table 3).

5.7 Effect of Location of Exposure — Corrosion rates of a metal also varies with the location where the structures are erected. The proximity to source of pollution also plays a vital role.

TABLE 1 DATA OF ATMOSPHERIC POLLUTION DUE TO SO_2 AND CHLORIDES

(*Clause* 5.5)

EXPOSURE SITE (1)	MEAN VALUE OF AVERAGE SULPHUR DIOXIDE POLLUTION (mg of SO_3/dm^2/day) (2)	MEAN VALUE OF AVERAGE SALINITY (mg. of NaCl/dm^2/day) (3)
Ahmadabad	0·42	0·82
Balasore	—	2·44
Bhavnagar	—	14·84
Bombay (NCML)	0·37	0·22
Calcutta-Rishra	0·31	0·16
Tiljala	0·18	0·16
Cambay	0·16	2·12
Cochin	0·091	0·60
Digha	—	0·83
Goa	0·63	—
Gulmarg	—	—
Hyderabad	0·27	—
Jamshedpur	0·99	—
Jodhpur	—	—
Kanpur	0·1925	—
Kandla	0·3575	2·728
Patna	0·0858	0·67
Rajkot	1·10	—
Tezpur	0·040	—
Chittaranjan	1·18	—

TABLE 2 CORROSION RATE AT MARINE SITES IN INDIA AT DIFFERENT DISTANCES FROM SEA

(*Clause* 5.5.1)

STATION	DISTANCE IN m FROM THE SEA-SHORE	CORROSION RATE IN mm/YEAR FOR MILD STEEL	
		Max	*Min*
(1)	(2)	(3)	(4)
Digha	33	1·35	0·06
	330	0·54	0·056
	2 200	0·28	0·023
Balasore	22	0·63	0·024
	45	0·25	0·009
Mandapam Camp	45	0·69	0·287
	405	0·147	0·088
Madras	30	0·34	0·13
	840	0·26	0·07

TABLE 3 ATMOSPHERIC CORROSION RATES OF MILD STEEL AT VARIOUS SITES

(Monthly rate for each month reported as mm/month and yearly rate as mm/year)

(*Clause* 5.3)

MONTHS	KANPUR	JODHPUR	CALCUTTA (TILGALA)	TEZPUR	BALASORE
January	0·006 7	0·000 2	0·015	0·003 8	0·001 5
February	0·001 5	0·000 3	0·023	0·001 5	0·002 8
March	0·001 5	0·000 8	0·020	0·001 2	0·026
April	0·000 2	0·000 5	0·008	0·002 1	0·035
May	0·000 8	0·001 5	0·010	0·002 1	0·012 6
June	0·001 7	0·003 3	0·016	0·003 5	0·020 3
July	0·004 2	0·001 9	0·012	0·003 8	0·007
August	0·004 7	0·002 1	0·018	0·004 1	0·013
September	0·004 2	0·000 7	0·017	0·004 3	0·005 2
October	0·003 8	0·000 2	0·016	0·004 2	0·000 8
November	0·004 2	0·000 2	0·010	0·002 6	0·001 3
December	0·007 2	0·000 2	0·013	0·005 2	0·001 8
Yearly	0·031	0·006	0·078	0·030	—

5.8 Effect of Orientation of Exposure — The orientation of metal specimens influences the corrosion rates due to its effect on the amount of moisture or atmospheric contaminants that can react with the surface. The relative corrosion of specimens facing different directions largely depends on the extent to which the prevailing wind may carry the pollution from their sources. The drying effect may also be different according to the directions. However, in a study at an industrial site with low sulphur pollution (Kanpur), it was observed that there was very little difference in the yearly corrosion rates of panels facing any direction. Table 4 shows the variation on corrosion rates of mild steel panels facing groundward and skyward.

5.9 Effect of Metal Composition — The type and chemical composition of ferrous metals have a marked influence on their resistance to atmospheric corrosion.

5.9.1 *Mild Steel* — Mild steels of the same composition but manufactured by different processes corrode at substantially the same rate. Increasing carbon content up to a limit of 0·25 percent has little effect. Ingot iron, which is really a steel with the lowest practicable carbon content, resists corrosion no better than ordinary mild steel.

TABLE 4 EFFECT OF ORIENTATION OF MILD STEEL SPECIMENS ON OUTDOOR CORROSION AT KANPUR

(*Clause* 5.8)

MONTHS	ORIENTATION OF EXPOSED SURFACE	CORROSION RATE (mg/dm^2/MONTH)			
		East	South	North	West
(1)	(2)	(3)	(4)	(5)	(6)
December 1961	Skyward	178	199	234	208
	Groundward	202	133	216	161
January 1962	Skyward	259	275	272	340
	Groundward	184	135	205	239
February 1962	Skyward	128	84	134	108
	Groundward	124	110	107	126
March 1962	Skyward	74	68	56	83
	Groundward	50	53	72	59
April 1962	Skyward	11	19	3	6
	Groundward	4	3	2	2
May 1962	Skyward	12	12	6	19
	Groundward	3	1	—	1
June 1962	Skyward	147	133	133	148
	Groundward	184	144	137	136
August 1962	Skyward	105	—	128	112
	Groundward	130	125	141	150
October 1962	Skyward	220	206	334	318
	Groundward	225	140	229	225

5.9.1.1 Small amounts of certain alloying elements, notably copper, chromium and nickel, increase the resistance of iron or steel to corrosion outdoors. The effect of the copper content is particularly marked. As is shown in Fig. 1, there is at first a progressive decrease in corrosion with increasing copper content but beyond a certain limit, which depends on the sulphur content of the steel, further additions cause little additional improvement. A copper content of 0·20-0·35 percent for the copper bearing quality of steel is specified in IS : 226-1975*.

5.9.2 *Low-Alloy Steel* — Low-alloy steels contain deliberate but relatively small additions of alloying elements. Some of them, for example, a steel with 1 percent chromium, 0·6 percent copper and relatively high phosphorus and silicon contents, corrodes in the open atmosphere at one-third or less of the rate for ordinary mild steel. They are not, however, immune to corrosion, and are better described as 'slow-rusting'.

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*Specification for structural steel standard quality (*first revision*).

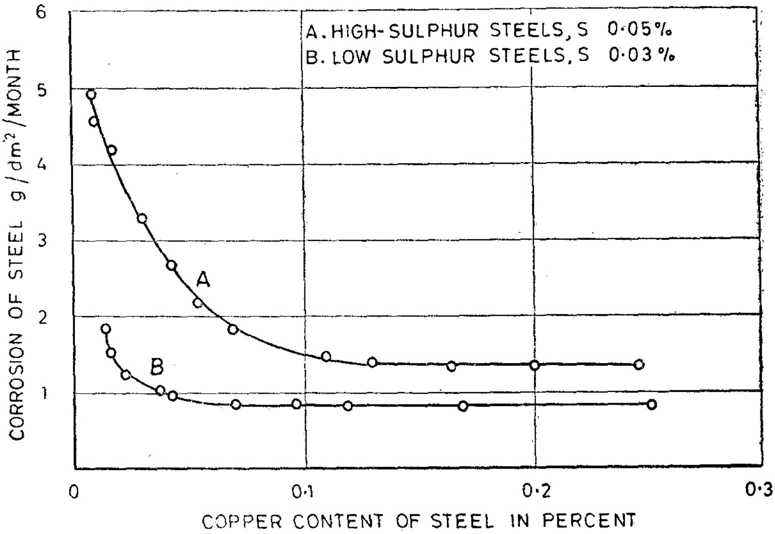

FIG. 1 EFFECT OF COPPER CONTENT ON THE CORROSION OF MILD STEEL OUTDOORS

5.9.2.1 The improved corrosion resistance of copper and low-alloy steels outdoors is associated with the formation of a more compact and less permeable surface layer of rust. Natural weathering seems to favour this because these steels show little or no advantage when exposed indoors or when sheltered from rain.

5.9.2.2 Corrosion is most rapid during the first year or so, and the beneficial effects of low-alloy additions are of greater practical value in the more corrosive atmosphere.

5.9.3 *Cast Iron* — Cast iron has good resistance to atmospheric corrosion and this is further enhanced if the casting skin on the iron is still intact. The corrosion resistance of nodular graphite cast iron is at least as good as that of flake graphite cast iron and there is evidence that it tends to be rather more resistant than the latter.

5.9.4 *Stainless Steel* — Stainless steels contain high percentages of chromium and often of other alloying elements. The most resistant, for example, a steel containing 18 percent chromium, 10 percent nickel and 2 percent molybdenum, are virtually incorrodible in normal atmospheres. This is due to the presence on their surface of a thin protective oxide film which reforms and heals itself spontaneously if the surface is damaged. Stainless steels are liable to lose their corrosion resistance in non-oxidizing environments, which cannot repair the oxide film.

5.10 Surface Condition

5.10.1 *Mill Scale* — Structural steel plates and sections produced by hot-rolling are covered with a thin blue-black or reddish-blue layer of iron oxides. The thickness and adhesion of the mill scale vary for different types and sizes of section and with the rolling conditions. Thicknesses of 25 to 50 μm are common on mild steel plate, but oxide scales up to 0·5 mm thick may result from forging or other heat treatment, or when a plate is heated for bending. Mill scale seldom adheres completely and permanently. It generally cracks and flakes appreciably while the steel is cooling down after rolling end is liable to spall from the metal during fabrication and subsequent exposure, even after protection by paint. Moreover, because its potential in dilute aqueous solutions is a few tenths of a volt nobler than that of bare steel, its presence on an immersed steel surface gives rise to a corrosion cell in which the steel is attacked wherever the mill scale has been broken.

5.10.2 *Casting Skin* — The casting skin on cast iron results from the reaction of the silliceous mould lining with the hot metal. It is more adherent than mill scale and is often protective. Rolled steel and cast steel of the same composition corrode at much the same rates when the mill scale or casting skin has been removed.

5.11 Corrosion Products

5.11.1 *General* — Corrosion produces a visible layer of rust on all ferrous metals other than the most resistant stainless steels. Sometimes rust stimulates corrosion by holding moisture in contact with the steel, but more generally its effect is to retard corrosion. The composition of the steel affects the composition and properties of the rust layer and consequently, the resistance of the metal to corrosion over a long period. The resulting differences between the corrosion rates of various types of iron and steel are more marked in the open air than when the metals are buried in soil or immersed in water, possibly because the conditions of outdoor exposure promote compaction of the surface rust.

5.11.2 *Cast Iron* — When cast iron corrodes, it does so in a way peculiar to this material. Grey cast irons normally contain elements other than iron to the extent of about 8 percent, including carbon in the form of graphite, phosphorus in the form of iron phosphide and silicon. The graphite and iron phosphide are virtually unaffected by most corrosion processes they are often found remaining '*in-situ*' after the iron has been removed by corrosion. The silicon also remains, but it is usually oxidized to silica or silicates, which help to bind the other constituents. As a result, the corrosion process leaves behind a non-metallic graphitic corrosion residue'. This largely retains the appearance and shape of the original iron, although, of course, it is much weaker mechanically.

6. METHODS OF CORROSION PREVENTION

6.0 The modifications in the composition of the metals provide only a partial solution to the problem of reducing the corrosion of iron and steel structures. Preventive measures are generally needed which fall into three main groups namely:

a) treatment of the environment,
b) protective coatings, and
c) cathodic protection.

6.1 Treatment of the Environment — Corrosion prevention by treatment of the atmosphere is necessarily limited to enclosed spaces. Here the condensation of moisture on the metal surface, caused either by rapid changes in temperature or by carrying on wet processes within a building, often lead to severe corrosion. Remedial measures include lagging the steel, space heating and the installation of air conditioning plants to reduce the relative humidity and the atmospheric pollution. To prevent rusting, the relative humidity should preferably be reduced to 50 percent and should never be allowed to rise above 70 percent. Desiccants may be used for this purpose in enclosed spaces, where air changes are not frequent. Volatile corrosion inhibitors, which create a thin film on the metal, may also be used.

6.2 Protective Coatings — The essentials of a protective scheme are proper surface preparation prior to coating coupled with impermeability and adequate thickness of the coating itself.

6.2.1 *Metal Coatings* — Steel may be protected from corrosion by coating it with a more resistant non-ferrous metal. Zinc and aluminium are most commonly used for coating steel plates and sections. Both these metals resist corrosion in natural environments much better than iron, except that in humid and enclosed atmospheres for example inside steam railway tunnels zinc corrodes as fast as steel.

6.2.1.1 Zinc and aluminium coatings have the further advantages that they resist abrasion better than paint, and that, being anodic to iron, they protect the steel at places where the coating is imperfect or becomes damaged. As an exception to this in some circumstances potential difference between zinc and iron in water is reversed at high temperatures. Preferential corrosion of the iron then occurs with heavy pitting.

6.2.1.2 Coatings of zinc or aluminium, at least 75 µm thick, may provide sufficient protection alone in rural districts. In more corrosive environments the coating should be increased in thickness to 150 µm or painted.

6.2.1.3 The life of bare coating of both metals are roughly proportional to the average coating mass per unit area. Zinc may be applied by several methods but the nature of the process has much less effect on coating itself. Aluminium coatings are generally applied by spraying or hot-dipping (*see* IS : 6586-1972* or IS : 8508-1977†).

6.2.2 *Paint Coating System*

6.2.2.1 *Paints* — A paint consists essentially of a finely divided solid constituent, the pigment, dispersed or suspended in a liquid constituent; the vehicle, which when spread out thinly changes in time to an adherent film. For most purposes, it is essential that this drying of the paint should occur within a few hours. For the majority of paints one or more of the following processes are involved.

a) Evaporation of a solvent from the vehicle, leaving behind a film of solid material. This applies, for example, to coatings simply of coal tar pitch or bitumen in an organic solvent.

b) Conversion of constituents of the vehicle, for example, linseed oil to the solid state by chemical changes, involving mainly oxidation by atmospheric oxygen. Paints often contain driers to hasten these changes. This applies mainly to air drying paints.

c) Polymerization, condensation, or other reaction between the components of the vehicle brought about by putting a curing agent in the paint or by stoving.

Many paints in common use depend particularly for their drying on the second process, but the nature of solvent present is also important. If the solvent evaporates too slowly, as may occur when painting outdoors in cold climate, drying will be retarded and the paint film may suffer serious damage whilst it is exposed to the weather in an imperfectly hardened condition. Too rapid evaporation may also lead to bad results for example it may cause condensation on painted surface.

6.2.2.2 *Paint vehicles* — There are three types of paint vehicles as follows:

a) Oil-based vehicles, which consist mainly of vegetable drying oils, such as linseed oil, tung oil and dehydrated castor oil, and oleoresinous vehicles, which are made by incorporating resins into drying oils. Both these types dry mainly by oxidation.

b) Alkyd-resin vehicles, which are virtually a special case of the previous type. Vehicles based on drying-oil-modified alkyd resins are particularly useful for the manufacture of weather-resistant finishing paints. These dry mainly by oxidation polymerization.

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*Recommended practice for metal spraying for protection of iron and steel.

†Recommended practice for hot-dip aluminizing of iron and steel.

c) Chemical-resistant vehicles, which are used for paints that have to withstand very severe conditions, such as exposure to chemical fumes or immersion in sea-water. In the latter case good resistance to saponification is needed, because alkali is produced at the cathodes of any corrosion cells that may develop. This property is even more essential where paint is used in conjunction with cathodic protection, which renders the protected steel surface strongly alkaline. Epoxide resin, coal tar-epoxide, polyurethane, chlorinated rubber, isomerized rubber and vinyl resin, are some of the vehicles in this category. These dry by a combination of evaporation and polymerization depending on the type of vehicle used.

6.2.2.3 *Pigment-binder ratio* — The choice of pigments for protective paints is discussed in **6.2.2.7**. In general, for a given paint there is an optimum value of the ratio of pigment to binder at which the dry film has its best physical properties and maximum protective value.

Although practical considerations, for example, the need for easy brushing, may necessitate the use of a lower pigment/binder ratio, marked deviations from the critical ratio will lessen the protective value of the paint.

6.2.2.4 *Paint systems* — The protective power of a paint film increases with its thickness, and there is a limit below which protection is not adequate. This limit naturally varies with the paint, the roughness of the steel surface, and the severity of the corrosive conditions. For protection against outdoor exposure four coats of ordinary air-drying paints are generally necessary. If the types recommended in this code are used, the average total dry paint film thickness of the complete paint system lies between about 90 and 140 μm (excluding filler and putti) according to the nature of the individual paints.

6.2.2.5 Discretion is needed in defining film thickness solely in terms of the average value, because marked differences, up to 100 percent, occur from paint to paint in the thicknesses applied by a skilled painter, and equally great differences occur as between one skilled painter and another.

6.2.2.6 Although thicknesses of 125 μm or more may be aehieved in a single coat with some types of paint, for example, high-build coal tar pitch or bitumen paints, most current paint systems consist of several coats, in which different formulations are used for the priming coats and the finishing coats. Multi-coat work helps to reduce the porosity of the paint film and to eliminate the risk of holidays and discontinuities. But it has the disadvantage of introducing internal contact surfaces between successive coats, where adhesion troubles may occur due to pollution during painting; normally, however, this is a relatively infrequent cause of failure.

6.2.2.7 Any multi-coat paint system should be studied as a whole. Each coat should be suitable for its function and be compatible with the other coats. Generally, a good bond results if the properties of successive coats are such, and the intervals between their application are so timed, that the wet upper coat exerts a slight solvent action on the surface of the lower one; this keys the whole paint system together.

a) *Priming paints* — The properties of the priming paint are most important. It should 'wet' the surface readily and provide a firm and adherent foundation for later coats. In addition, since paint films are not completely impermeable to corrosive agents, priming paints should contain inhibitive pigment.

The most common inhibitive pigments are red lead, calcium plumbate, zinc chromate, metallic lead and zinc dust.

Red lead and calcium plumbate paints are normally made with oil-based vehicles, which 'wet' steel well. More complex oleo-resinous vehicles, are often used for metallic lead and zinc chrome paints. Zinc rich paints are generally bound with chlorinated rubber, isomerized rubber, polystyrene, or epoxide resin vehicles; there is also a type in an inorganic vehicle.

A zinc-rich epoxide resin paint makes a useful prefabrication primer.

b) *Finishing Paints* — The undercoats and finishing paint serve to protect the primer and enable it to retain its inhibiting effect on the metal. Some undercoats also act as a link between incompatible priming and finishing coats.

Finishing coats should be highly impermeable to moisture and gases and show good resistance to the environment.

Inhibitive pigments are not necessary in finishing paints, and inert pigments are generally more serviceable. Among these are lamellar pigments, such as leafing aluminium, micaceous iron oxide and silica graphite, which orient themselves in such a way as to reduce the permeability of the film and to retard its chemical degradation by sunlight. Other commonly used pigments are red iron oxide, white lead and rutile titanium oxide.

NOTE — Care should be taken against the use of oil or oil based paint on metal sprayed structure exposed to marine environments because of the likelihood of saponification of these materials.

6.2.3 *Other Protective Coatings* — Various coatings besides non-ferrous materials and paints are also used to protect iron and steel. These include hot-applied coal tar pitch and bitumen, wrapping tapes, plastics, and cement and concrete coatings.

Most of these coatings are of the excluding or blanket type, that is, they protect the metal mainly or solely by keeping out the corrosive agent. The overriding considerations of adequate thickness and proper adhesion to the steel base also apply.

Indian Standard
CODE OF PRACTICE FOR PROTECTION OF IRON AND STEEL STRUCTURES FROM ATMOSPHERIC CORROSION

PART II PRETREATMENT

1. SCOPE

1.1 This standard (Part II) covers in detail the pretreatment to be provided to ferrous structures prior to application of protective schemes.

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions given in IS : 3531-1960* and IS : 1303-1963† shall apply.

3. GENERAL

3.1 The finishing of iron and steel is one of the most important aspects of the finishing of the building materials. For efficient planning and execution of painting work with ferrous metals, detailed data and information as given below should be taken into account:

a) The condition of the metal surface and the presence of harmful materials on it (scale, rust, moisture, grease, dirts, salts, etc),
b) Environment in which the paint coating will have to function, and
c) Information on the nature of previous finish (necessary for repainting during maintenance).

It is most important that any substrate, whether it has been painted previously or not, should be in a fit condition to receive paint.

3.2 Surface Preparation and Pretreatment — Pretreatment and priming of ferrous metals under controlled conditions of the factory gives the best results and it is therefore advisable to adopt this method whenever possible. The object of such treatment is to preserve and protect the metal surface during transport, storage and erection and to minimize the 'on site' preparation for final painting. Much will depend upon the time between the factory treatment and erection, the care with which the materials have been stored and handled during that period and the protective quality of treatment applied.

Application of a suitable priming coat should follow pretreatment without delay. Subsequent coats of paint may be applied on the site.

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*Glossary of terms relating to protection of metals.

†Glossary of terms relating to paints (*revised*).

4. FACTORY PRETREATMENT

4.1 Removal of Oil, Grease, Dirt and Swarf — Generally, the application of any coating, lining material, adhesive or paint, requires as its first essential a perfectly clean surface, which is of very great importance while dealing with the painting of ferrous metals. Steel is normally supplied covered with oil and grease either as a protective layer to prevent corrosion or as a left-over from machining and handling. The customary procedure of applying a so-called 'shop coat' of paint after fabrication which consists of wiping the surface with oily cotton waste left-over from other operations, defeats the purpose of painting at the start. Any paint coat applied on greasy or oily steel surfaces will lack proper adhesion and will lead to the failure of the paint film. It is, therefore, essential prior to the application of any paint that even the minute traces of grease and oil are removed. Grease removal shall be carried out either with solvent type or alkali type degreasing agents. The most common type of degreasing agents are dealt with in **4.1.1** to **4.1.3**. The material used is not so important as the final result which shall be a thoroughly clean surface without any oil, grease or alkali left-over.

4.1.1 *Solvent Cleaning* — There are numerous proprietary brands of solvents, alkaline and emulsion cleaners available; where these are used the manufacturer's instructions should be followed.

4.1.1.1 *Petroleum solvent cleaning* — These methods relate to the use of petroleum solvents (for example, mineral turpentine) for the removal of oil, grease, dirt and swarf from unit parts or simple assemblies having easily accessible surfaces. Petroleum solvents may also be applied to the '*in-situ*' cleaning of large units, assemblies or machinery which cannot be accommodated in degreasing equipment. Petroleum solvent should not be used for assemblies containing fabric, rubber, or other non-metallic materials, unless it is known that no harm will result. The procedure to be followed for petroleum solvent cleaning shall be as follows:

a) *Processes* — The two main methods are given below. Details depend upon the quantity and characteristics of the parts or assemblies to be cleaned.

   i) *Immersion* — This method may be used for unit parts or assemblies when contamination is light and when the highest degree of cleanliness is not essential; it is particularly suitable for hand cleaning in small tanks. The articles should be immersed in the solvent long enough to allow removal of the contaminants, and in no case for less than one minute. Agitation is desirable, and brushing or scrubbing will aid quick cleaning.

  - ii) *Brushing or wiping* — This method is intended for the removal of oil, grease and light contamination from bare metal areas of assemblies containing painted surfaces or non-metallic inserts that might be damaged by general application of solvent. It may also be used for the '*in-situ*' cleaning of articles too large for immersion tanks or spray cleaning systems.

- b) *Handling precautions* — Articles should be placed on hooks or racks or in suitable containers that permit adequate draining. They should not be handled with bare hands after cleaning; clean gloves or similar protection should be used and handling kept to a minimum.

- c) *Safety precautions* — Petroleum solvents should be used at room temperature and suitable exhausts and fire extinguishers should be provided, as these solvents are flammable. Oil-resisting synthetic rubber gloves should be worn when handling articles during cleaning, to protect the articles from sweat residues and to avoid any possible effect of the solvent on the skin. Care should be taken to avoid breathing the petroleum solvent vapour.

- d) *Limitations* — Petroleum solvent cleaning suffers from the following drawbacks:
  - i) Fire risk,
  - ii) Brush or wipe or immersion methods being manual in operation are slow and time consuming and therefore unsuitable on their own for continuous production lines, and
  - iii) The degree of cleanliness achieved by such methods is not high and they are generally used for preliminary cleaning to supplement a proper degreasing operation.

4.1.1.2 *Trichloroethylene cleaning* — This method relates to surface cleaning with the trichloroethylene solvent. Trichloroethylene degreasing should not be used on assemblies containing fabric, rubber or other non-metallic materials unless it is known that no harm will result. Trichloroethylene should be of the stabilised quality and shall be periodically checked for acidity to prevent corrosion. Perchloroethylene may also be used. The procedure to be followed shall be as follows:

- a) *Degreasing* — The three main processes are described below. The precise details of the equipment and the method of operation for each process depends on the quantity and characteristics of the parts or assemblies to be cleaned; the plant manufacturers' recommendations should be followed.
  - i) *Vapour process* — To remove simple films of oil and grease, articles may be subjected to the vapour process, in which the

parts are exposed in a bath of solvent vapour; the vapour condenses on the cold surface of the articles and the condensate dissolves the oil and grease, taking it away to the base of the tank. To ensure the maximum condensation the temperature of the articles should be as near to room temperature as possible at the time of immersion; they should be passed through or suspended in the solvent vapour until no further condensation occurs, after which no further degreasing will take place. Articles with a very heavy film of grease may need a second exposure after cooling.

ii) *Liquid process* — Loosely bound contamination (too much for vapour treatment) such as polishing compound, swarf and road dirt may be removed by immersing the parts in vigorously boiling trichloroethylene.

iii) *Jetting process* — Articles with obstinate dirt deposits that cannot be removed by boiling trichloroethylene may require jetting at high pressure with the hot solvent. The jetting should be carried out only in equipment, specially designed for the purpose.

b) *Handling precautions* — During processing, the articles should be placed on hooks or racks or in a suitable container. They should be so arranged that there is adequate opportunity for the solvent to drain from holes, crevices, pockets and other irregularities. Parts or assemblies that would trap solvent should be rotated or tilted during the degreasing process to prevent drag-out of trichloroethylene. Handling may be reduced by using mechanical and conveyor type degreasing plants which automatically rotate or tilt the articles. After cleaning, articles should not be handled with bare hands; clean gloves or similar protection should be used.

c) *Safety precautions* — Trichloroethylene is a toxic substance, care should be taken to avoid breathing the vapour near degreasing equipment.

4.1.2 *Alkaline Cleaning* — Alkaline solutions are good degreasing agents but as they are usually injurious to the skin, they should not be used except in process tanks. The exception is trisodium phosphate, a very mild alkali which is a good cleaning medium. There are three methods of alkaline cleaning as described below:

a) *Immersion process* — For removing simple films of oil and grease from articles having easily accessible surfaces, the alkaline immersion process may generally be used. The articles should be immersed in hot solutions near boiling temperature of suitable alkaline mixtures for 1 to 10 minutes depending upon the degree of contamination. The cleaning action may be assisted by agitating the solution and by low pressure sprays, particularly if small amounts of loosely bound dirt are present.

b) *Electro-cleaning Process* — This method is suitable for articles that cannot be cleaned by simple immersion method and is quicker and more effective in removing adhering solids. The steel tank containing the electrolyte or mild steel in a suitable form shall be used as one electrode. The component to be degreased shall be the other electrode. Graphite may be used as an alternative anode material. The treatment may be done over a range of temperatures extending from room temperature to near boiling temperature. Higher temperature facilitates quicker cleaning. For detailed procedure of carrying out the electro-cleaning process reference may be made to IS : 6005-1970*.

c) *Jet Cleaning Process* — For unit parts or simple assemblies with oil and obstinate dirt deposit, alkaline jet cleaning may be used. Articles should be placed in suitable apparatus and subjected to jet of hot alkaline solution at high pressure. The conveyor of continuous jet washing machines should be so loaded as to permit the jets of solution to reach all surfaces of the articles being cleaned.

4.1.2.1 *Rinsing* — All alkaline cleaning should be followed by adequate draining but the drainge time should not be so long as to allow the cleaning solution to dry on the articles. Water rinsing should follow draining to ensure that carry over of alkali to the next stage is kept to the minimum. The work should not be allowed to dry before rinsing.

Slightly alkaline rinse water (provided that the alkalinity does not exceed 0·1 percent) prevents steel from rusting during drying.

4.1.2.2 *Handling precautions* — During processing, the articles should be placed on hooks or racks or in suitable containers; for electro-cleaning these supports should maintain good electrical contact and be adequate to conduct the current. Articles should not be handled with bare hands during and after cleaning. Clean gloves should be used and handling kept to a minimum.

4.1.2.3 *Safety precautions* — Strong alkalies attack the eyes and the skin, and therefore goggles, rubber gloves and suitable protective clothing should be worn when handling alkaline mixtures or their solutions.

4.1.3 *Emulsion Cleaning*

4.1.3.1 These are diphase cleaners of oil/water emulsion type. They contain very little alkali but rely on powerful emulsifying agents and hydrocarbons to remove grease. While they cannot be compared to heavy

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*Code of practice for phosphating of iron and steel.

duty cleaners based on caustic soda, they are very satisfactory for most cleaning jobs. Emulsion cleaning is particularly preferred before phosphating as it subsequently leaves a fine textured phosphate coating. Besides, its operating temperature is generally lower than of heavy duty alkaline cleaners. Emulsion cleaners may be applied both by spray and dip, though the former is more common.

4.1.4 *Steam Cleaning* — This method relates to the use of a jet of high pressure steam for the '*in-situ*' cleaning of large unit parts, assemblies and machinery that cannot be accommodated in a cleaning apparatus. The cleaning may be carried out with pure steam, or with alkaline solution/ steam mixtures.

4.1.4.1 *Cleaning* — Where a steam supply is available it may be used in conjunction with a simple steam gun, or with an injector that will entertain alkaline solution into the steam jet, to remove oil and steam will remove most of the oil and grease, and loose adhering dirt. Alkaline solution/steam mixtures will readily remove closely adhering dirt as well as oil and grease. The alkaline solution should be at a concentration of 2 to 4 percent.

4.1.4.2 *Rinsing* — On completion of alkaline solution/steam cleaning; straight steam should immediately be directed over all cleaned surfaces so as to wash away alkaline deposits.

4.1.4.3 *Handling precautions* — During processing, the articles should be positioned to allow draining of the steam condensate. Care should be taken to ensure that steam does not enter delicate mechanisms, armature windings or other working parts from which water cannot easily be removed.

The handling of article during cleaning should be kept to a minimum and sweat contamination should be avoided by the use of clean gloves.

4.1.4.4 *Safety precautions* — Goggles and protective clothing should be worn when carrying out steam cleaning with strong alkalies particularly in confined places. Due care should be taken to avoid steam burns.

4.1.5 *Prevention of Contamination* — After degreasing has been completed, if no derusting or descaling is required, the selected paint coat shall be applied as soon as the surface is dry, preferably without touching the surface with bare hands which may be slightly greasy even when quite clean. Under site conditions, this may not always be possible; nevertheless care should be taken to prevent the surface from getting re-contaminated.

4.2 Removal of Rust and Scale — When steel leaves the rolling mill, it has a firmly adhering skin known as 'mill scale'. The continuous fresh layer of mill scale is in itself a good protection against corrosion of the underlying steel. However, on exposure to the atmosphere, mill scale absorbs moisture and finally again rust-formation takes place. Old steel which has been kept for a long time in the open, has heavy layers of rust formed on its surface. If paint is applied on the layers of rust or loose mill scale, rusting continues almost to the same extent as if there was no paint, with the added disadvantage that under heavy layers of paint, progressive corrosion is not easily detected. Derusting and descaling are the essential preparations required prior to the application of any type of coating on iron and steel. There is considerable difference between the condition of a new steel which requires painting and old steel which has been allowed to weather and rust; the approach to each problem is different. Generally, derusting and descaling of steel may be carried out either mechanically or chemically.

4.2.1 *Mechanical Cleaning* — This may be done by scraping, chipping, wirebrushing, rubbing with abrasive paper or steel wool, by flame cleaning or by sandblasting or shotblasting. New steel that is to be painted has normally a surface partly rusted and partly comprising of firmly adhering mill scale. Once the firmly adhering mill scale has broken, it is extremely difficult to determine whether the remaining mill scale is adhering firmly enough to be left on the surface or should be removed. For ordinary working conditions, it is practically impossible to remove firmly adhering mill scale by any hand operation. Any specification, which requires the cleaning down or removing of mill scale or rust by ‘ scraping ’, sandpapering, chipping, wirebrushing, etc, shall, therefore, be understood to mean that firmly adhering mill scale will not be removed.

4.2.1.1 *Hand scraping* — On the building site, the correct procedure shall be to scrape thoroughly with a hand scraper followed by wirebrushing (first with coarse and then with fine wirebrushes), and finally sanding the surface with a coarse sandpaper, steelwool or emery paper. For normal site application, this will give a reasonable assurance that no loose mill scale or heavy rust is left on the surface. For purposes of examination, the hand-cleaned surface shall be wiped finally with mineral turpentine, which also removes grease and perspiration left by handmarks.

4.2.1.2 *Scraping with mechanical power tools* — Appreciably better results than by hand scraping may be obtained by employing power-operated wire-brush, although it may not be possible to remove firmly adhering mill scale even with this type of tool. The use of chipping hammers is restricted only to old rust.

4.2.2 *Flame Cleaning* — Flame cleaning is carried out with the help of a special oxy-acetylene torch. The mill scale is rapidly heated while the underlying steel remains comparatively cold. Because of the difference in expansion between the heated mill scale and the bulk of the steel, the scale becomes loose and either falls off or is easily removed with a wire brush. As it may lead to buckling, of light gauge material, the process is not generally recommended for cleaning steel sheet or plate less than 6 mm in thickness or section under stress particularly where the latter are heavily corroded and several passes of the blow pipe are required. It shall always be ensured that the number of passes the oxy-acetylene flame makes over a surface does not exceed three. The primer coat of paint shall be applied when the surface is still warm that is immediately after the flame cleaning has been carried out and the scales removed by brushing or wiping.

NOTE — Necessary precautions should be observed against hazards from fumes and fire during flame cleaning.

4.2.3 *Sandblasting, Gritblasting and Shotblasting* — The process of sandblasting or shotblasting is the most thorough system of cleaning steel. The principle is to impinge under pressure of air, a jet of sharp sand or granulated steel (steel grit) on to the metal surface, removing in the process any rust and scale, including firmly adhering mill scale. A steel surface properly cleaned by sandblasting may be immediately recognized by its silver-grey surface and the criterion for good sandblasting or shotblasting is the even colour of the surface so cleaned. Precautions shall be taken when sandblasting or shotblasting light gauge steel to see that buckling does not occur as a result of continuous impingement of sand or steel shot under high velocity.

4.2.3.1 Sandblasting is injurious to the labour carrying out this work. Suitable spray masks shall, therefore, be worn by workmen to prevent them from inhaling silica sand dust, which may lead to silicosis.

4.2.4 In areas, where presence of inflammable vapours is a possibility, such as near petrol tanks in oil terminals or refineries, special non-sparking wire brushes, chipping hammers and scrapers shall be used. Precautions with regard to sandblasting operations in inflammable areas shall be observed.

4.2.5 Chemical Cleaning (Pickling)

4.2.5.1 *Sulphuric acid, hydrochloric acid or phosphoric acid pickling* — Where descaling is required to be done chemical pickling in any of the above acid is necessary. It also removes rust. Pickling is carried out at the factory premises. Sulphuric acid is used commonly between 5 to 20 percent concentration preferably hot (60 to 80°C). Hydrochloric acid, being a fuming acid, is used only at room temperature, having 20 to 50 percent strength. Phosphoric acid used generally hot (60 to 85°C) at 5 to 25 percent is the most expensive of the three acids. Where only derusting, is required to be done chemically, phosphoric acid solutions are preferably used. The detailed procedure to be followed for using these acids shall be in accordance with IS : 6005-1970*.

4.2.5.2 After chemical cleaning in any of the above acids, the articles shall be thoroughly washed to remove all traces of acid. This shall be done

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*Code of practice for phosphating of iron and steel.

in two or three successive water immersion baths or by water-power jets. After removal of the pickled steel from the washing bath, a fine layer of rust (oxide) will immediately form. This can be prevented by dipping the steel into a 1 to 2 percent phosphoric acid solution which should be carefully rinsed off with clean water. A phosphoric acid wash shall not be used, however, if the articles are subsequently to be phosphated for rust-proofing and paint bonding, and the phosphate wash should not be considered as a substitute for this.

4.2.5.3 Derusting in acids shall be handled with care in order to prevent excessive attach on, as well as embrittlement, of the metal. Acid inhibitors should be used for this purpose.

4.2.6 *Electro-chemical Cleaning* — It is possible to remove rust and scale by the following electrolytic methods. For details of the various methods IS : 6005-1970* may be referred.

4.2.6.1 *Cathodic treatment in acid solution* — Removal of rust and scale may be accelerated as compared with ordinary pickling. Acid is economized and attack on the metal is reduced, but hydrogen embrittlement may be serious.

4.2.6.2 *Cathodic treatment in alkaline solution* — Hydrogen embrittlement is less in this case than in acid solution.

4.2.6.3 *Anodic treatment* — This may be carried out in either acid or alkaline solutions. Passivating conditions are established and oxygen (not hydrogen) is produced at the surface. Hydrogen embrittlement is usually avoided but there is a slight risk, especially with highly stressed parts, of hydrogen being formed in the acid process when the current is switched off and while the work is being removed from the bath. Anodic treatment produces smut on certain steels which should be removed by brushing and washing before phosphate treatment.

4.2.6.4 *Alkaline derusting processes* — Derusting at factory site may also be carried out by processes employing alkalies with or without electrolytes. The processes will completely remove any rust and grease in the same operation without any attack on the metal.

4.3 Intermediate Protective Treatments — After the preparation of iron and steel surfaces and prior to the application of the protective and decorative paint finishes, a number of intermediate treatments may be adopted to give iron or steel articles additional protection against corrosion. Some important intermediate treatments are dealt below.

4.3.1 *Hot-Dip Metallic Coatings* — The principle is to immerse the iron or steel articles in a bath of molten metal thereby covering the surface with a protective film. The most commonly known of these processes is the

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*Code of practice for phosphating of iron and steel.

hot-dip galvanizing (*see* IS : 2629-1966*) process, that is, the immersion of the steel in molten zinc. Aluminizing (*see* IS : 8508-1977†) that is, coating by dipping steel into molten aluminium, may also be adopted; the painting of aluminized surfaces requires consideration in regard to the selection of the type of paint for the primer coat. Normally, red lead priming paints should not be used for aluminized surfaces.

4.3.2 *Metal Powder Cementation* — This process, the trade name of which is 'sherardizing', covers the application of zinc powder by heat cementation (sintering). The application is effected at a temperature around 380°C, in closed rotating drums having an inert atmosphere when the zinc diffuses inside the steel, to give a desired coating thickness. The finish is a dull grey, hard sponge, which for satisfactory corrosion resistance shall be paint-finished. This is the most important powder cementation process, but there are other processes based on aluminium and chromium.

4.3.3 *Flame Sprayed Coatings* (*Metal and Plastics*) — The most commonly used metals in this process are zinc, aluminium and cadmium. Application is made by feeding metal wire or metal powder through an oxy-acetylene flame gun. The coatings are porous and, therefore, require sealing with paints; the porous coating provides an excellent bond for the paint. The flame spraying process is also extensively used with plastics (polyethylene, polyamides, etc) which form highly corrosion-resistant coatings (*see* IS : 5905-1970‡ and IS : 6586-1972§).

4.4 Phosphate Treatment — The most widely used pretreatments for good adhesion of paint to metal surfaces as well as for the prevention of rust, are the numerous hot tank phosphating processes. These are most popularly known under such trade names as ' Granodising ', ' Bonderising ', ' Walterising ', etc.

The principle involved is the conversion of steel surface into an inorganic phosphate coating, such as iron, zinc or manganese phosphate. The use of phosphating solutions either by the hot or cold process is recommended (*see* IS : 6005-1970‖).

4.5 Non-aqueous Phosphate Resin Coatings — These are generally iron phosphate coatings based on solvent resin which forms a self-sealing iron phosphate coating on the surface. They may be applied on a clean dry surface by brush, dip or spray at room temperature both in the factory and at site.

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*Recommended practice for hot-dip galvanizing of iron and steel.

†Recommended practice for hot-dip aluminizing of iron and steel.

‡Sprayed aluminium and zinc coatings on iron and steel.

§Recommended practice for metal spraying for protection of iron and steel.

‖Code of practice for phosphating of iron and steel.

4.6 Etching or Wash Primers — This treatment is based on the deposition of an acid-bound resinous film on the surface in such a manner as to enhance the adhesion of subsequently applied paint coatings. The film may be applied by brush, spray or dip. The film has good adhesion to the metal substrate.

5. ON-SITE PRETREATMENT

5.1 Surface Untreated or Protected With a Temporary Protective — These are dealt with at site as follows:

a) Temporary protective materials applied to steel sheets to protect during storage, transport and erection should be removed with suitable solvent as a preliminary to other preparatory treatments (*see* **4.1.1.1** and **4.1.1.2**).

b) Lubricants used in the rolling of steel sheets may be particularly tenacious and may have undesirable effects on paint adhesion. The use of abrasive paper wetted with suitable solvent, is effective in removing the worst effects of these materials. Where joints are welded, soldered or brazed care should be taken to remove fluxing material before painting. This may be effected with a 10 percent aqueous solution of formic acid followed by thorough washing, or with suitable solvents.

c) Surfaces which are protected with a temporary protective may be steam cleaned as mentioned in **4.1.4.**

d) In the case of hardened alloys the surface shall be treated by mechanical roughening combined by degreasing. Such work should be carried out as thoroughly as possible to ensure that the paint will adhere well and give protection and durability. The surface should be well scraped or swabbed with a suitable solvent, and then abraded with abrasive paper and finally rinsed with successive portions of clean solvent on clean swabs.

e) Proprietary compositions may be used as recommended by the manufacturers to degrease and passivate or degrease and etch the surface, but care should be taken, unless the manufacturers specify otherwise, to remove all residues by wiping or washing where possible, before painting and also to ensure that the compositions do not contaminate other parts of the structure.

5.2 Surface Already Factory Pretreated and/or Primed — They should be carefully inspected and damaged areas should be thoroughly degreased by clean solvent swabbing, any corrosion products formed should be thoroughly removed and touched up with a coat of wash or etching primer or suitable chemical pretreatment solutions. The rectified areas should then be brought forward with appropriate primer, putty, finish coats, etc.

5.3 Solvent Cleaning — This shall be carried out in accordance with **4.1.1**.

5.4 Brush Derusting with Phoshporic Acid or Proprietary Products — Apply phosphoric acid, with a brush or swab, rubbing where necessary with a steel wool pad, to assist rust removal. Keep the surface well wetted with the phosphoric acid. Wash off the phosporic acid thoroughly after derusting paying particular attention to seams and crevices. Proprietary products are used following the manufacturer's instructions.

5.5 Mechanical Cleaning — This shall be carried out in accordance with **4.1.1**.

5.6 Etching or Wash Primers — This shall be carried out in accordance with **4.4**.

5.7 Phosphating — Proprietary products, both aqueous and non-aqueous for phosphating *in-situ* may be used following the manufacturers' instructions (*see* **4.4**).

6. PRETREATMENT OF METAL COATED STEEL

6.1 Zinc coated steel and galvanized steel surfaces should be chemically treated or allowed to weather before painting. This is necessary because zinc being reactive, forms zinc soaps with the paint medium and adhesion of paint is quickly impaired. In some cases wash primers/calcium plumbate primer may be used without special surface treatments. Aluminium coated surfaces is generally treated with pretreatment primer.

6.2 Factory Pretreatment—The surface should be freed of oil, grease or any external contaminant by means of the procedure described in solvent cleaning method before applying any of the treatments recommended below. Proprietary compounds, may be used in accordance with the manufacturers' instructions.

6.2.1 *Crystalline Zinc Phosphating Treatment* — The zinc surface is converted to a crystalline zinc phosphate to inhibit corrosion, increase adherence and durability of paint film. The treatment may be provided by dip, spray or brush application.

6.2.2 *Chromate Treatment* — This consists of a dip or spray with a dilute solution of a mixture of chromic and other acids to provide a thin amorphous chromate coating that increases corrosion resistance and paint adhesion (*see* IS : 1340-1977*).

6.2.3 *Aqueous Chromic Organic Treatment* — Certain water soluble resins with chromium compounds may be applied to zinc surfaces by roller coat

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*Code of practice for chromate conversion coating on zinc and cadmium coated articles and zinc base alloys.

or other suitable means, such as by dip or squeeze rolls. The resultant coating provides a corrosion resistant film that increase the adhesion of applied paint film.

6.2.4 *Etching or Wash Primers* — This treatment should be carried out on the lines given in **4.6**, for both zinc and aluminium coated surfaces.

6.3 On-Site Pretreatment

6.3.1 *Surfaces Untreated* — The surface should be thoroughly degreased by solvent wipe and then applied with wash or etching primers.

6.3.1.1 The surface should be thoroughly degreased by solvent wipe and then cleaned and brushed with suitable phosphating chemicals. Some of these are similar in action to the phosphating solutions, while others are based on acids or other mordants. The use of mordants containing copper is not recommended since the last traces of copper, which are difficult to remove, stimulate corrosion. After using the cleaning and phosphating solutions, the surface should be thoroughly wiped or rinsed with clean water to remove acids and salts, which might be deleterious if allowed to remain.

6.3.1.2 If the zinc or galvanized steel is allowed to weather up till the bright spangles disappear before painting, it attains a condition suitable to receive paint without the necessity of degreasing or etching; it will be necessary, however, to clean down to remove dirt, corrosion products, etc. Since galvanizing alone, if of reasonable thickness is sufficient to protect the steel from corrosion for some years in normal atmospheres, a few months delay before painting is not likely to result in corrosion.

6.3.1.3 An alternative process is to abrade the surface thoroughly with emery cloth lubricated with a suitable grease solvent to produce a uniform, fine matt surface, and subsequently wash with successive portions of clean solvent. This process is laborious and suitable only for small areas.

6.3.2 *Surfaces Already Factory Pretreated and/or Primed* — Such surfaces should be treated on the lines given in **5.2**.

7. IMPORTANCE OF EARLY APPLICATION OF PAINTS

7.1 After completion of the precleaning, the ferrous surfaces shall be immediately painted unless a rust-proofing (phosphating) or other interim process is employed. In the latter case, the precleaning shall be followed immediately by that process. If, for instance, a sandblasted piece of steel is left exposed in a coastal area for only 12 hours, slight rust formation would be visible and the iron oxide thus formed would readily absorb moisture from the humid atmosphere. Sandblasted steel left exposed for any length of time would thus have to be retreated. In chemical cleaning, after removal of excess acids by thorough washings, the articles shall be immediately dried and painted. Correct timing is essential in all processes of preparation, while painting the ferrous surfaces.

Indian Standard

CODE OF PRACTICE FOR PROTECTION OF IRON AND STEEL STRUCTURES FROM ATMOSPHERIC CORROSION

PART III PROTECTIVE SCHEMES

1. SCOPE

1.1 This standard (Part III) illustrates the details of painting operations, paint schedules and other coating applications applicable to ferrous structures for protection against atmospheric corrosion.

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions given in IS : 3531-1960* and IS : 1303-1963† shall apply.

3. GENERAL

3.1 All aspects of the work involved in the protection of steel structures against corrosion should be considered at an early stage in the development and planning of any project. This includes all the steps to be taken throughout the application of a protective scheme from the delivery of the materials to the fabricating shop to the completion of the work at site, together with provision for subsequent inspection and maintenance.

4. RECOMMENDED PROTECTIVE SCHEMES FOR GENERAL STRUCTURES

4.1 Basis of Recommendation — When selecting the appropriate grade of protection attention should be given to the severity of the exposure conditions, nature of the structure, its utility, expected life and maintenance schedule. The recommendations made in Table 1 for the protection of steel work used outdoors are based on the results reported from the outdoor exposure tests carried out at various centres in India and also on experience of the protective scheme gained both by research and by observations of their behaviour in service.

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*Glossary of terms relating to protection of metals.

†Glossary of terms relating to paints (*revised*).

4.1.1 On the basis of the relative corrosivity of outdoor atmospheres in various parts of India, the different regions may be broadly classified into the following categories:

Very high	Above 0·25 mm/yr
High	0·13 – 0·25 mm/yr
Moderate	0·05 – 0·13 mm/yr
Low	0·025 – 0·05 mm/yr
Very Low	Below 0·025 mm/yr

4.2 Protective Schemes — Taking into consideration the various factors, broadly three different grades of protective schemes have been suggested in Table 1 for areas with different corrosivities. They represent the minimum acceptable standard of good practice and should prove economical in maintenance. Each protective scheme consists of a metal coating or a method of preparing the steel surface, followed by a paint system, sometimes after an intervening pretreatment. Individual components of each system may be obtained from Table 1.

4.2.1 *Grade A Scheme* — This consists of an initial protective scheme applied to last for a period of 5 years or more with repainting period varying between 5 and 8 years and above depending on the environment.

4.2.2 *Grade B Scheme* — This consists of an initial coating to last for a minimum period of 3 years, with repainting schedule varying between 3 and 5 years.

4.2.3 *Grade C Scheme* — This consists of a coating system which requires renewal every year or every alternate year.

4.3 Performance of a Protective Scheme — It is rather difficult to predict the performance of a protective scheme and selection should generally be made on the basis of accumulated experience. The performance of coatings on similar structures or units generally provide the guidance on which to base a sound judgement. It is not always possible to recommend the unequivocally the best system for a particular situation; only systems which are expected to give a reasonably good life may be suggested. The user has to select the best combination of the protective scheme depending on economics and availability.

5. SURFACE PREPARATION

5.1 Proper surface preparation contributes more than any other single factor to the success of a protective scheme.

5.1.1 Where a metal coating is to be applied, the method of surface preparation is implicit in the nature of the metal coating itself, for example, gritblasting is essential before metal spraying.

5.1.2 Methods of preparation of steel surfaces for painting are discussed in Part II. The choice between them is influenced by the nature of the structure, the condition of the steel surface and the corrosiveness of the environment. Badly corroded steel needs special attention.

5.2 Blast cleaning is recommended for all paint systems applied to important steel structures and to structures whose location or function render access difficult. It should also be used for steel work subjected to the following service conditions:

a) Severely corrosive atmospheres,
b) Sudden variations of temperature,
c) Alternating stresses, and
d) Continuous vibration.

Blast cleaning roughens steel and it is essential that an adequate thickness of priming paint be applied to cover the peaks on the surface.

5.3 Where practicable, pickling followed immediately by an organic coating is an acceptable alternative to blast cleaning throughout, except that blast cleaning to a first quality finish is preferable beneath chemical resistant paints for best results.

5.4 Flame cleaning is inferior to blast cleaning and pickling for use on new steel work. It is of value for drying the steel at the time of painting and for some types of maintenance work.

5.5 Intermediate Protective Treatment — The adoption of intermediate treatment like phosphating and wash/etch primer treatment, after cleaning and derusting of steel surfaces and prior to application of protective paint finishes may give additional protection against corrosion. The life of a paint scheme may be improved by 50 percent due to phosphating and somewhat less for wash/etch primer.

6. METAL COATINGS

6.1 Metal coatings, when used in combination with suitable paint systems, prevent the onset of rusting in severely corrosive conditions where paint alone gives protection only for a limited (short) period. Therefore, they are particularly valuable where it is essential that rusting should not take place, or where the intervals between maintenance are protracted. They are also effective in chemical atmospheres, provided proper metallic coating is chosen.

6.1.1 For steel work the choice generally lies between hot-dip galvanising, sprayed zinc and sprayed aluminium. If a zinc coating is to be used alone, hot-dip galvanising should be generally preferred, because of the smoothness and freedom from porosity of this type of coating.

6.1.2 Aluminium coatings are useful for protecting steel in severe service conditions at high temperatures and form a good basis for heat resisting paints. Aluminium coatings need protection against alkaline exposure conditions.

6.2 Metal coatings need not be painted, provided they are thick enough to withstand the service conditions for the desired life of the structures. They give long term protection, for example, unpainted zinc coatings weighing 570 g/m^2 of surface (75 to 100 μm thick) have been observed to last for 5 years or more in an industrial environment and for much more than 20 years in a rural one. However, they do not protect steel in enclosed humid and polluted spaces. An unpainted aluminium coating 200 gm/m^2 had an even longer life of above 10 years in an industrial environment.

6.3 The paint may be applied to metallic coating with or without etch/wash primer followed by two coats of zinc chromate in modified phenolic stand oil primer or red oxide/zinc chromate primer for both aluminium and zinc coatings. The remaining coats of the paint system should be adequate to build up the necessary total dry film thickness. If the roughness of the sprayed metal surface exceeds the recommended limit of 100 μm maximum amplitude, extra coat of priming paint should be applied and the roughness should be reduced before painting by rubbing lightly with emery cloth. The finishing coat should be the same as shown in Table 1. The total dry film thickness should be atleast 150 μm.

6.3.1 A repainting schedule of once in every 4 years on a metal coated and painted steel structure has been found to prevent onset of rusting on the steel base of the structure.

7. PAINTS

7.1 Priming Paints — The essential property of the individual paints in a system is that they should provide successful protective schemes when combined in the recommended manner. Ordinary red-oxide may be dependent upon only for inland dry places like Delhi. Zinc chromate/red-oxide and barium chromate should be used in areas where humid tropical conditions are obtained. It may be necessary to use zinc chromate in modified phenolic stand oil or red lead primer in coastal areas where marined conditions are obtained. It has also been found advantageous to use zinc chromate in expoxy for both hand cleaned and pickled surfaces.

7.1.1 *Red Lead Primer* (*IS : 102-1962**) — Red lead in linseed oil priming paint has been used satisfactorily for many years. It is specially useful when paint has to be applied to imperfectly prepared surfaces, carrying broken mill scale and rust, which result from weathering and hand

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*Specification for ready mixed paint, brushing, red lead, nonsetting, priming (*revised*).

cleaning. Its relatively slow drying property is a disadvantage when painting outdoors in grossly polluted atmospheres or where limited covered space is available for painting indoors.

7.1.1.1 The use of red lead is permissible only within the provision oı the Lead Regulations. Such paints shall not be applied by spray. They shall not be put on surfaces that are to have flame treatment for example, cutting or welding nor they be used in confined spaces where wire-brushing or other abrasive treatment is probable at the time or for later maintenance work.

7.1.2 *Zinc Chromate Primer* (*IS : 1874-1962**) — This consists of zinc chrome pigment and suitable extender based on an oleo-resinous medium. It is specially suitable for priming light alloys used in the aircraft industry, but is generally used for the protection of light alloys as well as steel work.

It may be used both under marine and inland outdoor conditions. It is, the other usual alternative to red lead primer where use of lead pigment is prohibited. It is non-toxic and is suitable for application both by brushing and spraying, and dries quickly.

It is valuable for use over sprayed metal coatings for which purpose redlead primer is unsuitable. Generally a pretreatment should be applied before the zinc chrome paint.

It has been commonly used as shop coats but it should not be left long before being overcoated. The inhibitive chromate pigment may be leached out if it is exposed to rain.

7.1.3 *Zinc Rich Primer* — The metallic zinc pigment in these primers should be bound in a medium of epoxide resin, chlorinated rubber or polystyrene so as to yield a paint suitable in all respects for brush application. Zinc rich paints in cold-cured epoxide resin media are used as prefabrication primers and are also applied at full coating thickness to fabricated steel.

Other uses of zinc rich paints are as primers in chemical resistant paint systems and for making good the damage to metal coatings which, for example, occurs after welding, before these are painted. Zinc rich paints should be applied only to carefully prepared steel, preferably to blast-cleaned surfaces.

7.1.4 *Red Oxide, Zinc Chromate Primer* (*IS : 2074-1962*†) — It consists of 16 parts of zinc chrome in combination with red oxide of iron and small proportion of suitable extender based on an oleo-resinous medium.

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*Specification for ready mixed paints, universal zinc chrome, priming (synthetic) for light alloys for aircrafts.

†Specification for ready mixed paint, red oxide-zinc chrome, priming.

Being non-toxic it is suitable for application both by brushing and spraying and it dries quickly. It may be used both on ferrous and nonferrous surfaces but it is generally used for the protection of steel in inland outdoor conditions. In respect of protective property on ferrous surfaces it is inferior to zinc chromate primer.

7.2 Finishing Paints — The distinction between undercoats and finishing coats is not sharply defined in paint systems used to protect structural steel work. Frequently the undercoat is a tainted version of the finishing paint.

7.2.1 Aluminium paint conforming to IS : 2339-1963* is recommended mainly for its reflective value.

7.2.2 Synthetic enamel conforming to IS : 2932-1964† in long oil alkyed medium is an acceptable alternative.

7.2.3 Oil based paints conforming to IS : 117-1964‡ and IS : 128-1962§ containing lead, zinc and titanium pigment may also be used. They lose their gloss and their colour is slightly impaired particularly, in rural environments. Chlorinated rubber based paints may also be used especially for marine environment.

7.3 Application of Paint — The performance of any painting system is strongly influenced by the manner and circumstances in which it is applied. Important factors include programme, correct storage of paint and its preparation for immediate use, the ambient conditions at the time of painting, the perparation of the surface for painting, the method of applying the paint, and the standard of workmanship.

7.3.1 It is difficult to apply paint satisfactorily outdoors in bad weather, therefore if site painting is contemplated, it is wise to study the local meteorological data and chose the periods when the best weather conditions are to be expected for example, in summer (hot and dry days) and not rainy seasons. Where painting under adverse conditions is unavoidable, provision of heating or of some form of temporary shelter may be helpful.

7.3.2 Painting is skilled work, which should generally be done under competent and qualified supervision. For important work suitable inspection arrangements should be made.

7.3.3 The common methods of applying paint are by brush, rolling, air pressure spraying, airless spraying and dipping.

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*Specification for aluminium paint for general purposes, in dual container.

†Specification for enamel, synthetic, exterior, Type 1, (a) undercoating, (b) finishing, colour as required.

‡Specification for ready mixed paint, brushing, finishing, exterior, semi-gloss, for general purposes.

§Specification for ready mixed paint, brushing, finishing, semi-gloss, for general purposes, black (*revised*).

7.4 Thickness of Paint Film — Total thickness of the dry paint film is an important factor and it is vital that this should be adequate for the purpose in hand. Where circumstances permit, full use should be made of non-destructive thickness testers to check the thickness of individual coatings and of the complete painting scheme. The paint systems suggested in Table 1 are intended to provide an average total dry paint film of at least 90 to 140 μm according to the individual paints used.

8. CONDUCT OF THE WORK

8.1 Surface Preparation — The surface preparation should be thorough and the bare metal surface should be primed as soon as possible afterward but in any case within 4 hours. If prepared surfaces are left uncoated for a longer period, they should be inspected before painting and if necessary, prepared again.

8.2 Acceptable standards, as regards the condition for application of the protective scheme at the fabricator's works and site, surface cleanliness before coating, interval between coats and the conditions during transport to the site, should be mutually agreed upon.

8.3 Application of Coating — The procedure of applying the whole or the major part of the protective scheme under cover before despatch to the site is preferred since the painting may be done under predetermined controlled conditions. The resulting performance of the protective scheme shall generally be markedly superior to that obtained when painting is done at site.

8.3.1 When any part of the protective scheme is to be applied outdoors, at works or at site, it should be ensured that the weather condition is as favourable as possible. Some indication may be obtained by studying the local meteorological data.

8.4 Sprayed Metal Coatings — They are porous and when they are to be painted, they should preferably be sealed immediately after application with a pretreatment primer or other suitable organic coating.

8.5 Contact Surface and Edges — In structures in exposed positions or in highly corrosive conditions, the surfaces to be permanently in contact having been properly cleaned, should each be given a coat of priming paint before assembly and brought together while this is still wet. Special care should be taken of rough surfaces and the contact surfaces should be left painted.

8.5.1 In the case of structures within the electricity industry that may be subject to heavy fault current, for example, overhead line towers and substation structures, no paint should be applied to the mating surfaces of joints unless it has been confirmed that the paint has and shall retain in service an adequately low resistance.

8.5.2 The contact surfaces of joints made with friction grip bolts should be left unpainted. Special care should be taken after assembly to paint all edges and corners near the joints, together with the bolt heads, nuts and washers, so as to prevent the ingress of moisture. Special care is necessary for areas condensation and restricted air movements.

8.6 Drying Time — Each coat should be allowed to dry thoroughly (and to become sufficiently cured in the case of chemical resistant paints that dry by reaction between their components) before the next one is applied. Before proceeding, a check should be made that the new coat is not softening the underlying paint.

9. MAINTENANCE

9.1 Maintenance is made much easier if the necessary requirements are taken into account at the design stage.

9.2 The aim should be to keep the steelwork free from deterioration and need of repair, whilst retaining an acceptable appearance, with the minimum of expenditure. This may be achieved by well thought out, predetermined maintenance programmes, or by repainting when inspection, which should be made systematically at regular intervals, shows this to be necessary. In assessing maintenance, any operational losses and other indirect costs due to interruption of production or service should be included.

9.3 The repainting of structures should always be taken in hand before the protective coating shows sign of serious breakdown. Postponement of repainting until this occurs will inevitably increase the cost of the work. Secondly, it pays to aim at the longest possible interval between repaintings by using the paints best suited to the particular conditions. The cost of the material generally forms but a small part of the total cost of repainting, although the quality of the paints purchased should naturally be commensurate with the prices paid for them.

9.4 Maintenance work may involve repainting the whole structure, or alternatively patch-painting to make good local breakdown followed later by complete repainting when general deterioration of the old paint has become evident. The work itself is usually more difficult than initial painting, because the choice of method of surface preparation is more restricted; moreover, the conditions at site may be controlled only to a limited extent. This is particularly true for marine structures where the maintenance of areas in the tidal and splash zones is especially difficult, because of the relatively short period varying from day to day during which these are accessible. Similarly, in industrial environments, there are many places where steam, exhaust gases, fumes, grit and other forms of atmospheric pollution render it difficult to obtain good conditions for painting.

9.5 The procedure adopted should be designed to restore a continuous film of paint of the necessary minimum thickness, generally an average of 125 μm, over the whole surface of the structure. Present practice rarely achieves this standard over badly corroded areas.

9.6 Unless experience has shown the need for change, it is preferable to use the same types of finishing paint again. It may be necessary to change the priming paint to accommodate the site conditions, and for the paint manufacturer to adjust the formulation of paints to be applied over old paint, for example by altering the pigment/vehicle ratio, so as to compensate for the porosity of the weathered surface. Where a change is made, the new paint shall be compatible with the old. For example, there is a risk of failure when an oil paint is applied over an old coal tar pitch or bitumen coating; some coal tar pitch and bitumen coatings are also mutually incompatible.

9.7 It is improbable that the degree of breakdown of the protective scheme may be uniform over the whole structure. Minor modifications to the structure to increase paint durability at the worst affected areas should, therefore, be considered. There may be places where smoke and fumes are trapped or where the drainage is ill-devised and water lies about on the steel. Drainage may be improved, smoke traps bricked up, and removable baffles fitted to protect the steel against exhaust and chemical fumes.

9.8 Clearly, maintenance painting is practicable only for structures that are accessible for at least limited periods. For inaccessible immersed parts of marine structures and for buried structures generally, the only possible course when the initial protective scheme fails to last for the desired life of the structure is to install cathodic protection [*see* IS : 8062 (Part I)-1976* and IS : 8062 (Part II)-1976*].

9.9 Criteria for Repainting

9.9.1 *Paint* — The breakdown of the protective paint film, in order of increasing seriousness, takes the form of chalking, checking, cracking blistering, ruststaining and, finally, the breakthrough of rust and flaking of the paint.

9.9.1.1 Repainting should always be carried out before the finishing coats have ceased to protect the priming coat properly, or have deteriorated to such an extent that they do not provide a suitable basis for new paint. This procedure makes it unnecessary to remove the bulk of the old paint, and in time leads to the building up of a thick paint film all over the structure. If breakdown is not permitted to proceed beyond the chalking stage, the only surface preparation needed before repainting is washing down and drying off.

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*Code of practice for cathodic protection of steel structures:

Part I General.

Part II Underground pipelines.

9.9.1.2 The difficulty and cost of maintenance painting increase greatly if the work is deferred beyond the time when marked erosion of the finishing coats has occurred, accompanied possibly by the development of rust pustules that have not broken the paint film. After the paint film has been ruptured by rust, breakdown proceeds at an increasing rate and the stage is reached at which repainting cannot be done satisfactorily without removing the old paint completely, which adds greatly to the expense incurred.

9.9.1.3 The criteria for deciding whether repainting should be undertaken or not will vary with the age of the structure. The decision may also be complicated by the fact that breakdown is seldom uniform all over the surface, so that some parts may need renewal and others not.

9.9.1.4 The necessity for repainting old structures that have been properly maintained and already repainted several times generally arises through serious degradation of the outer coat or coats of the paint system or through the development of serious rusting at joints, edges, nuts, bolts, and places that are difficult to protect well, for example pockets or parts subject to stress concentration or vibration. Then the degradation of the old paint and the degree of local breakdown are the determining factors, and pictorial rust scales, have little bearing on the matter.

9.9.1.5 For new structures, failure of the initial painting scheme generally takes a different form, and is often determined by blistering and flaking of the paint film, with rusting of the basis steel, over a relatively small proportion of the surface. This may occur long before the degradation of the paint itself reaches the critical stage. The type of failure is characteristic of weathered and hand-cleaned steel, and it should become less frequent now that blast-cleaning and other better methods of surface preparation are more generally adopted.

9.9.1.6 In practice, therefore, where the paint was applied to weathered and hand-cleaned steel, it may be wise to regard a small degree of rust and rust-staining as the criterion for repainting a structure in the early stage of its life. On blast-cleaned surfaces initial breakdown may take the form of pinpoint rusting at peaks in the steel surface that have not been adequately covered with paint. On pickled surfaces and on blast-cleaned surfaces to which sufficient paint cover has been provided, peak rusting is absent, and repainting becomes necessary only when the finishing coats are showing erosion to such an extent that the priming coats are not sufficiently protected.

9.9.1.7 If peak rusting develops, repainting should be undertaken at once. If the work is done as soon as the defect becomes evident a thorough scrubbing down with clean, fresh water should prove sufficient surface preparation for the application (after the surface has dried thoroughly) of a further coat or further coats of paint.

9.9.1.8 Another type of failure occurs, in which the paint film becomes embrittled and loses much of its adhesion without serious rusting of the substrate. As paint in this condition does not provide a suitable basis for repainting, it is necessary to strip to bare metal and start again.

9.9.2 *Metal Coated Structures* — Hot-dip galvanized surfaces left unpainted originally should be painted before the useful life of the zinc coating nears its end. Slight rust-staining is not an infallible indication of this, because the discoloration is often due to corrosion of the iron-zinc alloys that lie below the surface of the coating itself and not to attack on the basis steel. The safest course, however, is to paint as soon as marked discoloration is observed.

9.9.2.1 Bare sprayed metal coatings may be adjudged to require painting at the following stages:

a) When the first signs of rusting of the basis metal are observed, on a zinc coated surface. Generally the transition from slight rusting to complete rusting takes only a few months and the painting should be undertaken immediately.

b) When the coating itself begins to crumble appreciably because of the formation within it of aluminium corrosion products, on a aluminium-coated structure.

Rust stains frequently develop at an early stage on bare sprayed aluminium coatings (probably because of the porosity of the coating). These are generally transient and may be ignored.

9.9.2.2 As a general principle, it is advisable to paint over a metal coating some time before this is approaching the end of its life rather than to postpone the operation until the coating shows marked failure. It is important to avoid delay in repairing paint over metal coatings. Moisture retained in a broken down paint film may cause rapid corrosion and wastage of a metal coating beneath it.

9.10 Timing of Operations — Although there may be rare cases where it is practicable to remove a structure, part by part, paint the parts under good conditions elsewhere, and replace them after painting; maintenance painting almost invariably takes place on site. If the structure is an outdoor one, inclement weather will seriously interfere with and complicate the operations. Maintenance should, therefore, be programmed for times when suitable weather can be expected. Local factors, such as the closing down of nearby smoke-producing plant during a works holiday, may affect the choice of date.

10. PROCEDURE FOR REPAINTING

10.1 General — If good practice has been followed at all stages of the initial or previous painting, and maintenance is undertaken at the proper time, it should seldom be necessary to strip all the old paint from a structure before repainting it. The ideal condition in which none of the old paint has deteriorated beyond the stage at which a simple washing down suffices is equally rare. Some parts of the structure will need repainting before the main body of the paint has neared the end of its life. It may be better to repair these damaged areas by patch-painting and to leave the rest alone until later. Experienced judgement will strike the economic balance between this course and repainting all over at regular intervals. The decision may well turn on aesthetic considerations and the accessibility of the structure.

10.1.1 The number of coats to be applied when complete repainting is undertaken will also be decided by economics. The increase in the interval between repaintings resulting from the use of more coats of paint should be balanced against the increased cost of materials and labour, the comparisons being made on a cost per annum basis.

10.1.2 It is more difficult to attain the desirable standards of workmanship and satisfactory ampient conditions for application at site than in the shop, where practicable temporary screens or cover should be provided to shield areas from rain and heavy atmospheric pollution.

10.2 Surface Preparation

10.2.1 *General* — Thorough surface preparation is essential to the success of maintenance painting. With the exception of pickling, the methods described in Part II are also practicable at site, but in general they are likely to prove less efficaceous there than when used initially in the shop.

10.2.1.1 The choice of method depends on the condition of the old paint. Since the conditions of the paint may vary in different parts of the structure, it may be better to employ a variety of methods.

10.2.1.2 Chemical rust removers and paint strippers are not recommended. If, exceptionally, paint strippers have to be used, a non-flammable solvent type, based on methylene chloride, should be selected, and great care should be taken to remove all residues from the surface.

10.2.1.3 All removable obstructions to the surface, for example advertisement hoardings, should be taken down and as few as possible of them replaced after the repainting is completed.

10.2.1.4 Particular attention should be paid to the cleaning out of crevices and other places where dust and dirt have collected, and the filling in of such crevices with inhibitive mastic paste or steel packings coated with red lead paint, should be considered. The use of fillers to build up a smooth surface prior to repainting badly corroded members is best avoided where stress-carrying members are concerned, because this may disguise the loss of section and thus lead to a false sense of security.

10.2.2 *Hand-Cleaning* — Hand-cleaning, to be effective, must be done thoroughly.

Washing down with fresh water will often be necessary and should be regarded as a normal procedure for marine structures; failure to remove the deposits of sea-salts on these may lead to rapid failure of paint applied to them. The water should preferably be warm and contain 1 or 2 percent of liquid detergent. The cleaning should be completed by rinsing with clean, hot, fresh water, taking care to remove residues of the cleaning agent from folds and crevices.

10.2.2.1 Pressure steam jets are effective for removing adherent grime from sound paint, but care is needed to avoid damage to the paint itself. Emulsion cleaners may also be used and are less liable to damage the paint, but the residues must be thoroughly removed by warm water rinsing.

10.2.2.2 Any oil or grease present on the old paint should be removed by treatment with clean white spirit or naphtha or a mixture of the two or by means of mixtures of aqueous detergents with organic solvents; alternatively, steam jets may be used. The same methods may be used to clean bare steel surfaces.

10.2.2.3 If deterioration has not reached the stage where stripping to bare metal is desirable, light scraping and wire-brushing should precede the cleaning. The aim should be to break any fine blisters and to remove any isolated nodules of rust and all loosely adherent pain without damaging the firmly adherent paint surrounding these isolated areas.

10.2.2.4 Whatever the condition of the old paint that is allowed to remain, some slight roughening of the surface, for example by light sand-papering, is desirable as this tends to improve the adhesion of the new painting scheme. Mild surface abrasion may be essential when preparing some hard gloss finishes for repainting.

10.2.3 *Blast-Cleaning* — Where the old paint has to be removed completely, blast-cleaning, if practicable, is the best surface preparation. The conduct of this process at site is made cheaper by the use of an expendable abrasive; when this cannot be used because of the dust created, closed-circuit vacuum apparatus may be a substitute. The same precautions should be taken as in the shop to avoid contamination of freshly blasted surfaces and to limit the interval before priming them. Because of these factors, the progress of blast-cleaning at site is greatly expedited by the use of a quick-drying primer.

10.2.4 *Flame-Cleaning* — Where access is difficult, or where the steel has become badly pitted, or where humid conditions make it difficult to get a dry surface for painting, flame-cleaning is often the best and sometimes the only practicable means of obtaining a reasonable standard of surface preparation.

10.2.4.1 Flame-cleaning should not be used to remove thick coatings of tar or bitumen; nor is it an economical procedure for stripping old intact paint. As a rough guide, its use should be considered only when the breakdown of the old paint has reached roughly 20 percent of rust by area or beyond.

The process cannot be used near glass or flammable materials, and difficulty may arise in disposing of the dust to which it gives rise. The heat of the flame distorts light sections.

10.2.5 *Metal Coatings*

10.2.5.1 Where zinc and aluminium coatings are intact, the preparatory work may be restricted to washing down with fresh water and scrubbing with hard bristle brushes. This procedure should be used when zinc-coated steel that has not been painted initially has begun to show signs of deterioration but has not rusted appreciably. Where the zinc coating has disappeared over areas of appreciable size and patches of rust have appeared, the surface preparation should be the same as for steel. Unless, however, the zinc has corroded away entirely, hand-cleaning shall generally be preferable to blast-cleaning or flame-cleaning (which destroy the zinc). Steal wire brushes should be used.

10.2.5.2 Where sprayed aluminium coatings have crumbled appreciably or where local rusting has occurred, vigorous wire-brushing is recommended.

10.3 Painting Schemes

10.3.1 The surface preparation together with the types and number of coats of paint used for maintenance painting will be governed to a large extent by the condition of the old paint, which may not be uniform all over the structure. Broadly, three kinds of surface may be distinguished:

a) Areas of intact adherent paint where deterioration is confined to chalking and erosion of the outer coats, accompanied perhaps by slight checking and unbroken blistering. These areas should be cleaned, washed down and dried, and then given one or more coats of finishing paint.

b) Areas where appreciable but not excessive paint breakdown has occurred and there is some blistering and pinhead rusting, but where the coating is otherwise sound and adherent. These areas should be scraped, wire-brushed, washed down and dried. They should then be given one or two coats of suitable priming paint, followed by two coats of the finishing paint.

c) Areas where the paint has deteriorated badly and has lost its adhesion, and where the steel has rusted appreciably. These areas should be cleaned down to bare metal, preferably by blast-cleaning;

flame-cleaning may be an acceptable alternative. If neither method is practicable, resort shall have to be had to hand-cleaning, assisted with power tools. A complete painting scheme should then be applied to these bare areas in accordance with the appropriate recommendations.

In practice, a uniform and clear-cut distribution of these three types of breakdown over a given structure seldom occurs, and a broad subdivision of the complete surface into areas of reasonable size may prove necessary.

10.3.1.1 Experience is the best guide as to where to draw the dividing line between areas of type (b) and type (c). The former are most likely to arise at early maintenance paintings. Generally, the performance of the maintenance scheme will fall off progressively as the degree of rusting of the surface over which it is applied increases.

10.3.2 The total number of coats of paint in the maintenance schemes suggested above is a matter of judgement, but it should suffice to restore the paint film to a satisfactory thickness everywhere. In some circumstances, for example where access is difficult, it may be economical to apply more coats than the minimum necessary, so as to increase the interval between maintenance periods.

10.4 Conduct of Maintenance Work

10.4.1 Where different treatments are given to different areas of a structure, planned co-ordination of the work is important. It may, for example, be advisable, where complete repainting is contemplated, to clean down the firmly adherent paint before patch-painting is taken in hand. At areas where the paint is removed entirely, the areas of clean bare metal should extend for at least 25 mm all round the boundary of the defect. The ridges of sound paint surrounding the patch-painted areas should be carefully chamfered with sandpaper, so as to remove steep edges between the old and the new paint.

10.4.2 Immediately following the preparation of the surface for patch-painting, the first priming coat should be applied. This coat and each of the following coats should be carried over the adjoining sound paint all round for at least 50 mm. When the structure is not to be completely repainted, an attempt should be made to match the finishing paint to the old paint, but a full finishing coat or coats may have to be applied if a uniform appearance is essential.

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TABLE 1 RECOMMENDED PROTECTIVE SCHEMES TO BE USED UNDER DIFFERENT CORROSIVE CONDITIONS

(*Clauses* 4.1, 4.2, 6.3 *and* 7.4)

COMPONENTS OF PROTECTIVE SCHEMES			INTENSITY OF CORROSION				
			Less than 0·025 mm per year	0·025-0·05 mm per year	0·05-0·12 mm per year	0·12-0·25 mm per year	More than 0·25 mm per year
Surface Preparation	Hand-cleaning		■ ●	■ ●	○		
	Flame-cleaning		▲	▲	▲ ■ ●	●	
	Pickling					□	□
	Sand- or grit-blasting					▲ ■	▲ ■
Metallic Coating	Aluminium	0·07-0·12 mm thick					▲
		0·02-0·07 mm thick				▲	■
	Zinc	0·07-0·12 mm thick					△
		0·02-0·07 mm thick				△	□
Primer Paint Coating	Zinc-chromate	Single coat	▲ ■	▲ ■	●		■
		Double coat	□	□	□	▲	▲
	Red lead	Single coat	△	△	○		
		Double coat			▲ ■	■ ●	
Finishing Paint Coating	Aluminium pigmented	Single coat	■	■			
		Double coat	▲	▲ ●	△ ■ ●	▲ ■	▲ ■
	Synthetic enamel	Single coat	□	□			
		Double coat	△	△ ○	▲ □ ○	△ □ ●	

▲ Grade A — Scheme to last for initial period of 5 years. ■ Grade B — Scheme to last for initial period of 3 years. ● Grade C — Scheme to last for initial period of 1 year.

△ Alternative. □ Alternative. ○ Alternative.

NOTE 1 — One of the three grades of the protective scheme should be chosen depending upon the required initial life for a particular type of structure. The components of that grade of the protection scheme may be obtained from the table for areas with different corrosivities.

NOTE 2 — Life of the various painting schemes, indicated in the table may be improved substantially, if the steel surfaces are subjected to intermediate protective treatments, like, phosphatic and etch/wash primers (*see* **5.5**).

INDIAN STANDARDS
ON
CORROSION PROTECTION

IS:	
3531-1966	Glossary of terms relating to corrosion of metals
3618-1966	Phosphate treatment of iron and steel for protection against corrosion
4180-1967	Code of practice for corrosion protection of light gauge steel sections used in building
4777-1968	Performance tests for protective schemes used in protection of light gauge steel against corrosion
5555-1970	Code of procedure for conducting field studies on atmospheric corrosion of metals
6005-1970	Code of practice for phosphating of iron and steel
7808-1975	Code of procedure for conducting studies on underground and subsoil corrosion of metals
8062 (Part I)-1976	Code of practice for cathodic protection of steel structures: Part I General principles
8062 (Part II)-1976	Code of practice for cathodic protection of steel structures: Part II Underground pipelines
8629 (Parts I to III)-1977	Code of practice for protection of iron and steel structures from atmospheric corrosion

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TO
IS : 8629 (Parts 1 to 3) - 1977 CODE OF PRACTICE FOR PROTECTION OF IRON AND STEEL STRUCTURES FROM ATMOSPHERIC CORROSION

(*Page* 15, *clause* **6.2.2.4**, *line* 8) — Substitute '90 to 300 μm' *for* '90 to 140 μm'.

(*Page* 37, *clause* **7.4**, *line* 7) — Substitute '90 to 300 μm' *for* '90 to 140 μm'.

(SMDC 29)

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