

CORROSION

Volume 2

Corrosion Control

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17.2 Thermoplastics

The use of plastics for corrosion-resistant coatings is a new and expanding field, consumption for this purpose having risen from ≈ 250 t/year in the early 1950s to 10 000 at the present time. While the maximum economic thickness of paint films rarely exceeds 0.25 mm, coatings of many thermoplastic materials can be applied in much greater thicknesses, and application, by dipping or spraying, is very rapid.

These coatings combine good anti-corrosive properties with good adhesion, high abrasion resistance, and attractive appearance. Their use permits simultaneous advantage to be taken of the mechanical strength of metal and the corrosion resistance of plastics.

Application Methods

The coatings can be applied in several ways which will now be described.

Dipping into a Liquid Plastisol

The plastisol method of coating consists of dipping a heated and primed article into a tank of cold liquid p.v.c. The action of the heat causes the plasticiser and polymer to cross link forming a gelatinous deposit. A subsequent curing operation completes the reaction, giving a tough resilient coating. The only material that is applied by the plastisol method is p.v.c. and it should be remembered that while this technique is ideally suited to anticorrosive or protective coatings, it does not give such an attractive appearance as can be achieved with a powder technique. Tanks, pipes or fabrications can be coated up to 12 mm thick in one operation.

Dipping into a Fine Powder

The powder technique is used principally for polythene, nylon, c.a.b., Penton and some grades of p.v.c.* It consists of dipping the heated article after the necessary metal preparation into a gas-agitated bed of fine powder. The article is subsequently reheated to fuse all the powder into a smooth

*See p. 17.15 for full names of abbreviations.

coating. Automatic machines have been developed to handle up to 10 000 articles per day by this method.

Spraying

The high labour costs of spraying tend to make this method of application uneconomic when compared to dipping, but most thermoplastic materials can be applied by spraying if size or other features make it desirable. Some fluorocarbons, e.g. p.t.f.e. and p.t.f.c.e., can be applied only by this method. Other typical examples of sprayed coatings include the lining of tanks which are too large to dip or require a one-side coating only of nylon, c.a.b., Penton or h.-d. polythene.

Electrostatic Spraying

A high voltage is applied to the nozzle of a powder spray gun and the powder spray, produced at a low velocity, acquires a strong charge. The object to be coated is earthed and so attracts the charged powder. As all parts of the object are earthed the powder will envelop it completely and not just coat the visible surfaces. The coated object is then heated to fuse the powder into a continuous film.

The process has achieved commercial success with epoxy powders which are thermosetting and outside the scope of this review, but special p.v.c. and nylon powders are becoming available.

Vacuum Coating

This process relies upon a high vacuum to draw powder from a fluidised bed into the preheated article. When the powder has entered the article and has been dispersed the residual vacuum is maintained whilst the powder fuses onto the hot metal. The absence of air during this process yields a coating devoid of air entrapments. The process, which is patented, is best used for pipes and chemical vessels and is normally confined to Penton powder and to a lesser degree to nylon powder.

Flame Spraying

The major advantage of flame spraying is that work can be coated on site. A powder of approximately 60 mesh size is agitated and forced through a flame in front of the pistol, which is surrounded by an inert gas shield. The powder is therefore heated by convection rather than by passage through the flame itself, which would denature it. The powder in the molten state falls on to the metal in the form of globules which are subsequently fused together by gentle passes of the naked flame. Great skill is required if the coating material is not to be carbonised or embrittled by excessive heat and this is the principal limitation to the wide adoption of this process.

The most suitable method of application to be used in any instance is dependent upon many factors but, in general, it has been found that where both spraying and dipping can be employed, the cost of raw material saved by spraying only part of a component is more than offset by the extra hand work involved. Wherever possible, dipping is preferable as masking techniques are now available which enable almost any part of the component to be left entirely free of the coating medium.

Whichever method of application is chosen, pretreatment is of the utmost importance. This is carried out by degreasing and/or shot blasting, the latter being usually essential where adhesion of the coating is important. After such treatment, the coating operation must be carried out with the minimum of delay in order that rusting shall not reoccur.

Coating Plastics

At the present time there are six thermoplastics which provide satisfactory commercial coatings.

1. Plasticised polyvinylchloride (p.v.c.)
2. Penton
3. Nylon
4. Cellulose acetate butyrate (c.a.b.)
5. Polythene (high density and low density) and
6. Polytetrafluoroethylene (p.t.f.e.) and polytrifluoromonoethylene (p.t.f.c.e.)—a closely related material.

General characteristics of thermoplastic coatings are given in Table 17.4.

Polyvinylchloride (p.v.c.)

This is probably the most versatile of plastics coating materials. Its resistance to corrosion is slightly impaired by its plasticiser content, but it is none the less markedly superior to natural rubber and is not subject to the same deterioration with age. Its three outstanding characteristics of resilience, corrosion resistance and electrical insulation enable it to compete with rubber in many situations.

One of the advantages of p.v.c. for coating is that its properties can be varied widely, e.g. Shore hardnesses of between 35 and 95 can be obtained by varying the plasticiser and solvent percentages and by use of an appropriate polymer.

The metal to be treated is usually well cleaned by pickling, degreasing, or shot blasting, and then primed with adhesive primers based on a mixture of nitrile rubbers and phenolic resins. In addition to the spraying technique both the liquid-plastisol and the fluidised-bed method can be used for applying p.v.c. The former method is used for industrial finishes and those where the application calls for a substantial protective, rather than decorative, coating.

Coatings up to 12.5 mm thick can be applied in one dip on substrates having suitable thermal capacity. The ease with which thick, uniform coatings can be achieved with p.v.c. makes it in many cases very much

cheaper than conventional rubber lining, as it eliminates the hand-work associated with the latter. The dip coating process necessitates simultaneous coating of external and internal surfaces of the metal, which can be advantageous when the article is intended for service in corrosive conditions, as the outside coating obviates the necessity for further painting or maintenance. If the external coating is not required, adhesive primers are not applied to the external surfaces before coating.

If a thinner attractive drip-free coating is required, then the powder coating method is the more suitable and the choice of whether p.v.c., nylon, c.a.b. or polythene is to be used will depend upon what other conditions of temperature, corrosion and abrasion are to be encountered. The technique of coating is similar to that for the other powder coatings but as the powdered raw material is more expensive, for industrial applications it is generally applied as a liquid plastisol. Air-curing cold-applied p.v.c. solutions can be applied by spraying. Its properties are not quite as good as those of the other grades available and it is rather more costly, but it can be used for on-site application. Coatings of up to 0.25 mm per pass can be obtained by this method but there is a danger of thin spots on sharp angles and corners. Complete cure takes approximately 24 h.

P.V.C. coatings have been applied as replacements for rubber linings in situations where ambient temperatures do not exceed 65°C, but limited exposure at higher temperatures of up to 100°C is harmless under certain circumstances. Typical uses are on fencing, partitioning and guards; on pumps, pipelines, fans and fume ducting; on stirrers, paddles, vessels and plating jigs; as insulation on electrical equipment and cathodic-protection plant; and as anti-abrasion coating on dredger slurry lines, fullers' earth plant, cement works and coke plants.

P.V.C. powder coatings applied to road poles and lighting columns demonstrate the excellent weatherability and toughness of this material. Powder coatings on automatic dishwashers also reveal the heat and detergent resistance of p.v.c.

Penton

Penton is a trade name for a chlorinated polyether—a thermoplastic which is a semitranslucent, hard, reasonably non-brittle material normally applied to a thickness of approximately 0.65 mm. Its primary interest is that it has an unusual combination of chemical and mechanical properties which opens new fields for the development engineer. By coating a relatively cheap substrate metal in Penton, resistance to a great many corrosive liquids at temperatures up to 120°C can be achieved at a fraction of the cost of stainless steel or glass lining. Penton is entirely non-toxic and can, of course, be steam-sterilised. It can be sprayed as a straight powder, or as a powder in a liquid carrier and subsequently sintered, or, preferably, by the simpler process of fluidised dipping as a powder and subsequently sintering.

Fluidised-bed dipping is the most suitable for quantity production of relatively small articles. Coatings up to 1.12 mm can be achieved by one dip with this process on metals which have sufficient thermal capacity, and as the Penton is in powder form there is no danger of drips.

Table 17.4 General data on thermoplastic coatings

Characteristics		Safe working temperature range (°C)		Normal thickness range (mm)	Process temperature (°C)	Volume resistivity at 20°C (Ω cm)	General chemical resistance	Abrasion resistance	Toxicity	Inflammability	Shore hardness	Surface finish	Application method												
		Min.	Max.											Min.	Intermittent										
Coating																									
P.V.C. 40% plasticised	-35	65	80	0.38-12.5	170	3×10^9	Good; poor for solvents	Very good	Very slight	Slow to self-extinguishing	60-70	Gloss	Dipping or spraying												
Penton	-60	120	150	0.20-1.15	350	10^{15}	Very good	Good	Non-toxic	Slow	98	Gloss	Dipping or spraying												
Nylon	-50	100	120	0.25-1	300	6×10^{13}	Good for solvents; unsuitable for strong mineral acids	Excellent	Non-toxic	Fair	95	Gloss or matt	Dipping or spraying												
C.A.B.	-40	85	100	0.38-1.25	325	10^{13}	Fair	Good	Non-toxic	Slow	100	Gloss	Dipping												
Polythene l.d.	-70	70	105	0.38-2.5	200	3×10^{17}	Very good; unsuitable for trichloroethylene	Fair	Non-toxic	Medium	70	Gloss	Dipping or spraying												
Polythene h.d.	-70	70	115	0.30-2	250	10^{16}	Very good	Good	Non-toxic	Medium	85	Matt	Dipping or spraying												
P.T.F.E.	-80	250	300	0.0125-0.125	400	10^{17}	Very good	Poor	Non-toxic	Non-flammable	75	Gloss	Spraying												
P.T.F.C.E.	-70	200	225	0.125-0.25	270	1.2×10^{18}	Very good	Fair	Non-toxic	Non-flammable	97	Gloss	Spraying												

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The normal surface preparation as outlined is the most satisfactory method in order to obtain maximum adhesion of these coatings.

Sprayed coatings are applied directly to the shot-blasted surface and subsequently sintered by stoving. Spray coating is normally used where the article is too large or has insufficient thermal capacity to enable the dip coating process to be carried out.

Penton can be used as an anti-corrosive coating on pumps, pipelines, valve bodies and plugs, and on stirrers, paddles and other items which require many of the outstanding corrosion-resistant properties to acids, alkalis and solvents of the fluorocarbons, but at rather lower temperatures and at a fraction of the cost.

Nylon

Although nylon is not as corrosion resistant as the other finishes available, excepting possibly c.a.b., it has other properties which make it a useful coating material. Most nylon coatings are based on nylon Type 11 or nylon Type 12 owing to their low water absorption. It can be applied to a thickness of 0.9 mm, it is easily coloured and will not chip. Its primary interest as a coating material lies in its excellent oil and solvent resistance, and in the fact that it can be used at temperatures up to 120°C, which makes steam sterilisation possible. At the same time the hardness of the coating and its excellent low frictional properties make it extremely useful as a light bearing or guide material. Nylon is applied, like other thermoplastic powders, by fluidised dipping or by spraying. It is a particularly useful material where coatings of attractive appearance and only mild corrosion resistance are required. Self lubrication can be enhanced when necessary by the impregnation of the nylon with molybdenum disulphide.

Advanced masking techniques, which have been developed over several years, now make it possible to leave any parts of an article entirely free of coating. This not only results in raw-material savings, but also leaves the coated edges smooth and bevelled. Natural adhesion to steels, aluminium and mazak is outstandingly good, but it is less satisfactory on copper and some brass alloys owing to oxidation, though the use of special primers can often overcome this.

Nylon has been applied in the form of coatings to resist trichlorethylene and methanol, erosion-resistant coatings for heat-exchanger heads, corrosion-resistant linings for pumps and pipework, decorative and semi-corrosion-resistant coatings for industrial metering equipment, electrical switchgear, etc., non-toxic coatings for the foodstuffs industry, non-contaminatory coatings for de-ionised-water equipment and non-chip coatings for metal furniture.

Cellulose acetate butyrate (c.a.b.)

Cellulose acetate butyrate is used principally as a decorative coating in similar applications to nylon. The same techniques as for nylon are used in applying this coating, and the resultant finish is self-polishing and has a

higher gloss surface finish, but the adhesion is generally poor and uses are therefore restricted to those in which a completely enveloping coating is required. In general it can be said that the corrosion resistance is somewhat inferior to that of nylon, but c.a.b. has its uses on, for example, hand-wheels and levers, where the finish provides a degree of thermal insulation which protects the operators' hands from extremes of temperatures. The use of c.a.b. in powder coating has declined over the years and has now been almost entirely superseded by nylon and p.v.c.

Polythene

Two grades of polythene are available—high-density, which has a higher melting point and is tougher, and, while not giving such a decorative coating, has better adhesion to substrate metals and can withstand sterilising temperatures; and low-density which is simpler to apply and gives a more attractive coating, but is less tough. Like Penton, nylon and c.a.b., the coatings are applied as powders either by spraying or dipping, and by this means there are no drips and runs to detract from the attractive appearance of the material. Generally, high-density polythene is best for industrial applications where corrosion resistance is required. The thickness of deposit is dependent upon the thermal capacity of the substrate metal but it can be varied from 0.0004 to 0.0032 mm.

Polythene is prone to environmental stress cracking under certain adverse chemical conditions. This is aggravated by the difference between the coefficients of thermal expansion of the coating and the substrate and this defect is particularly apparent when coating sheet metal. The problem is generally overcome by annealing to produce a stress-free coating and such process control is vital when lining tanks and pipework.

High-density polythene is used as an anti-corrosive coating on fume ducting, pipework, chemical vessels and tanks, machine guards, cable trays, expanded metal, etc.

Low-density polythene is widely used in domestic products such as refrigerator shelves, self-service display wirework, etc. where a comparatively cheap decorative finish is required.

Polytetrafluoroethylene (p.t.f.e.) and Polytrifluoromono-chlorethylene (p.t.f.c.e.)

P.T.F.E. is largely used as an anti-stick or low-friction surface-coating material, and the application of p.t.f.c.e. is limited to specialised highly corrosion-resistant coatings where cost is of secondary importance. Both materials are sprayed as dispersions on to a suitably cleaned substrate, and subsequently heat sintered to fuse the particles together. In the case of p.t.f.e. these dispersions can be applied to metal and other surfaces which will withstand a processing temperature of around 400°C. Layers approximately 0.01 mm thick are applied, with sintering between each application. Dispersions applied to suitable substrates provide surfaces of outstanding anti-stick and low-friction properties, high heat stability (up to 250°C) and

good low-temperature characteristics. The resistance of bulk p.t.f.e. to attack by acids, alkalis and solvents is well known, but dispersions cannot be guaranteed to give protection against chemical attack on a substrate because they cannot be built up to a thickness sufficient to eliminate micro-porosity. It is, however, possible to obtain a limited measure of protection which may prove worthwhile for some applications.

It is difficult to assess the abrasion resistance of p.t.f.e. coatings. Although they are relatively soft and might be expected to have low abrasion resistance, they have a very low coefficient of friction and may be considered self-lubricating. Therefore, unless a surface is damaged by hard, sharp or gritty substances, it may be expected to have a relatively long life.

It has been claimed that nothing sticks to p.t.f.e., but experience shows that some substances do tend to stick, especially when hot. Among these are glues and resins, but when these materials return to room temperature they can generally be very easily removed by a light tap. This aids cleaning operations so that expensive stripping down of machines is often unnecessary.

P.T.F.E. coatings applied to moulds give easy release to rubbers and parts potted in epoxy resins. The use of p.t.f.e. on rubber moulds is particularly valuable as in addition to increased speeds of production because of easy release, mouldings made are not stained by release agents and the moulds require far less maintenance.

Most of the desirable properties mentioned may be achieved with a coating 0.05 mm thick. Typical applications where full use is made of these properties are on paper-mill rollers, powder hoppers, baking tins, tyre moulds and chocolate moulds.

P.T.F.C.E. is without doubt the best of the anti-corrosive coatings. A completely non-porous coating can be applied at between 0.15 and 0.3 mm depending on the substrate metal. P.T.F.C.E. is suitable for use at temperatures up to and including 180°C, and can be applied to all metals capable of withstanding the stoving temperatures of approximately 270°C.

The stoving process is extremely long and, for this reason, the coating is by far the most expensive of all those listed. It has slightly less resistance to corrosion than p.t.f.e. and it is widely used for its electrical insulating properties on complex components of electronic equipment. With the advent of Penton, which is far less costly, the chemical uses of p.t.f.c.e. are now limited to those comparatively few instances in which Penton does not give the required degree of protection. Some typical applications are on such articles as bursting discs, diaphragm valves, high-temperature pipework, immersion heaters and mixing vessels.

The use of plastics as heavy protective coatings continues to grow at a rapid rate, as their remarkable properties when combined with substrate metals become increasingly recognised.

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