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First International Conference on the
*internal and external
protection of pipes*

University of Durham,
1975

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internal and external protection of pipes

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OPENING ADDRESS

My first duty - and a very pleasant one is to welcome you to this Conference, with a special greeting to those from overseas who come from no less than 22 countries, and to congratulate the Organisers on their choice of this beautiful historic city and their success in attracting such a numerous and distinguished attendance.

Herodotus, that intriguing if some what imaginative Greek historian, has described what was, perhaps, the earliest, and most marvellous large-scale water-pipe that has ever existed. Some 2½ thousand years ago a main, of length equal to a 12-day's journey (presumably by camel, not by Concorde) was constructed by Aames, an Egyptian king, to convey water from a river to three large reservoirs for the use of his army in the desert near the north end of the Red Sea. The pipe was of a type regrettably overlooked in the papers before you - it was made of cow-hide and other skins stitched together. We do not know the sort of pressure it was called upon to withstand, for, surprisingly, no river now exists which could have been the source from which the water was obtained and which might have given us a clue as to the profit of the main. Incidentally, the Egyptian army was defeated, whether by reason of thirst or other cause we are not told.

Although I cannot find any mention of pipes of stitched cow-hide in the papers submitted to the Conference, these certainly do cover a wide and interesting range. But there is one aspect which deserves, I think, more prominence than it has received, namely the efficiency of pipes as transporters of materials with low energy absorption. How many contractors for a pipeline are willing to guarantee the conductivity of their laid main - say, the value of the Hazen and Williams Constant "C"? This of course depends mainly on the internal surface, its roughness and its waviness which are mentioned in certain of the papers, and on the design, and the execution of the jointing which is scarcely noticed in this connection, all of which are the responsibility of the pipeline provider. So, at any rate where the supply and the laying of a main are the responsibility of the same contractor, such a guarantee, preferably on a bonus-and-penalty basis, should be logical and feasible. Yet, whereas contracts for pumping plant, for instance, are often subject to such a stimulus to cooperation in effecting efficiency and progress and a placing of the benefits, I know of no case in which it has been applied to contracts for pipelines, although pipe-friction is the chief consumer of the energy produced by the pumps! Of course it may be objected that the internal cleanness of pipes may be only temporary, especially in the case of water - incrustation and growths may occur, corrosion, erosion and abrasion may arise, which may be outside the control of the contractor. True, but initial conductivity is nevertheless usually a very pertinent indication of the carrying efficiency to be expected over the years. I am at the moment concerned with a large pipe contract for water and would like to introduce some incentive towards, and insurance of, the minimisation of power-loss. Any gleanings from your forthcoming discussions will be most welcome to me.

But let not the vapourings of an old man - about one-thirtieth of the antiquity of Herodotus' stitched cow-skins - encroach further on your valuable time. May your collective experience and informed discussions have the success they deserve!

I have pleasure in formally declaring the Conference open.



Hugh R. Lupton, Vice-President BHRA Fluid Engineering
O.B.E., M.C., M.A., F.I.C.E.
F. I. Mech. E., M.I.E.E., Hon. M.I.W.E.
M. Cons. E.

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First International Conference on the

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internal and external protection of pipes

September 9th - 11th, 1975

University of Durham

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THE COATING OF PIPES IN THERMOPLASTIC POLYMERS

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Summary

The process used for the coating of pipes and allied items in thermoplastic polymers is briefly described. Reference is made to the plant used for the process and the chemical resistance of the commercially available materials is discussed.

Metal substrates are coated in plastic to protect them against corrosion. In addition, the coating can confer other very desirable properties to the coated article. For example, a thick coating of resilient PVC on stillages ensures that the in-plant movement of delicate instruments is trouble free. The electrical insulation afforded by certain plastic coatings results in them being specified for many electrical components.

The particular plastic to be specified for coating depends on the relative significance of such factors as corrosion resistance, chemical resistance, impact resistance, abrasion resistance, electrical properties, outdoor durability, ease of post-forming, etc. In addition to the above physical property considerations which affect the choice of coating material, there are many occasions when the choice between several technically acceptable finishes is governed by the nature and shape of the article to be coated.

The Coating Process

The dip coating process depends on the fact that at some time during a heat cycle of a polymer there is a thermoplastic phase so that the polymer will fuse into a continuous coating. The technique of plastic coating consists in essence of heating a piece of metal to a temperature such that when it is dipped into a thermoplastic polymer the polymer which adheres to the metal melts and flows into a coherent coating. It is usual in practice to re-heat the article after dipping in order to complete the melting or sintering process.

Plastic coatings may be applied as liquids or as solids. The liquid system applies only to PVC and is confined to a simple dip process. The solid or powder process applies to Polyethylene, Nylon, PVC, Penton, EVA, Polyesters, and a number of fluorocarbons and a variety of methods of application are available, namely, flock gun spraying, flame gun spraying, fluidised bed dipping, and electrostatic techniques.

Procedure

There are four major stages in the dip coating process

- (i) Metal preparation.
- (ii) Pre-heat.
- (iii) Dipping.
- (iv) Sintering.

(i) Metal preparation

(a) Metal Cleaning

The first stage in metal preparation is the removal of all forms of oxidation. This is carried out by conventional shot blasting or chemical pre-treatment. Chemical pre-treatment which includes phosphating places a limitation on the temperatures which may subsequently be used, since such phosphates decompose at elevated temperatures.

(b) Priming

The second stage is the priming of the cleaned article. Adhesive primers which promote a satisfactory bond between the substrate and the coating are applied. The primers require to be heated after application in order to

develop their adhesive properties. Since the article has to be heated to pick up the coating, this operation serves to cure the primer also. The primers are different for different coating materials, but they can all be rendered in-effective by over heating. The primers therefore constitute a further limitation to the coating process in that the time and temperature of pre-heat are restricted by the nature of the primer.

It cannot be over emphasised that the metal preparation stage holds the key to the success or failure of a technical coating. Thus inadequate cleaning will lead to failure of a coating, since the presence of rust or scale will prevent adequate bonding between the substrate and the coating. A good bond may be obtained between the coating and the rust but there is no bond between the rust and the substrate. Failure of a clean substrate will occur if the adhesive primer is maltreated.

Lack of adhesion will manifest itself in bubbling of the coating and eventual corrosion of the substrate. Vapour will pass through a coating if there is a void behind the coating in which the vapour can accumulate. Vapour will not pass through a coating if there is no void and when the coating is completely adhered to the substrate no such void exists. Thus the necessity for complete adhesion is paramount.

(ii) Pre-heat

The cleaned, primed article is then pre-heated at a temperature and for a period of time, both of which are best determined by experiment, so that when the article is dipped into the plastic, it contains sufficient heat to melt the plastic so that it will flow and form a coherent coating. It is obvious that the article being coated must be capable of withstanding the temperatures of the process. High output coating equipment may run at very high temperatures and it is essential to ascertain the maximum to see that the item will not melt, crack or distort. Fillers are usually unreliable and tend to bubble during the heating. Soft solder will often be quite impracticable. Certain fluxes and other deposits may cause trouble during the heating and cause blisters in the final coating, although the normal pre-treatment methods will generally remove them. The amount of coating that is picked up is a function of the pre-heat conditions since the coating thickness depends upon the amount of heat available above the melting point of the particular material. This heat depends upon the temperature of the article, its specific heat, and its cross section. The thickness of coating is also dependant upon the period of dip. For a given material and temperature one would expect the heavier sections to attract a thicker coating than the thinner sections and this what, in practice will occur, although the method of heating can do much to minimise this effect.

The sources of heat used for pre-heating can vary considerably; re-circulating ovens are generally found to be most efficient, since an even temperature can more easily be maintained throughout. Radiant heaters are also used quite extensively, but these can cause trouble when a variety of metal surfaces are encountered, since reflective surfaces may be impossible to heat sufficiently, or may take up costly time and fuel in obtaining the required temperature.

Induction heating, resistance heating, and direct flame heating can also be used, but the first two impose severe limitations on the shapes of acceptable articles and the third is difficult to control. Nevertheless, these techniques are receiving increasing attention. Thus induction heating is used in the continuous coating of tubes and wires and direct flame heating is used in coating inside heavy walled pipes. (See Fig. 1)

(iii) Dipping

The dipping stage consists simply of immersing the pre-heated article in a tank of PVC plastisol or in a fluidised bed of plastic powder for a sufficient length of time to enable it to be coated to the required thickness. The practical details of a fluidised bed are now well known and so need not be further described here.

All dip coated articles require to be suspended for the dipping operation and where the article is specified for complete coverage it is necessary to seal the suspension point by a subsequent operation. It often occurs, however, that the customer does not require an enveloping coat and in consequence the coater can take advantage of this for suspension.

(iv) Sintering

When the dipping operation is complete, the coating may need a further heat treatment in order to flow it to a smooth coating. Whether this extra sintering operation is required depends upon the heat content of the article and the rheological properties of the polymer being applied. Thus low density polyethylene invariably needs the sintering stage whereas many applications of Nylon and PVC do not. It is obviously preferable to eliminate this extra stage since a cheaper process results, but there are occasions when the limitations imposed by the metal preparation stage prevent sufficient heat being accumulated in the article in the pre-heat stage to avoid the sintering stage. Similarly a very thin item usually needs the sinter stage. In addition, the inclusion of the sinter stage sometimes enhances the physical properties of the coating by reducing voids and bubbles in the coating.

Liquid PVC plastisol invariably needs this second heating stage to complete the gellation of the PVC. In this case the second stage is referred to as curing rather than sintering.

Principle Coating Materials

The only thermoplastic material applied as a liquid is PVC. The materials currently applied by the fluidised bed techniques are Polyethylenes, PVC, and Nylon, and to a lesser extent EVA, Penton, Polyester, and the Fluorocarbons. General properties of the major materials are detailed in Table 1.

Polyethylenes

Low density Polyethylene is still the most commonly used fluidised bed coating powder, because of ease of application. It usually requires the sintering stage described above. It is entirely satisfactory for coating a wide range of wire articles where a decorative finish with atmospheric corrosion resistance is required. The fact that Polyethylene has poor resistance to stress cracking has precluded its use for the coating of items for long term exterior exposure and for corrosion resistance in severe chemical environments. Because of its ease of application and its inherent chemical resistance, much work has been carried out to overcome the stress cracking problem. One approach has been to use co-polymers of ethylene which do not suffer from the stress cracking problem. Ethylene-Vinyl Acetate (EVA) co-polymers have had some success in this respect and they are finding limited use. Unfortunately, the maximum working temperature of EVA is rather low.

The major tonnage of Polyethylene used for fluidised bed coating has a high melt flow index and this, of course, is one of the main reasons for the stress cracking difficulties. High melt flow material has to be used to yield a smooth decorative

finish. Where this is not essential, species with much lower melt flow indexes may be used and the stress cracking problem is greatly reduced. Thus for the coating of pipes for underground gas and water mains a low melt flow index coating is entirely satisfactory.

Polyethylene is, of course, a relatively soft material and so it cannot be used where abrasion and scuff-resistance are required.

Conventional adhesives are not effective with Polyethylene, but Polyethylenes have been developed which have self-adhesion to mild steel.

PVC

The coating of pipes and ancilliary equipment for pipe lines such as valves has been an established market for PVC plastisol (i. e. liquid PVC) for many years and has been complemented recently by the introduction of PVC powders.

PVC Plastisol

PVC is the only material applied from the liquid form. Other polymers such as nylon, penton, polypropylene and cellulose acetate butyrate could be applied by solvent dipping, but the cost would be excessive because of the solvent loss or expenditure on recovery plant, and the many precautions needed for factory handling. It should be emphasised that PVC plastisol is not a solvent system. In a PVC plastisol, resin is suspended in a plasticiser and the action of heat brings about a homogeneous mixture of resin and plasticiser; no material is lost during this process.

PVC plastisols are available in a wide range of hardnesses ranging from soft and rubbery to extremely hard. This range is achieved by the addition of varying amounts of plasticiser to the host PVC resin. In addition by suitable choice of plasticiser type, it is possible to achieve oil resistant and exceptional low temperature flexibility grades. PVC resin is extremely resistant to chemical attack and once again the careful choice of plasticisers results in a flexible material with similar resistance to the host resin. Plastisol coating of chemical plant has now largely replaced the alternative more costly rubber lining (See Figs. 2 & 3).

PVC Powders

By the use of PVC resins having good plasticiser absorption characteristics it is possible to manufacture a PVC powder with acceptable powder flow properties to enable it to be applied by the fluidised bed process. PVC powder produces a thinner coating than PVC plastisol (500 microns compared to 3000 microns). In much the same way as with PVC plastisols variations in plasticisers and additives will produce powders with a wide range of physical properties.

The exterior coating of pipes in PVC powder can be carried out as a batch process and as a continuous process. The equipment for the batch process is shown in Figs. 4 and 5. In the continuous process discreet lengths of pipe are linked together before passing through an adhesive bath, an induction heater and a fluidised bed.

Grades of PVC powder are available which yield coatings which comply with the requirements of Water Authorities for the piping of potable water. Such materials are used for the coating of T's, elbows and bends for joining concrete and other types of pipes.

Nylons

Nylon 11 and Nylon 12 are the only commercially available types of Nylon which can be used for coatings. Other types such as Nylon 6 and Nylon 66 have incorrect rheological properties to enable them to be used.

Nylons have good abrasion resistance and good impact resistance and this has lead to their use in a wide range of applications in industry. In addition, when properly applied they have excellent outdoor durability. Adhesives are available which give a good long term bond.

Penton

Penton, a chlorinated polyether, is used where coatings for contact with extremely aggressive chemicals are required. It is a high priced material used exclusively for chemical vessels and pipes. Fig. 6 illustrates a typical item coated in this material. Penton is unfortunately a brittle material and has, therefore, to be handled with care.

Fluorocarbons

There has long been a need for a melt processible polymer that has the chemical and electrical properties of fluorocarbons and the mechanical strength of Nylon. Such a product has been developed and is finding steady commercial acceptance. The product, Halar, is an ethylene-chlorotrifluoroethylene co-polymer. Coatings from this material are extremely tough and have excellent resistance to acids and alkalis up to 120°C. Solvents resistance is also extremely good. This high priced material finds specialist uses in the aggressive environments of the chemical industry.

Conclusions

Plastic coatings are being increasingly specified for long term protection of many articles. Protection is required over long periods of outdoor exposure as well as in aggressive chemical environments. Such coatings need to be applied with care and precision but there is little doubt that providing such precautions are taken the resultant coatings will endure for a very long time.

TABLE 1

Property	Units	PVC Plastisol	PVC Powder	Polythene	Nylon	Penton	CTFE Copolymer
Tensile Strength	$\text{Nm}^{-2} \times 10^{-6}$	8.27	10.34	10.34	48.26	47.29	48.47
Elongation	%	300	175	150	17	25	200
Hardness	Shore A	60	80	70	95	90	85
Working Range	$^{\circ}\text{C}$	-20 to +65	-20 to +65	-50 to +60	-50 to +80	-60 to +120	-50 to +150
Taber Abrasion Resistance	$\text{m}^3 \times 10^{-6}$	0.03	0.04	0.06	0.045	0.01	0.005
Acid Resistance	-	Good	Good	Good	Poor	Excellent	Excellent
Alkali Resistance	-	Good	Good	Good	Good	Excellent	Excellent
Solvent Resistance	-	Poor	Poor	Poor	Good	Excellent	Excellent

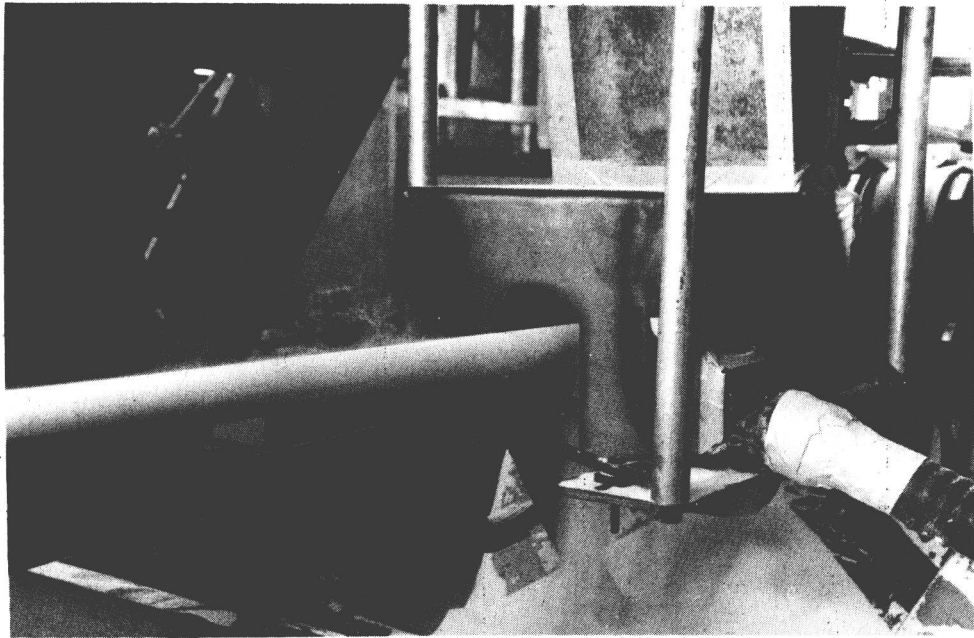


Fig. 1. A PVC powder coated steel tube emerging from the powder application unit.

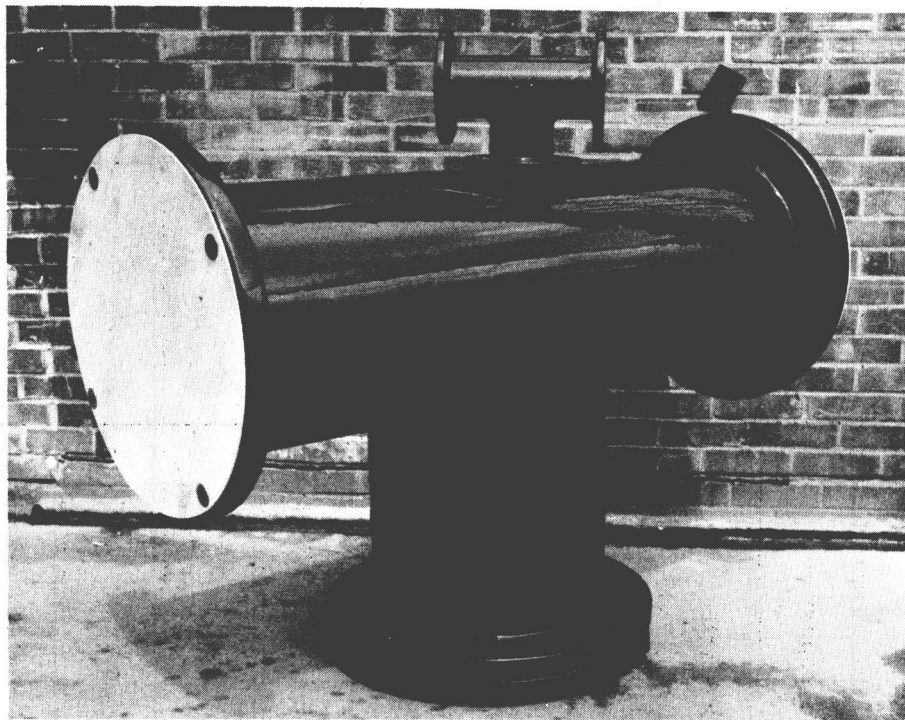


Fig. 2. A PVC plastisol coated pipe connector.