

Concise Guide to Powder Coatings

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Powder Coatings

1. Introduction

Powder for Surface Coatings?

The concept of finishing metallic surfaces by applying dry powders which, when fused, form continuous and integrated coatings, has developed steadily since its practical inception in the mid 1950's. Initially thermoplastic resins were employed, but within the last three decades thermosetting powders have been developed which open up a much wider field of use.

The increasing use of thermosetting powders has been necessary because of the need to reduce air and water pollution coupled with the fact that with today's rising costs of basic raw materials and labour, powder coating is often a viable commercial consideration when compared to conventional industrial liquid paints.

Some of the more obvious advantages of using thermosetting powders are:

Ready for use - Powders are immediately ready for use. They do not have to be mixed with any other ingredients such as solvents or catalysts. This saves on shop floor time and also eliminates a variable which it is vital to control with liquid paints to obtain satisfactory film properties.

Reduction in the fire risk as no solvent required - As no solvent is required with powders, there is a reduction in fire risk which gives cost savings on statutory safety features in plants, reduces insurance premiums and savings can be made on manpower time. Powders, because they are solvent-free, are not subject to the Highly Flammable Liquids and Liquefied Petroleum Regulations (1972), or similar Regulations and Orders containing requirements in respect of flammable liquids. For information on possible dust and explosion hazards arising from powder usage, see Section 6 'Safety Considerations'.

No costly wastage of solvent : environmental cleanliness - There is no costly wastage of solvents which, at application viscosity, constitutes up to 70% of conventional liquid paints. These solvents, which volatilise during application and stoving are usually not recoverable and legislation introduced in various parts of the world has prohibited their discharge to atmosphere and in some cases, therefore, after-burners have had to be installed to eliminate solvents with an attendant increase in costs.

This legislation covering atmospheric pollution and effluent is extremely important. An example is the German 'TA-Luft' Regulation⁽¹⁾. This regulates the content of gaseous or vaporous material in exhaust streams. These materials are divided into 3 classes. Each class has a specified maximum mass concentration in the exhaust air which may not be exceeded at or above a specified total MASS flow.

No effluent disposal problems - With liquid paint systems, water wash spray booths are commonly employed. The overspray is usually emulsified in the water, which in some cases is put directly to drain or in other cases, allowed to settle out in sludge tanks. Powders do not give rise to these problems and extra costs.

No air pollution - Oversprayed powder is recoverable and no powder need escape into the atmosphere.

Reduced health hazard to operators - There is a reduction in health hazards to operators. As powders do not contain solvent there is a marked reduction in nose, mouth and throat irritation as is sometimes noticeable particularly during hot weather in liquid paint shops. Any liquid paint which comes into contact with an operator's skin needs to be washed off with solvent, and then removed by emulsifying with soap in hot water. In difficult cases special industrial hand cleaners have to be employed. These remove essential oils from the skin and in some cases can cause skin irritation. In general powder does not cause skin irritation though in rare cases individuals may react to certain types of powder. The powder can be removed from the skin easily by washing with warm water.

Concern in recent years about possible mutagenic effects of TGIC, one of the materials commonly used in powder coatings, has been alleviated after development of TGIC-free products provided an alternative option.

Considerable improvements have also been made in reducing the heavy metal content of powders, in particular lead. Lead-free products are now achievable for the vast majority of shades.

Processing time reduced - Powder processing times are generally shorter than those used for wet stoving paints since, as there is no solvent, no flash off period is required; the powder coated articles can pass directly into the oven. This gives substantial saving in space and time.

Economy in reduced energy requirements - There is a cost saving during stoving because no energy is required to evaporate solvent and evacuate it from the oven.

Superior film properties - With solvent based systems, the solvent balance must be carefully adjusted to the polymeric type, application and curing conditions, as many film defects can be traced directly to incorrect solvent balance. With powders no such condition exists and in general superior film properties such as adhesion and corrosion resistance are obtained with powders compared to polymers deposited from liquid systems.

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Damaged parts easily rectified - Damaged or poorly coated areas can be easily rectified before baking by blowing off the powder and re-coating.

Air requirements reduced : cost savings - Air extraction in a powder spray booth is very much less than for solvent based paints and this leads to economies in ventilation and consequential heating of work areas. As less warm air has to be replaced in workshops, less dust is attracted and there is less air-draught for the operators to contend with.

95% powder utilisation - Material loss can be kept to less than 5% by powder overspray recovery. The powder recovered can be blended with virgin powder to provide up to 95% utilisation.

Controlled film thickness - A controlled more uniform and, if required, a higher film thickness can be obtained with powders than with conventional paint systems in one application. Improvements in the appearance of thin films has also made this a viable option for certain applications.

Wide range of coatings available - A broad variety of decorative and functional coatings are achievable using powder. These range from matt to high gloss, smooth to textured finish and include metallic and other speciality effects. Choice of polymer type can optimise properties such as corrosion resistance and exterior durability.

Minimal operator training required for application - Operators require much less training to apply powders than solvent based systems.

Surface pretreatment - As with most coated metallic surfaces, preparation and pretreatment are important to maximise corrosion and environmental resistance.

Powder cleaner to use - Applying powder is much cleaner than applying wet paint. A spray booth can be cleaned down by use of a rubber squeegee whilst the normal air extraction in the booth is operating. Brushes or an air hose should not be used for this purpose. Any spillages of powder outside the booth should be removed with an industrial vacuum cleaner which is fitted with an air-driven or dust-tight motor.

Powder application plant less costly - Powder application plant, either manual or automatic, is extremely simple to operate and less costly than a two-coat liquid electro-deposition system.

Lower cost of packaging for coated articles - A much higher order of physical and chemical resistance is obtained with thermosetting powder polymers than with their liquid counterparts. This leads to a lowering of the cost of protecting the work during transportation to the user.

Non-metallic surfaces can be coated - Surfaces such as glass and certain thermosetting mouldings which can withstand the stoving temperatures involved can be powder coated. The scope of materials which can be used is ever-increasing as advancements in lower bake technologies are made.

Less storage space required for the powder - Less storage space is required for powder compared to paint which means cost saving on factory floor space.

There are, however, certain disadvantages to using thermosetting powders and these include:

Thin films difficult to obtain - Thin films ($\mu 25$ microns) are more difficult to obtain with powders than with wet paint systems. However, the overall economics of applying a somewhat thicker coating of powder could still prove favourable.

Colour change slower - Colour change is more rapid with liquid paints than with powders. However improvements in application equipment and cleaning techniques has reduced this time considerably in recent years.

Powders cannot be mixed - Powders cannot be mixed with one another to obtain different colours. However, this is not considered vital as most industrial coaters use paints or powders already matched to specific shades.

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2. Application Techniques

Powder coatings are currently being applied commercially by either fluidised bed or electrostatic spray, the latter being by far the most common.

Fluidised bed - The fluidised bed was originally designed for the application of thermoplastic powders and remains the most common method of application of these products. In the case of thermosetting powders its use is generally confined to cases where an exceptionally thick, eg. 250-500 micron, coating is required in one application; such as the coating of valves for gas and water pipelines where a tough durable and corrosion resistance finish is essential.

The fluidised bed consists essentially of a tank with a porous membrane base through which a controlled low-pressure air supply is fed. This serves to fluidise powder within the tank giving it properties similar to a liquid, thus reducing its resistance to items entering it and ensuring a homogeneous coating.

The objects to be coated are preheated to a temperature above the fusion point of the powder before immersion in the fluidised bed. The coating thickness is determined by time of immersion in the bed and the preheating temperature of the object. Where the objects are sufficiently massive the retained heat may be sufficient to cure the polymer otherwise post-heating will be required.

Advantages

- 1) An exceptionally thick and corrosion-resistant coating can be obtained in one immersion and stoving cycle.
- 2) With properly formulated powders very uniform films can be obtained.
- 3) Low initial plant cost.

Disadvantages

- 1) Relatively large quantities of powder are required to charge the tank.
- 2) The workpiece must be preheated and, in some cases, post-heated to complete cure.
- 3) This method is only applicable to those cases where a high film thickness is required.
- 4) This method is confined to articles of relatively simple shape.
- 5) Thin gauge metal cannot be coated because of its insufficient heat capacity.

Electrostatic spray - The powder, usually contained in a hopper adjacent to the application booth, is delivered in an air stream to the electrostatic spray gun which charges the particles on emission and so causes them to deposit on the earthed workpiece. Subsequent fusion and curing takes place in an oven. Powder not deposited on the workpiece is collected and re-used.

Advantages

- 1) Intricately shaped articles can be coated.
- 2) Film thickness of 35 to 125 μ can be achieved in one application.
- 3) Automatic operation can be installed for high production rates.
- 4) Colour changes can be introduced.
- 5) Preheating of the workpieces is not required.
- 6) Thin substrates (eg. metal foils) can be coated.

Disadvantages

- 1) Cost of application equipment is higher than with fluidised bed.
- 2) Coating rate is slower than with wet paint.

A typical electrostatic coating line would comprise:

- ✓ A powder hopper.
- ✓ A source of compressed air at controlled humidity to transport the powder from hopper to gun.
- ✓ A high voltage generator (typically 30-100kV).
- ✓ Powder application guns which may be:
 - hand operated
 - automatic, either static, reciprocating or wagging.
- ✓ A specially designed booth, to allow all excess powder to be continuously removed by an air stream to the recovery unit.
- ✓ A recovery unit may consist of:
 - a cyclone unit
 - bag or frame filters
- ✓ **or** - a combination of both.
- ✓ A rotary valve and sieve unit to remove contaminants from the recovered powder before returning it to the hopper.
- ✓ An earthed conveyor.
- ✓ A curing oven, normally operating at 160-200°C.

(see Figures 1 & 2 for a typical manual electrostatic spray gun & powder coating line).

Powder feed - There are three techniques for delivery of powder from the powder storage hopper to the spray gun, all using air as the carrier medium.

The basic principle to be observed is that the powder supply should be so controlled as to flow to the gun at a steady rate, free from surges or pulsing. Independent control of powder and air volume usually assures that the proper ratio can be delivered. The powder feed should be so designed that the discharge pressure and velocity feed to the electrostatic gun, even at some distance from the gun, are maintained.

Most hoppers are of similar design in being cone-shaped at the base. The powder exit zone varies in diameter according to the method used for powder transit.

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In the worm-screw feed system, the powder is screwed from the hopper into an air stream, where it is picked up and delivered to the gun. This method of delivery can be finely adjusted to give a constant and reproducible flow of powder. This technique overcomes the initial puffing which can be experienced with other forms of powder feed from the gun when spraying recommences after a shut-down period.

The venturi is only activated, as in the other methods, when the gun trigger is operated. Also, an additional air control valve serves to vibrate the powder hopper to eliminate any tendency of the powder to bridge in the centre, so causing insufficient, or preventing altogether, powder from flowing into the venturi. An alternative method is the use of a rotating bridge-breaker.

In the third technique, the powder contained in a flat-bottomed hopper can be fluidised and delivered to the gun by utilising a vacuum created by a variable choke injector.

It is advantageous that the powder feed line connections, ie. at hopper and at gun, are of the snap-on variety as this facilitates speed of line cleaning and changing from one colour to another.

High voltage supply - The high voltage generator, usually specified to deliver variable voltages between 30 & 100kV, is generally situated in close proximity to the powder feed hopper and spray equipment. The gun handle should have a total surface area of at least 20cm² of either metal or a low resistivity material which is connected to the earth terminal. The high voltage cable should include an earthed metallic screen protected by an insulating sheath. In most cases the power, powder feed and air lines are all contained within the same outer protective cover.

Some generators are designed to provide negative and/or positive outputs. All generators should incorporate an overload adjustment for any high voltage malfunction. Should a short circuit occur in the system the high voltage generator should immediately shut down and in addition some visual or audible alarm should indicate trouble.

Spray gun - A range of spray guns, both manual and automatic, is usually offered by the gun manufacturer. The internal powder feed passage in the gun should be as straight and as smooth as possible. Any irregularities or bends within the passage could cause powder build-up and blocking which could cause 'coughing' or 'spluttering' of the powder on emission.

Usually powder spray patterns can be adjusted by diffusers to give a wide fan, cone or fine rod shape. The width and diameter of the powder fan can be adjusted to suit the workpiece.

There are a number of diffuser designs available which may be cone-shaped, either concave or convex, and with single or multiple SLOTS. Diffusers may also be equipped with an air shroud to control and direct the charged powder to the workpieces.

Most guns are designed to permit a high rate of powder delivery. However, the higher the powder throughput rate the lower the deposition efficiency and the greater the quantity of overspray powder to be collected.

Powder spray guns can usually be adjusted to provide a powder discharge to suit particular circumstances. At the lower end of the discharge rate, flow of powder can be from 100-200g/min (approximately 6-12kg/hr), and at the higher end, at a rate of 500-600g/min (approximately 30-36kg/hr). At 14kg/hr, assuming 60% deposition efficiency of the powder ejected from the gun, at a film build-up of 50µ, 1.74m² per minute of surface can be coated.

In an automatic plant the guns may be:

- ✓ Held in fixed positions but individually adjustable to direct powder to the workpiece.
- ✓ Mounted on mechanical reciprocators which may be on one or both sides of the spray booth and may contain one or more guns on each reciprocator.
- ✓ Pivoted to continuously traverse over a present arc (ie. 'waggler guns').

Manual coating is recommended when:

- ✓ The workpieces are of complex shape.
- ✓ The workpieces have semi-enclosed areas.
- ✓ The workpieces have unfavourable width/ depth ratio.
- ✓ The total surface area to be coated is so low that one spray operator can cope adequately.

Automatic coating is recommended when:

- ✓ The workpieces are of relatively simple and flat surfaces.
- ✓ The total surface area to be coated in a given time is large.

In some automatic electrostatic powder spray plants the same basic principles as outlined previously apply. However, the gun(s) are positioned to move about the workpiece in a predetermined path and are automatically stopped and started as required. This movement or reciprocator speed should be as slow as possible, probably between 20 & 35m/minute and consistent with the other conditions applying. It is usually advisable that on an automatic line, a hand touch-up gun should be available. This can be used to coat areas difficult to spray, eg. recessed areas prior to automatic coating. It is advisable to incorporate more guns to be able to run at a reduced throughput which improves transfer efficiency and gives greater flexibility in gun adjustment and in the variety of workpieces which can be coated.

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Tribostatic guns - If a powder is brought into contact with a surface and is caused to move along that surface, the powder particles acquire an electrical charge. This frictional charging is a function of, among many parameters, the chemical and physical structure of both powder and surface of contact, relative humidity and particle velocity.

Powder is fed to the gun from a fluidised bed powder hopper, from which it is drawn by vacuum created by a variable choke air injector. The vari-choke controls the volume of powder delivered to the gun and the air injector pressure governs powder velocity, which is approximately proportional to the resultant charge. No electrical controls are required, so that the operator has only three variables:

- fluid bed pressure
- injector air pressure
- & powder injector choke control to adjust.

Advantages

- 1) Low cost - no high voltage generator required.
- 2) Good penetration characteristics into recessed areas.
- 3) Spark free.
- 4) Self-limiting coating thickness tends to be greater than that obtained from conventional electrostatic spray guns.

Disadvantages

- 1) Because powders are of different composition in relation to polymer, pigment type and concentration, the charge potential varies greatly and in some cases so small is the charge pick-up that little or no powder deposition takes place.
- 2) Charging efficiency falls off with increasing relative humidity.
- 3) Charging efficiency decreases with increasing time of use.
- 4) Powder deposition rate is slower than that of a conventional electrostatic spray gun, therefore production line throughput rates could be slower.

Electrostatic powder spray efficiency - For powder spray application, charging of particles is usually accomplished by corona discharge or ion bombardment. This takes place at or near the point of exit of the powder, where the discharge electrode is situated at the gun head. A high voltage is applied to the electrode so that a high electrical gradient is produced. This creates an electrical corona, or air breakdown, in the vicinity of the electrode. The gas molecules in the air become conductive when they are subjected to bombardment by the electrons which move freely at the discharge head. Those particles which are charged to the sign opposite to that of the electrode are immediately drawn to the electrode. Those of the same sign are repelled into the space about the electrode. The powder particles are propelled through this space and, by collision or ion

bombardment, the charge on the air particles is transferred to the powder particles and so they in turn become charged. Once charged they move to deposit on the earthed workpiece.

Any spray gun will exhibit variations in performance as:

- ✓ Its voltage is adjusted upwards and downwards.
- ✓ Its powder flow rate and exit velocity are adjusted.
- ✓ The distance from the gun exit to workpiece varies.
- ✓ The powder particle size varies.

In addition guns of differing structure, such as guns from two different manufacturers, will behave differently when adjusted to identical delivery rate conditions.

The specific gravity of the powder, the volume, resistivity, the shape of the particles and particle size distribution are all recognised as being significant features affecting powder deposition efficiency.

The powder particle must be able to accept the maximum charge as it passes through the ion cloud and to achieve this as long a dwell time as possible in this area is recommended. A powder particle of high resistivity is preferred as powders with a low resistivity will not deposit on the workpiece in a ready manner and dissipation or leaking away of charge once deposited on the article could lead to powder particles falling off and therefore not producing a uniform coating.

The 'Transfer Efficiency' of a powder can be expressed as a ratio of weight of powder transferred to the workpiece in a given operation, divided by the total weight of powder that is passed through the application spray gun in the same operation.

The efficiency of any given operation is affected, not only by the powder properties and spray equipment, but also by the size, configuration and dwell time of the workpiece in the electrostatic powder spray. For flat panel components Transfer Efficiency is higher than, for example, parts fabricated from bent and welded rod or tubing.

In electrostatic spray application, the charged particles move towards and deposit on the earthed workpiece. A charged layer of powder therefore builds up on the surface of the workpiece. Since the charged powder which has already deposited on the surface will tend to repel those particles which arrive later during the building up of a heavy film, the transfer efficiency will fall off as the coating becomes heavier and heavier until a point is reached where no further powder can be deposited. Although this self-limiting factor was considered as being the fundamental factor in causing progressive repulsion of the charged powder particles, it has been suggested that a reverse discharge occurs in the powder layer as deposited, when ions stream out of the deposited layer towards the gun.

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It has been shown that this discharge is accompanied by constant ejection and eruption of the powder particles.

If the discharge is localised, 'pin-holing' or moon-cratering' can result.

Figure 1: Electrostatic Spray Gun

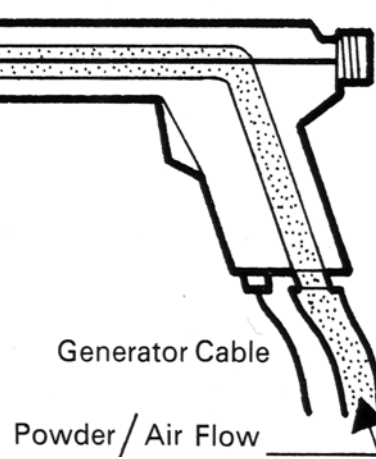
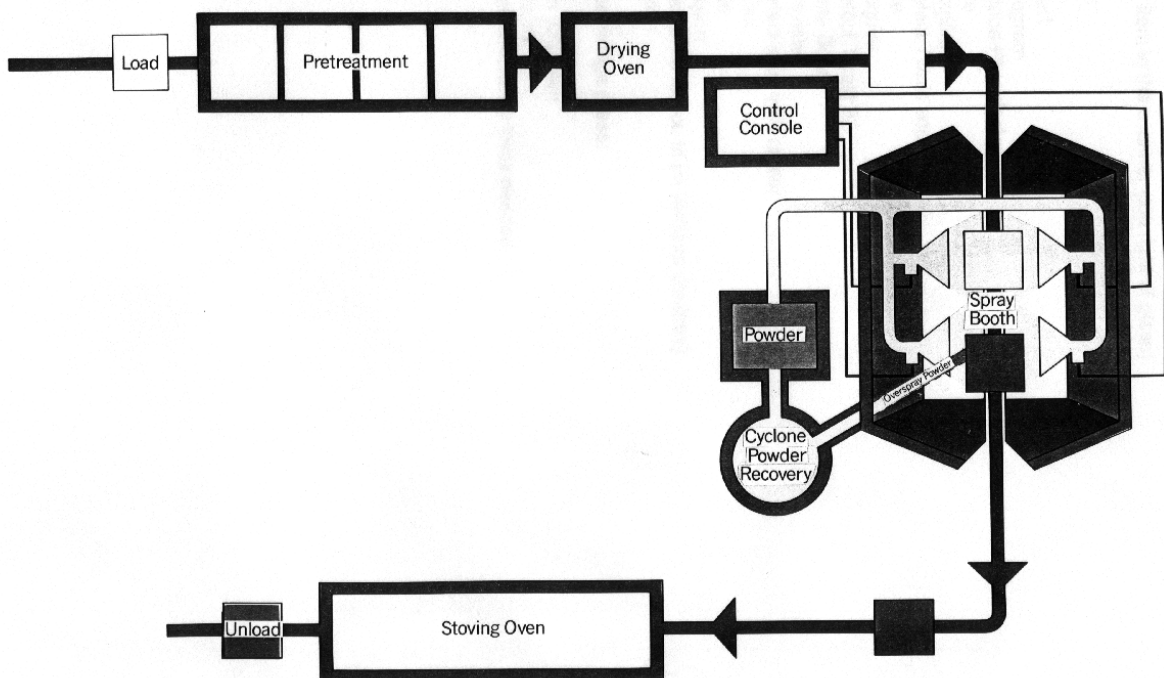


Figure 2: Typical Automatic Powder Coating Line



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3. Spray Booths

Spray booths play a fundamental role in achieving maximum efficiency and economy in powder coating operations. The basic fundamentals are that the spray booth should be as completely enclosed as possible to prevent powder escaping from the booth and that the openings for the spray gun and workpieces should be as small as possible.

These principles can be applied effectively in automatic plants but manually operated systems must have a relatively large sidewall opening to permit the operator to apply the powder.

The interior surfaces of a spray booth should be as smooth as possible, internally free of ledges or corners where powder can collect.

Cleaning down may easily be accomplished by use of a rubber squeegee whilst the normal air extraction in the booth is operating.

The conveyor system should move outside the booth so that only the jigs containing the workpieces hang into the spray area through a slot in the ceiling of the booth. This arrangement not only prevents powder escaping, but much more importantly, prevents the conveyerised system from becoming coated in powder. Jigs coated with several layers of cured powder are difficult to clean. Often it is preferable and cheaper to use jiggging which is disposable.

The powder recovery air should exhaust through the bottom of the booth. The side walls of the booth base should slope towards the exhaust opening to prevent a build up of powder overspray from collecting on the floor of the booth. It is sometimes desirable to incorporate removable or hinged sidewall panels to permit manual touch-up where necessary, or to permit experimental work to be carried out on workpiece configurations.

A powder spray booth should ensure that the overspray powder is transferred and collected efficiently for recycling back into the feed system. This means that a carefully controlled air flow through the booth is a prerequisite for efficient operation.

Ideally the air in a powder spray enclosure should be static so that the electrostatic forces associated with the powder particles, along with the projectional velocity on leaving the gun, impart a fully controlled movement of the particles to the workpiece being coated.

However a carefully controlled air stream must be operational within the spray chamber. This modulated air stream is always directed from the booth openings, over the workpieces, and exits via the exhaust ports at the base of the booth.

This air stream serves several purposes:

- 1) It keeps the powder concentration in the booth well below the explosive limit, ie. 10gms powder /m³ air (see Section 6 'Basic Design Considerations').
- 2) It reduces the amount of overspray accumulating in the booth and is the first stage in the powder recovery system.
- 3) It provides confinement should a fire occur so that any damage is restricted to the spray area.
- 4) It creates a negative pressure within the booth so that the powder is prevented from escaping from the booth into the atmosphere.
- 5) It maintains cleanliness within the spray booth area.
- 6) As it prevents emission of overspray from the booth it produces a clean environment for operators carrying out manual operations which have to take place in the spray booth vicinity.

The prime consideration must be to (1) above and the volume throughput of air to achieve this should be calculated using the maximum powder discharge from all guns operating simultaneously, but making allowance for the quantity deposited on the workpieces under average conditions.

To achieve the remaining objectives in (2)-(6), a linear velocity at booth opening of 0.4-0.5 metres per second is adequate.

In the case where compliance with (1) creates an excessive air velocity this condition may be remedied by inserting air filter panels in the ceiling of the spray booth.

Spray booths may be fabricated from metal or plastic. Choice of material depends on local conditions such as labour costs, life expectancy of booth, ease of construction, economics and factory inspectorate regulations. Generally metal booths are used in the UK; sections are easily formed into the required shape and size. They provide a long life and give maximum protection in case of fire.

However, being metallic, the walls and base attract the electrostatically charged powder particles, so that cleaning to remove the powder during change over from one colour or type of powder to another requires some time. Metal booths may reduce the efficiency of electrostatic spray guns, while the chance of accidental electrostatic arcing is increased due to the mass and nearness of metal.

Plastic booths which can be made out of glass fibre, acrylic, polythene or butyrate sheeting offer a more easily cleaned surface since the powder does not adhere as tenaciously on plastic as on a metallic surface.

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3. Spray Booths

Gun efficiency is increased and electrical discharges minimised compared with a metal booth. However they are more expensive and difficult to fabricate than metal. The prime function of a spray booth is to contain and direct the powder that does not adhere to the workpieces and serves as the first step to powder recovery. The movement of controlled air flow through the spray booth is usually accomplished by means of a fan connected to the powder collector.

The size and design of a spray booth is determined primarily by the size and configuration of the parts to be coated and the speed of the conveyor system. Obviously for highly automated plants, experimental work to establish the number of guns, their spacial arrangement along with reciprocation speed and path, powder emission rate and spray patterns, has to be undertaken prior to spray booth design.

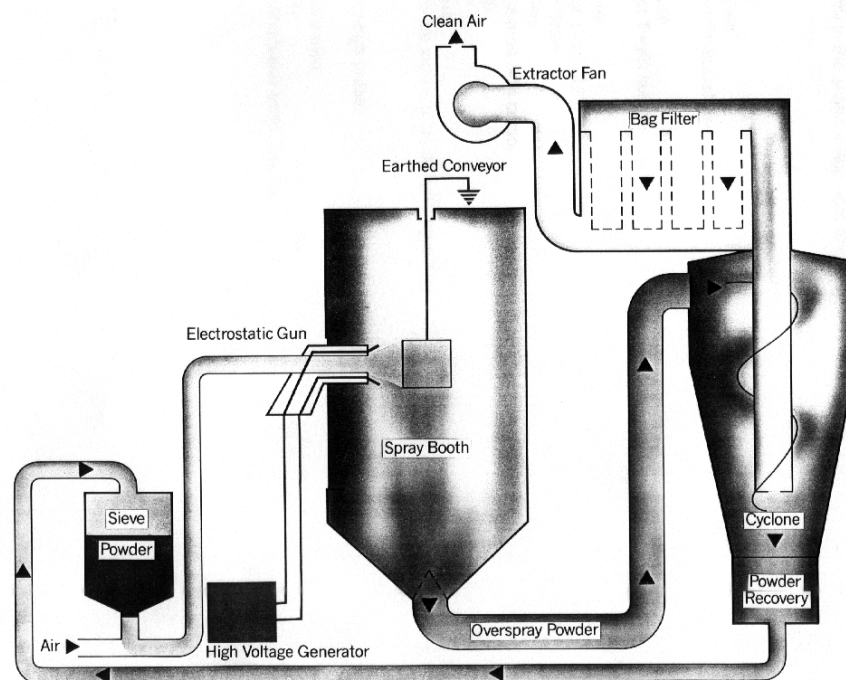
Once the spray booth design has been determined, the extraction fan and collector capacity can be estimated along with piping size and ducting. The powder collector should be situated as close as possible to the overspray powder chamber. This keeps the size of extraction fan required for powder exhaustion from the exit chamber of the spray booth to a minimum capacity and also reduces the cost of ducting.

Usually an air flow of 20 metres per second is sufficient to carry the powder through the recovery system. The air movement within a spray booth can be of several types. In a down draught booth the air is pulled in through all openings and down through a hopper or funnel that covers the entire booth base. The hopper should have straight sides so as not to trap the powder.

In a back-draught booth the air is drawn through a rear set of distribution panels. The air movement causes the powder to flow over the workpiece. However the overspray powder has a tendency to build up on the floor. In some booths a combination of back and floor extraction is used.

In a moving floor recovery booth, the guns and powder charging techniques are conventional but the floor of the booth consists of an endless belt of filter fabric. The powder-laden air is extracted through this belt and the clean air is discharged to atmosphere. The deposited powder is removed from the belt continuously by a vacuum head at the exit from the booth and the powder is recovered by means of a cyclone. The advantage of this system is that much smaller volumes of air need to be handled and the size of the recovery equipment can consequently be reduced.

Figure 3: Powder Application & Recovery



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4. Powder Recovery

The function of a powder recovery system is to collect the overspray material and render it suitable for recycling and at the same time to remove the powder particles from the exhaust air stream before discharge into the atmosphere.

There are two types of collectors:

- Cyclone collectors

- Cartridge collectors

(there are more designs of collection systems which use these two principles).

Cyclone collectors - The input to the cyclone is connected to the booth while the output is connected to a suitable exhaust fan. The overspray powder arrives at the cyclone inlet at a velocity of about 20 metres per second.

On entering the cyclone chamber tangentially the air/powder mixture is given a rotary motion which creates a centrifugal force on the particles. The larger and heavier particles tend to be ejected to the outside walls of the chamber and fall to the bottom where they are collected. The lighter fractions will stay suspended in the air stream which on reaching the bottom is deflected by a conical tail air/powder mix into a rising spiral which is then carried through the central stack to a filter collector.

For a standard powder the recovery efficiency can be as high as 95%. For lines that have a high % of particles $<10\mu$ in the recovered powder the recovery efficiency will be reduced (as low as 85%). Inevitably therefore a cartridge filter is used in conjunction with a cyclone solely to prevent discharge of the fine powder to the atmosphere.

Despite these limitations cyclones are popular for powder recovery, especially if colour changes are involved, as cleaning is comparatively easy compared with cartridge filters. Also in automated systems at high throughput rates, cyclones enable oversprayed material to be collected continuously at the required speed.

An additional advantage of cyclone recovery, with particular reference to colour change, is that due to frictional contact of powder particles, one with another and 'bounce-back', little or no adherence of powder particles occurs on the cyclone wall. This means that in many cases only the powder collection hopper need be thoroughly cleaned between colour changes. In many cyclones cones are removable and substitutes can be made as required if spares are held in stock. The contaminated cone can then be cleaned while the replacement is in operation.

The recovered powder is removed from the cyclone by means of a rotary valve and is then passed through a sieve to remove any agglomerates and foreign matter. The recovered powder is then blended with the virgin material in predetermined proportions.

As cyclone efficiency depends on maintaining a high particle size velocity through the cyclone, the cartridge filter following the cyclone must be designed to maintain the stability of the required velocity throughout the system.

The filter media should permit easy and frequent cleaning. The fabric filters which historically were used collected powder on the inside of the bag which does not fit with high production requirements as the bags have to be periodically cleaned down.

A superior method is to arrange a series of cartridge filters within a metal enclosure so that the powder collects on the outside of the filters and are then cleaned by a reverse compressed air flow which operates about every 30 seconds to provide an air counter current to the powder air flow. The total resistance of this multi cartridge system can be balanced with that of the cyclone so that the cyclone efficiency can be maintained.

Cartridge filters - In this technique the overspray powder from the application booth arrives at an enclosure containing a number of cartridge filters.

Typical filter materials:

- Paper cartridges

- Scinter lamellar (plastic)

- Polyester cloth.

The cartridge filters separate the powder from air by causing the powder/air mix to pass from the outside of the cartridge to the inside through a layer of filter material which retains the powder and allows the air to permeate through and on to the atmosphere.

As filtering continues the retained powder accumulates on the upstream side of the cartridge and forms a powder layer which, being permeable to air flow, increases filtration efficiency albeit at the expense of increased resistance to air flow. This powder layer must be continuously removed to control filter resistance. The retained powder particles are periodically removed from the outside of the filters by reverse air jet blowing. The high speed, high-pressure reversing jets operate for less than 0.2 seconds at 30 second intervals and, because they are applied to only part of the filter for a brief dwell time, they have no practical effect on the main air flow, thus giving a continuous filtration characteristic.

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4. *Powder Recovery*

The powder particles released from the cartridge filter then drop into a hopper to be sieved and returned to the system.

Cartridge filters are extremely effective being up to 99% efficient. The degree of efficiency depends on the type of filter employed and the regularity of its cleaning.

Attached to the material discharge of either cyclone or cartridge filter recovery system must be a dust tight seal, ie. a rotary valve, with which the reclaimed powder can be metered after passing through an inline sieve into the virgin material.

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5. Colour Changing

In any powder coating operation using multiple colour or powder types there is risk of contamination occurring during the change over between powders. It is however possible to minimise this risk using well ordered cleaning procedures.

When performing a colour change the cleaning operation should follow the same route as the powder does when spraying. Therefore cleaning should begin with the hopper followed by the pumps, hoses and guns which in turn are followed by thorough cleaning of the booth enclosure. Clean down is completed by cleaning or changing the recovery system. All cleaning operations using compressed air should be performed inside the booth to ensure that the powder is contained, thus reducing the risk of airborne contamination.

The length of time that colour changing takes can vary widely depending on the plant type and configuration. For operations which require many colour changes to be performed often and swiftly then it may be necessary to have multiple booths. Alternatively most major equipment suppliers now offer booths with polyethylene sheeting walls which are replaced with each colour change to eliminate cleaning of the booth.

Cyclone recovery systems are for the most part self cleaning and require little maintenance.

In the case of cartridge systems it is necessary to colour dedicate cartridge collector units. If many colours are required it may be impractical to use a large number of units.

For more information on plant design, configuration and equipment specification a list of the major suppliers can be provided on request.

Powder Coatings

6. *Safety Considerations*

The main safety hazards involved in the electrostatic application of coating powder are from:

- ✓ dust explosion
- ✓ fire
- ✓ electrical shock
- ✓ exposure to hazardous substances
- ✓ compressed air

Methods for minimizing the risk posed by each of the above are outlined in the booklet:

**“Code of Safe Practice - Application of
Thermosetting Coating Powders by Electrostatic
Spraying”**

published by:

**British Coatings Federation of Great Britain Ltd
James House
Bridge Street
Leatherhead
Surrey
KT22 7EP
United Kingdom
Tel: 44 (0) 1372 360660**

This guidance booklet was prepared in consultation with the Health & Safety Executive and following this guidance will usually be enough to comply with the law.

The powder manufacturer should also supply a Material Safety Data Sheet for each product and the recommendations in this should be followed in conjunction with the Code of Safe Practice.

Powder Coatings

7. *Compressed Air Supply*

Currently all powder coating units utilise compressed air at some stage of the operation. The compressed air should be delivered at 5.6-7.0kg/cm² to the areas of use.

Moisture in air agglomerates powder which reduces the uniformity of the film and causes material wastage. Additionally moisture can cause the powder to adhere and build up on the inside walls of the delivery hose and within the gun. When this occurs powder aggregates will be periodically blown from the gun causing an unacceptable level of unevenness in the cured coating.

Air contains approximately 77% nitrogen, 20% oxygen and 1% inert gases. The balance is made up, depending on environmental circumstances, of water vapour, dust and other particles. Also during compression lubricants, with their allied chemical additives and decomposition products thereof, vaporise during the 150-200°C heat of compression. Obviously when the air is compressed and used for transporting powder material it must be treated to remove these contaminants. It is vitally important that the compressed air supply be scrupulously clean as powders are highly susceptible to pick-up of contamination such as oils or moisture from unclean air.

The first step therefore in moisture and contamination control is to pass the air through an after-cooler which causes the vapour to condense. This removes the bulk of the condensate. Compressed air dryers and/or air line filters are then normally inserted into the compressed air ring main. Also, particularly if the air line is lengthy, draining points are incorporated at regular intervals.

Air should be maintained at a relative humidity of 30-40%. Higher relative humidities could cause the powder to form agglomerates and give rise to 'clogging' (or blockages) in powder feed lines and reclaim filters, as well as causing 'spluttering' of the powder as it is projected from the gun head.

Powder Coatings

8. Ovens

In determining the oven best suited for a particular application, many variables including the product size, shape, thickness, material composition, production throughput, operating cost and type of powder to be used must be considered.

As powders are cured or hardened by resin polymerisation, time and temperatures are critical considerations. Within certain limits a period at a lower temperature may be equivalent to a shorter exposure period at a higher temperature. However it must be emphasised that the curing temperature specified by the powder supplier refers to the article temperature itself and not to the air or panel temperature of an emitter.

Ovens should be designed so that efficient use can be made of production labour and that minimum maintenance is required. Maximum use should be made of fuel and efficient recycle of the hot air maintained where possible.

Temperature should be exactly controlled, if possible within $\pm 3^{\circ}\text{C}$ of the specified curing temperature, by instrumental means. Temperature indicating heads should be situated as near as possible to the path of the workpiece in the oven.

Due allowance should be made for possible extension of the oven and/or possible changes in the type and flow of workpieces being processed.

Care should be taken that air velocities within a forced convection oven should not be so strong as to blow powder off or to move workpieces so that they come into contact with each other during stoving. Air velocities which are acceptable lie in the 1-2 metres/second range.

If the oven has relatively small openings normal exhaust seals will be adequate but with larger openings recirculating types of seals to minimise heat loss should prove effective.

Ovens available to cure powders differ widely using a variety of heating methods.

Convection ovens - This is by far the most popular method where gas or oil-fired heaters are used to heat air which is circulated through an enclosed space where it provides the required temperature. Workpieces are then carried into this space where they absorb heat, reach the surrounding temperature and are held at this temperature for the specified time.

In a direct fired oven, the products of burner combustion are carried directly into the heat holding zone whilst in an indirectly fired oven the burner products pass through a heat exchanger so that only clean air enters the heat holding zone. In the latter case, the hot air is free of combustion products which can in some instances interfere detrimentally with the powder during the curing cycle.

The quantity of air exhausted from a convection oven must be sufficient to keep the atmosphere within the oven below the lower explosion limit of the gases being released in the oven.

Care must be taken, especially in the case of direct fired ovens, to regularly inspect and clean the oven interior as foreign material can build up on the inner oven sections, which can from time to time flake off and adhere to the workpieces which in turn can lead to rejection.

Infra-red ovens - Basically, infra-red heat energy is emitted by a hot body and transferred in straight lines until it makes contact with another body when the heat is absorbed by the latter causing it to rise in temperature. The main advantage of radiant heating is that it produces a rapid rise in object temperature. As the temperature of the heating source is increased, so the proportion of heat transferred by radiation as opposed to convection increases appreciably. The amount of heat energy radiated from any source depends upon its area, its temperature and its emissivity.

Medium temperature radiation offers the most effective source of radiant heat for curing thermosetting powder. Usually the emitter panels are gas-fired giving a panel surface temperature of $850-950^{\circ}\text{C}$, or alternatively sheathed electric panels of a surface temperature of $750-850^{\circ}\text{C}$. The workpiece is maintained at about 30cm from the emitter panel surface with a minimum distance of 15cm.

The colour of the powder is an important consideration - light colours can reflect (depending on powder composition) proportionately more infra-red radiation and do not heat up as quickly as the darker colours. This means that each and every powder must be evaluated to determine the optimum curing conditions.

As radiant heat tracks in straight lines, coated articles of intricate design, or having sections shielded from the radiation source cannot be processed using this method. Ideally infra-red radiation is used for simple workpieces such as relatively flat surfaces.

Powder Coatings

9. *Substrate Pretreatment Prior to Coating*

The main aims in the preparation of a metal surface prior to powder coating may be defined as follows:

- 1) The complete removal of all foreign matter, eg. scale, grease, cutting oil, soil, welding splatter, etc.
- 2) The conditioning of the surface so as to render it suitable for the coating that is to be applied.
- 3) The pretreatment should impart uniformity throughout all treated workpiece surfaces, irrespective of the source of the metal or of the contaminants that might adhere.

As with other methods of organic finishing attention to the pretreatment stage is essential in order to achieve the full potential of the powder coating.

Surface pretreatment may vary depending upon the specific end-use requirements of the finished products - from a single-step cleansing operation to a multi-stage sophisticated pretreatment which deposits a conversion coating on the surface of the metal.

Application of a coating of electrostatically charged particles to an earthed metal surface can only be achieved if the surface is free of any composition which has a high electrical resistance. The presence of any insulating film on the surface of the workpiece to be coated will limit or in some cases prevent powder being deposited.

Substrates - Steel, aluminium, copper, zinc alloys and galvanised steel are common metals on which powder is used. In a number of cases where normal service conditions apply, satisfactory properties can be obtained on thoroughly cleaned metal.

Steel - For iron/steel surfaces maximum corrosion and salt spray resistance are given by a zinc phosphate conversion coating.

Aluminium - For aluminium and its alloys, although the clean surfaces are easily coated and adhesion is excellent, performance can be upgraded using a proprietary chromate conversion coating.

Zinc alloys - With all zinc based substrates such as Zintec, Mazac and Galvanised Steel a suitable phosphate coating is recommended.

Porous castings and 'blast cleaned' surfaces - These surfaces can give considerable difficulty with 'blowing' of the powder coating due to entrapment of air. The profile of the metal and thickness of coating must therefore be strictly controlled. Preheating for a few minutes sometimes overcomes this defect.

Oxide and scale removal - This can be achieved by mechanical scuffing, wire brushing or for larger areas, by abrasive blasting. Sand as an abrasive material has been banned in the UK as well as in many European countries.

The coarse expendable types of abrasive or re-usable metallic abrasives which took over from sand are now augmented by a whole range of ultra-fine abrasives, ranging from 600 mesh fused aluminous oxide (which is as fine as talcum powder), soft vegetable abrasives such as walnut shell and peach stones, through to tiny glass spheres less than 25 μ in diameter. With these extremely fine abrasives a complete surface uniformity can now be achieved. Obviously using a very fine grit the rate of scale removal is rather slow, whereas a too coarse grit will give such a rough surface that the flow of the powder during stoving will be inhibited with consequent loss of gloss accompanied by an extremely rough surface profile.

To provide some idea of the relative surface roughness on a steel surface which has been shot blasted the 'peak to valley' measurement would be about 100 μ . With fused aluminous oxide (grade 180/220) it would be 3-5 μ , while with glass beads it would be 1-1.5 μ .

Oil and grease removal - This is usually the first step in the preparation of metallic surfaces for coating. There are numerous ways of carrying out this operation and some of the more common methods are briefly enumerated below.

Solvent wipe - Grease removal can be achieved by wiping the workpiece with a cloth soaked in a suitable solvent. This method will remove grease and solid matter fairly efficiently until first the cloth and then the solvent become dirty. Thereafter this method will only spread the grease and for really effective cleaning the rags and solvent will have to be replaced frequently. If only loose dust is the contaminant, tack-rags are often used.

Although this method is quick and convenient for small scale production, it suffers from high labour and material costs and, depending on the solvent selected, can be a fire or health hazard.

Solvent dip - With this method the workpiece is immersed in a tank of solvent and after withdrawal, when the solvent has evaporated, all oil and grease should have been removed.

This method remains effective until, like the solvent wipe, contamination has built up in the solvent dip tank and an equilibrium is reached whereby as much oil or grease is redeposited on the work as it takes off. The only difference between the two methods is that this oil is spread over the whole component.

Better results can be obtained by having a number of tanks in line on a cascade principle, but this takes up considerable space and is expensive as solvent losses due to evaporation are high.

Powder Coatings

9. *Substrate Pretreatment Prior to Coating*

Again, depending on the solvent used it can be a health or fire hazard. Neither the solvent wipe or solvent dip methods are recommended.

Solvent vapour degreasing - Using this technique the workpiece is suspended in the vapour of a chlorinated solvent such as trichlorethylene in a specially designed plant and the metal is degreased by the condensation of the vapour on its cold metal surface, which solubilises the oils and grease which run off the parts with the liquid as it returns to the sump.

This is a much more efficient process because the solvent is continuously boiled up to replace the vapour that condenses.

On its own this method will degrease effectively but any solid particles left on the surface may remain there after all the oil and grease has been removed.

Improvements can be obtained by including a boiling liquor stage or by the use of ultrasonic agitation. In addition special additives can be put into the chlorinated solvent to improve efficiency.

Detergent - The workpiece can be dipped into or preferably sprayed with a solution of a suitable detergent in hot water and then rinsed and dried. This will effectively remove light contamination but will not deal with aged oil, grease or heavy soils.

Emulsion cleaners - Emulsion cleaners are usually pre-emulsified kerosene/water emulsions, or kerosene-based concentrates which emulsify when added to water. Like the alkali cleaners, emulsions are most efficient when used in spray equipment but can be quite effective as immersion cleaners in many instances.

Emulsion cleaners normally operate at lower temperatures than the alkali type and in some cases can be used at ambient temperatures.

Alkali cleaners - Again the workpiece can either be dipped or sprayed with a hot aqueous solution of a suitable alkali mixture and then rinsed twice and dried. Spray application is more effective than dipping and is cheaper as higher operating temperatures (70-90°C) and concentrations have to be used with the latter. Spray application varies in time from 5-60 seconds whereas dip takes from 1-5 minutes. Immersion cleaners can disperse the grease and oil by emulsifying them into the solution. Alternatively cleaners are available which separate the oil into a layer so that it can be floated off the cleaner surface over a suitable weir.

Alkali cleaners can effectively remove oil, grease and soils and will cope readily with the heaviest contaminants.

There is a wide variety of alkali cleaners whose properties can be adjusted to give effective cleaning from any set of contaminants. These cleaners often include grain refining agents to ensure that phosphate coatings subsequently applied to steel surfaces have a fine grained crystal structure.

In addition to the alkali the mixtures contain detergents, emulsifiers, sequestering and chelating agents and occasionally water-softening additives.

It should be noted that only under controlled conditions are alkali cleaners suitable for light alloys, zinc, galvanised metal or aluminium which are all attacked by alkali.

Acid cleaning - Acid pickling using either inhibited sulphuric or hydrochloric acid can completely remove rust and scale and can also condition the surface. This method is usually confined to iron or steel surfaces.

It is of paramount importance that when aqueous cleaning methods are employed great care be taken to ensure that subsequent water rinsing is of high standard to ensure that the dried and cleaned components are not contaminated with acid, alkali or emulsion. Also if a conversion coating system does not follow on in sequence the work must be dried rapidly and effectively to prevent rusting of the surface.

Phosphating conversion coatings - The recognised pretreatment for steel substrates just prior to application of powder is phosphating which can vary in coating weight.

The greater the conversion coating weight the greater the degree of corrosion resistance achieved; the lower the coating weight the better the mechanical properties. It is therefore necessary to select a compromise between mechanical properties and corrosion resistance. High phosphate coating weights can give trouble with powder coatings in that crystal fracture can occur when the coating is subjected to locally applied mechanical forces, eg. bending or impact.

Due to the excellent adhesion of the powder coating to the phosphate coating, disbondment will usually occur at the phosphate/metal substrate interface rather than at the phosphate/powder coating interface.

Phosphate coatings are covered by BS3189/1959, Class C for zinc phosphate and Class D for iron phosphate.

A fine grain crystalline zinc phosphate is recommended at coating weights of 1-2g/m² and for iron phosphate at 0.3-1g/m². Application can be made by spray or dip. Chromate passivation is not usually necessary.

Powder Coatings

9. *Substrate Pretreatment Prior to Coating*

Iron phosphate coatings are normally spray applied in a three or four stage operation. The work usually passes through two water rinse sections before drying.

Zinc phosphate can be either spray or dip applied in a five stage operation, ie. alkali degrease, rinse, zinc phosphate, two water rinses.

It is essential that the workpiece after phosphating is powder coated as soon as possible after drying.

Pretreatment for zinc surfaces - A lightweight zinc phosphate coating is recommended. Generally electro-deposited zinc coatings present no pretreatment problems but hot dipped galvanised coating can affect adhesion. Increasing degree of spangle decreases adhesion characteristics.

Chromate conversion coatings - The main conversion coating for aluminium and its alloys is a chromate coating which can be colourless or of the yellow chromium oxide or green chromic phosphate type. The coating weight recommended is 0.1-0.5g/m².

The five stage process normally consists of an alkali degrease, rinse, chromate conversion, followed by two rinses.

Again the chromate coating should be of low film weight for maximum adhesion.

For high quality applications it is usually necessary to employ a final rinse with de-mineralised water. The conductivity of the final rinse bath is then monitored to ensure its cleanliness.

No-rinse systems - One way of avoiding the need for this is to use a dry-in-place or no-rinse process. These are predominantly a form of chromate. It is arguable whether they are true conversion coatings or merely dried-on films with some reaction with the substrate but the advantages of needing no rinse are obvious.

Heavy-metal free pretreatments - The increasingly strict environmental standards in the developed world mean that there is a move away from heavy-metal containing pretreatment, particularly chromate. Early chromate-free pretreatments had poor performance but more recently standards have improved with the first approvals for use on architectural aluminium applications being awarded by the Qualicoat organisation in 1996.

Effluent disposal - Local authorities work to different standards in dealing with effluent discharge. However they are all becoming more stringent and cautious as to what effluent they will accept.

Generally iron phosphate solutions can be passed to drain without treatment, zinc phosphate solutions usually have to be below a specified concentration level which can normally be achieved by diluting in ordinary water.

Some final rinse solutions contain chromate, which requires special treatment because of its toxic effects on marine life.

Powder Coatings

10. Thermosetting Powders

The ultimate success of any powder coating depends not only on the equipment parameters which have already been discussed but also on the nature, composition and condition of the powder.

Currently there is a wide variety of powders to choose from and the final selection will depend on the end use requirement of the coated substrate.

In thermosetting systems, the polymer is generally of a low molecular weight species which melts and flows during fusion and simultaneously undergoes a chemical conversion to a thermoset (cured or cross-linked) condition. Once this condition has been achieved it can no longer be remelted to a plastic condition as is the case with thermoplastic compositions.

The cross-linking reaction occurs in thermosetting powders between the functional (reactive) groups of the resin and those of the curing agent. Obviously to achieve a smooth film the polymer must flow out to a continuous, even film before cure is initiated.

Invariably a powder is a compromise balancing the softening temperature with the melt viscosity or fusion characteristics and the speed of cross-linking. As with solvent-based paints thermosetting powders can be formulated to produce high and low gloss decorative coatings, aluminium, bronze & metallics and textures & hammered finishes.

Powder composition - The basic components required for the manufacture of thermosetting powders are:

- ✓ Polymers
- ✓ Hardener, catalyst, cross-linking or curing agent(s)
- ✓ Flow control additive.

The choice of components will be influenced by:

- ✓ The film properties, such as gloss, colour, hardness, flexibility, adhesion and chemical resistance.
- ✓ Application technique.
- ✓ The curing time and temperature.

Polymers - Solid grades of resin are used for powder coatings. The selection of suitable grades is extremely important as these control properties such as melting point, flow, levelling and film properties. Resins having a softening point between 70-110°C are usually employed. Resins of lower melting point may have a pronounced tendency to 'cake' in the powder form on storage and have such a marked degree of flow on curing that only a low degree of 'sharp edge coverage' is obtained; by contrast, those of higher softening point may have insufficient flow on curing and tend to give an orange peel effect but coverage on sharp edges is good. In addition there is a danger that at the higher processing temperatures required during manufacture the hardener may start to react with the polymer.

Hardener, catalyst, cross-linking or curing agent -

The method of manufacture, application, curing and properties required in the coating all influence the choice of curing agent to be used with the particular type of polymers to be used in the formulation. The hardener should be unreactive at room temperature, remaining latent up to 100°C and should react fully between this temperature and 180°C. The reaction should not be so rapid as to prevent complete flow out of the fused resin but too long a curing time must be avoided because of commercial considerations.

Pigment and extender - Pigments which are currently used in solvent-borne conventional surface coatings may be used for powder coatings, provided they are chemically inert, fast to light and heat resistant.

Titanium dioxide is used virtually exclusively in the manufacture of white, pastel and light tints. Carbon black is used for blacks and greys. For more highly coloured coatings a wide variety of both organic and inorganic pigments are used, although emphasis is now moving onto the organic types as reduction in heavy metals such as lead is made. However, some organic reds have a tendency to react during processing, losing their brightness and cleanliness so careful choice is important to ensure stability. Aluminium and bronze powders are used to give metallic effects.

Certain inorganic extenders can be incorporated in formulations without reducing the gloss, flow or mechanical film properties. The extenders are usually of high specific gravity and although reducing the raw material cost they also adversely affect the area covered by the powder. The true economics of these can only be calculated from assessing the unit area covered per unit of powder. Other extender types can be used to purposefully adjust the gloss level and appearance of the coatings.

Flow control additive - Having selected the appropriate resin/hardener/pigment system, adjustments to the formulation are usually required to modify flow and film properties to suit application and curing conditions.

It is normally essential to incorporate flow control agents for without them powder coatings tend to pinhole, ciss or crater during curing and frequently orange peel effects may appear. The flow control agents reduce the tendency of the resin to ciss by decreasing the surface tension of the system and by promoting flow-out they give smoother films. Acrylic polymers and other resinous materials have been used successfully in this context.

Powder Coatings

10. Thermosetting Powders

Occasionally coatings may tend to flow out too rapidly giving poor 'sharp edge coverage'. To give adequate cover on these parts and to prevent sagging, thixotropic agents such as the organic derivatives of montmorillonite, eg. 'Bentones' finely divided silicas and other extenders may be used. However they have to be judiciously chosen otherwise film properties, such as gloss and colour, may be affected.

Epoxy powders can be formulated to give very high gloss and smooth coatings with excellent adhesion, flexibility and chemical resistance. The main deficiency is a pronounced tendency to yellow at elevated temperatures or when exposed to daylight. In addition, on exterior exposure they chalk rapidly. However film integrity on exterior exposure is excellent. The curing of epoxy powders is an additions mechanism and no volatiles are released during stoving.

Polyester powders have excellent outdoor durability coupled with high resistance to yellowing under ultra-violet light and have to be stoved at extended times and

elevated temperatures compared with epoxies. Their general chemical resistance is somewhat lower than epoxies.

Epoxy-Polyester hybrid powders are a widely used class of thermosetting powders in which the epoxy resin acts as a curing agent for the polyester resin. Depending on the choice of resins and their relative proportions, the properties of the hybrid will lie between those of the pure epoxy and the pure polyester. The presence of the epoxy resin leaves this type of resin susceptible to chalking on exterior exposure.

Polyurethane powders are based on hydroxy-containing polyesters reacted with masked (or blocked) isocyanates. They provide good all-round physical and chemical properties as well as giving good exterior durability.

Table 1 summarises the main difference between the principal thermosetting polymers used in powder coatings.

Table 1: Comparison of Powder Performance Characteristics

| Property | Powder | | | | | | |
|-----------------------|--------------------|--------------------|-----------|-----------|--------------|-----------|-----------|
| | Standard Polyester | Enhanced Polyester | Epoxy | Hybrid | Polyurethane | Acrylic | PVDF |
| Exterior Durability | Good | Excellent | Very Poor | Poor | Good | Excellent | Excellent |
| Corrosion Resistance | Good | Good | Excellent | Good | Good | Good | Good |
| Impact | Excellent | Poor | Excellent | Excellent | Good | Poor | Excellent |
| Flexibility | Excellent | Good | Excellent | Excellent | Good | Good | Excellent |
| Adhesion | Excellent | Excellent | Excellent | Excellent | Excellent | Excellent | Poor* |
| Cost | Medium | Medium/High | Medium | Low | Medium | High | High |
| Film Appearance @ 50µ | Good | Very Good | Good | Good | Excellent | Good | Poor |
| Volatile Emissions | Very Low | Very Low | Very Low | Very Low | Low | Very Low | Very Low |
| Low Bake | Yes | No | Yes | Yes | No | Yes | No |
| Chemical Resistance | Good | Good | Excellent | Very Good | Good | Very Good | Good |
| Gloss Range | 10-95% | 20-95% | 5-90% | 5-90% | 5-95% | 30-90% | 30-60% |
| Heat Resistance | Very Good | Good | Poor | Good | Very Good | Good | Good |
| Abrasion | Good | Good | Very Good | Good | Good | Good | Poor |
| Compatibility | Good | Good | Good | Good | Good | Very Poor | Very Poor |

* Requires a primer

Powder Coatings

11. Powder Manufacture

There are several distinct stages in the manufacture of powder as follows:

Resin size distribution - The resin is first reduced in size by passing through a hammer mill or similar piece of equipment to give particles having a size appropriate to subsequent processing.

Raw material blend - The crushed resin is then blended with the other ingredients to produce a homogeneous mixture.

Extrusion - The mix is then fed into the extruder, the barrel of which is maintained at an exact predetermined temperature. The barrel temperature is set so that the resin is only just liquefied. Too high a temperature will give a low melt viscosity, low shear and poor pigment dispersion which in turn produce coatings of low gloss. The feed rate on the hopper and the speed of the screw are then balanced so that the screw is kept fully loaded. By careful adjustment of these three parameters, conditions of high shear and therefore intimate mixing are maintained within the extruder. The molten extrudate passes between cooling rollers and emerges as a thin sheet which is then broken up into chips of about 10-20mm.

Final grinding - The chips must be subjected to a further grind to reduce them to a suitable particle size or the chosen method of application. For this a pin-disc or hammer mill is employed.

In modern mills an internal classifier is used to limit the maximum particle size, oversized particles being continuously fed back to the mill.

Sieving - This is the final operation in the process, irrespective of the method used to produce the powder.

The optimum particle size of the powder will depend on the method to be used to apply the powder coating.

Powder storage - the powders after final sieving should be stored in tightly closed containers in a dry place so as to prevent possible contamination by environmental fall-out or possible moisture pick-up for, in common with many other finely divided materials, they tend to absorb moisture and this may cause surface defects in the applied coatings. Normally in transit the powder is contained within a polythene bag, suitably sealed, which in turn is contained within a cardboard box or tinplate drum. The polythene bag should therefore be resealed after withdrawing the required amount of powder. For long term storage powder should be maintained at as low a temperature as consistent within the factory area, preferably below 25°C. Powders should be kept away from moving parts as frictional heat will cause the powder to fuse and possibly cure.

Powder Coatings

12. Powder Particles

Particle size - One of the main physical requirements of a powder is that the particle size and distribution should ideally be suitable for the application considered.

As most thermosetting powders are applied by electrostatic spraying, the powder must be receptive to accepting an electrical charge. This must be sufficient for the powder particles to be electrostatically attracted to the surface being coated. The electrostatic charge must be adequate for cover over edges and for 'wrap-around', but the deposit of electrostatically applied powder should not be so insulating as to inhibit film build-up.

The fluidity of the powder is also of particular importance as it must meet various transport demands, eg. from manufacturer to customer, from storage container to storage vessel. Blocking, which occurs when the powder 'cold flows' to form a solid or partially solidified mass, must be avoided at all costs.

Powder fluidity depends upon the shape and size of the particles as well as on their material composition and ambient powder storage conditions.

Under certain adverse conditions such as high ambient temperature some polymerised materials exhibit a tendency to deform, so causing them to block.

The tendency of a powder to be free-flowing depends to a considerable extent on the particle size distribution. At the present time most thermosetting powders are applied by electrostatic spray and most commercial powders would have a particle size within 2-100 μ , with the peak between 30-40 μ . These powders have reasonable flow characteristics. Powders with a wide particle size spectrum are less satisfactory as regards powder recovery than those with a narrow one. The wider the particle size range the more likely is the particle size distribution of the recovered powder to vary in relation to the virgin powder.

Film thickness - The relationship of the powder particle size and ultimate cured film thickness is important. Currently all thermosetting powders consist of irregularly shaped, multi-sided particles of varying size and particle size distribution. Graph 1 illustrates a typical particle size distribution of a commercial pigmented epoxy powder.

Figure 4 illustrates the relationship of powder particle size and film thickness. It can be seen that it would be extremely difficult to obtain a 50 μ powder coating film with particles larger than 50-75 μ , unless the polymer has exceptionally good flow out.

Ideally for the formulation of smooth, non-porous films, the powder should be as densely packed as possible on the surface prior to fusion and cross-linking so that shrinkage and formation of voids, pinholes and orange peel is minimised.

It is generally easier to obtain a smooth film with a narrow particle size band distribution, especially at low particle size cuts, eg. 10-20 μ , than it is at wider or higher particle size distribution. However, powder of the lower particle sizes have to be specially formulated to apply using existing spray application equipment.

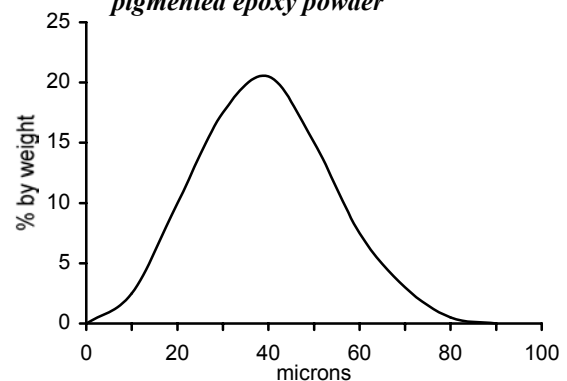
Because of these factors, the melt-flow index and rate of cure of the powder are critical properties in achieving surface smoothness and maintaining adequate edge cover.

Obviously therefore the powder particle size, shape and size distribution influence the quality and appearance of the resultant powder coating. Smaller particle sizes accept a higher charge relative to their weight than larger particles. The attractive force between the charged particle and the workpiece being coated is therefore greater, which usually leads to preferential deposition and wrap-around with smaller particle size.

However because of the Faraday cage effect the smallest particles are less apt to penetrate down into openings and recessed areas.

Coating thickness can be increased by preheating the workpiece as recorded in Table 2. Table 3 summarises the basic difference between fine powder (10-40 μ) and a coarse powder (50-100 μ).

Graph 1: Typical particle size distribution of pigmented epoxy powder



Powder Coatings

12. Powder Particles

Figure 4: Relationship of Particle Size to Fused Film Thickness

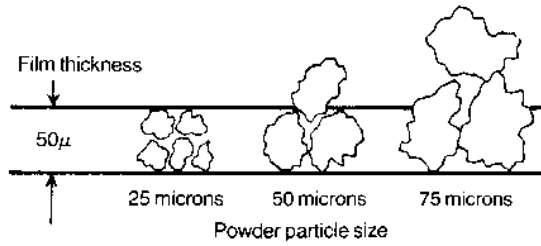


Table 2

| Temperature (°C) | Film Thickness (μ) |
|------------------|--------------------|
| Ambient | 25-125 |
| 50 | 125-150 |
| 80 | 150-225 |

Table 3

| Powder | Fine | Coarse |
|-------------------------------|--|--|
| Dry flow | Controllable | Excellent |
| Package stability | Controllable | Good |
| Moisture sensitivity | Higher | Lower |
| Fire/Explosive hazard | Slightly higher | Slightly lower |
| Ease of spray application | Controllable | Excellent |
| Efficiency of powder recovery | ~95% | >95% |
| Film thickness | Easier to produce opaque thin films | Difficult to produce films lower than 40μm |
| Film appearance | Better levelling. Less orange peel. Higher gloss possible. | Poor appearance at lower film thicknesses |
| Coverage per kg | Higher | Lower |

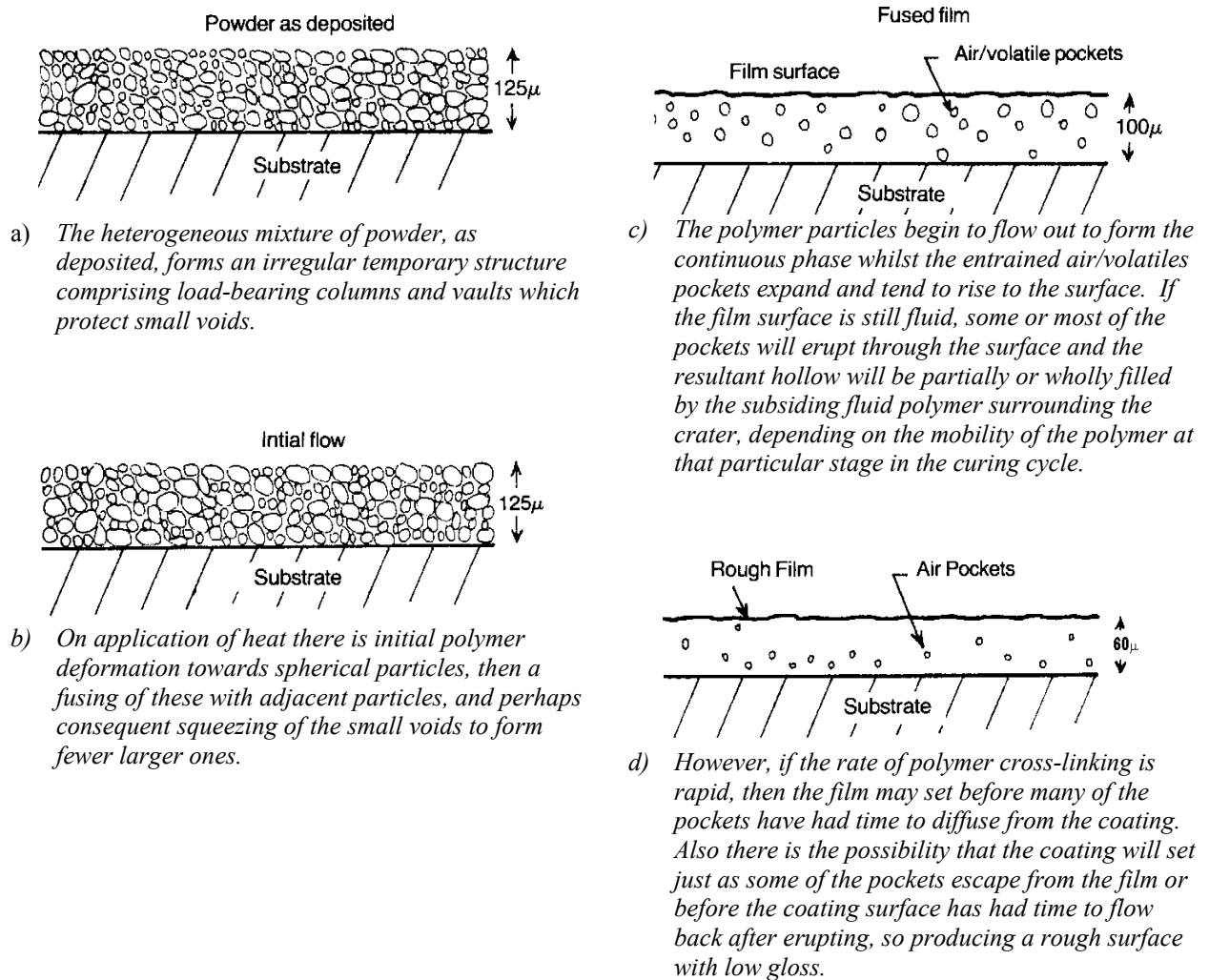
Powder Coatings

12. Powder Particles

Film formation - The mechanism of film formation can be visualised as a transition from the 'as applied'

powder to the cured coating in the sequence shown in Figure 5.

Figure 5: Mechanism of Film Formation of a Powder



Powder Coatings

13. Economics of Powder Coating

How often is the question asked 'Is powder coating more equal to or less expensive than finishing with solvent based industrial paint?' The viability of the process must be based initially on the technical merit of the process in relation to alternative finishing techniques.

Each and every case must be independently assessed as there are so many factors to consider when deciding the economics. Some of these factors can be detailed as

costs but others are aesthetic which will appeal to trade unions, operators and plant managers.

In the following 'Check List' table a basic production line has been broken down into sections. In most instances costs relating to these sections can be acquired, even if not readily available.

Considerations of costs should be shown as:

1. Capital investment
2. Production costs
3. Material cost per unit area of production.

| Process Requirements | | Solvent-based Paint | Powder |
|---|------------------------|---------------------|--------------|
| Pretreatment | Number of stages | | |
| | Chemical type | | |
| | Passivation | | |
| | Drying oven | | |
| | Cooling before coating | | |
| Spray booth(s) | | | |
| Spray gun(s) | | | |
| Powder recovery system | | Not Required | |
| Paint overspray treatment | | | Not Required |
| Solvent extraction | | | Not Required |
| Make-up air for application area | | | Not Required |
| Paint make-up room | | | Not Required |
| Paint recirculation system | | | Not Required |
| Compressed air supply | | | |
| Flash-off zone | | | Not Required |
| Stoving schedule | | | |
| Stoving oven | | | |
| Conveyor system | | | |
| Floor area required for total coating line | | | |
| Floor area required for raw material storage | | | |
| Labour costs on operation | | | |
| Labour costs on routine maintenance | | | |
| Labour costs on full maintenance | | | |
| Labour costs on maintaining paint viscosity | | | None |
| Down time and labour costs in changing colour (if applicable) | | | |
| Cost per kg/litre of powder/paint | | | |
| Number of applications to achieve required coating thickness | | | |
| Coverage/unit area/at required film thickness | | | |
| Cost of coating/unit area | | | |
| Cost of coating rejects | | | |
| Cost of packaging coated workpieces | | | |

Essential data requirement for cost comparisons -
The three main considerations which influence the adoption of powder coatings for finishing are:

1. Economic - cost saving
2. Pollution avoidance
3. Superior coating performance.

Normally it is the economic advantage which decides the final issue the other 2 factors being bonuses. It is important when calculating the cost of powder coatings to look at cost/m² rather than cost/kg (see tables 4 & 5).

These tables are based on 100% utilisation of powder and corrections must therefore be made for some powder losses during application. On a typical powder coating line the amount of powder which applies to the areas where it is required is 70-80%. The other 20-30% are losses such as:

- ✓ Coating jigs
- ✓ Wrap around
- ✓ Escapes from booth
- ✓ Losses to final filter

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Table 4: Coverage Calculator m^2/kg (100% efficiency)

| Specific Gravity | Film Thickness (μ) | | | | | | | | | | |
|------------------|--------------------------|------|------|------|------|------|------|------|------|-----|-----|
| | 30 | 35 | 40 | 45 | 50 | 60 | 70 | 80 | 90 | 100 | 125 |
| 1.0 | 33.3 | 28.6 | 25 | 22.2 | 20 | 16.7 | 14.3 | 12.5 | 11.1 | 10 | 8 |
| 1.1 | 30.3 | 26.0 | 22.7 | 20.2 | 18.2 | 15.2 | 13.0 | 11.4 | 10.1 | 9.1 | 7.3 |
| 1.2 | 27.8 | 23.8 | 20.8 | 18.5 | 16.7 | 13.9 | 11.9 | 10.4 | 9.3 | 8.3 | 6.7 |
| 1.3 | 25.6 | 22.0 | 19.2 | 17.1 | 15.4 | 12.8 | 11.0 | 9.6 | 8.5 | 7.7 | 6.2 |
| 1.4 | 23.8 | 20.4 | 17.9 | 15.9 | 14.3 | 11.9 | 10.2 | 8.9 | 7.9 | 7.1 | 5.7 |
| 1.5 | 22.2 | 19.0 | 16.7 | 14.8 | 13.3 | 11.1 | 9.5 | 8.3 | 7.4 | 6.7 | 5.3 |
| 1.6 | 20.8 | 17.9 | 15.6 | 13.9 | 12.5 | 10.4 | 8.9 | 7.8 | 6.9 | 6.3 | 5 |
| 1.7 | 19.6 | 16.8 | 14.7 | 13.1 | 11.8 | 9.8 | 8.4 | 7.4 | 6.5 | 5.9 | 4.7 |
| 1.8 | 18.5 | 15.9 | 13.9 | 12.3 | 11.1 | 9.3 | 7.9 | 6.9 | 6.2 | 5.6 | 4.4 |
| 1.9 | 17.5 | 15 | 13.2 | 11.7 | 10.5 | 8.8 | 7.5 | 6.6 | 5.8 | 5.3 | 4.2 |
| 2.0 | 16.7 | 14.3 | 12.5 | 11.1 | 10 | 8.3 | 7.1 | 6.3 | 5.6 | 5 | 4 |

Table 5: Powder Cost per m^2 ($\text{£}/m^2$)

| Coverage m^2/kg | Powder Price ($\text{£}/kg$) | | | | | | | | | | |
|-------------------|--------------------------------|------|------|------|------|------|------|------|------|------|------|
| | 2.00 | 2.50 | 2.75 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 | 5.50 | 6.00 | 6.50 |
| 30 | 0.07 | 0.08 | 0.09 | 0.10 | 0.12 | 0.13 | 0.15 | 0.17 | 0.18 | 0.20 | 0.22 |
| 28 | 0.07 | 0.09 | 0.10 | 0.11 | 0.13 | 0.14 | 0.16 | 0.18 | 0.20 | 0.21 | 0.23 |
| 26 | 0.08 | 0.10 | 0.11 | 0.12 | 0.13 | 0.15 | 0.17 | 0.19 | 0.21 | 0.23 | 0.25 |
| 24 | 0.08 | 0.10 | 0.11 | 0.13 | 0.15 | 0.17 | 0.19 | 0.21 | 0.23 | 0.25 | 0.27 |
| 22 | 0.09 | 0.11 | 0.13 | 0.14 | 0.16 | 0.18 | 0.20 | 0.23 | 0.25 | 0.27 | 0.30 |
| 20 | 0.10 | 0.13 | 0.14 | 0.15 | 0.18 | 0.20 | 0.23 | 0.25 | 0.28 | 0.30 | 0.33 |
| 16 | 0.13 | 0.16 | 0.17 | 0.19 | 0.22 | 0.25 | 0.28 | 0.31 | 0.34 | 0.38 | 0.41 |
| 13 | 0.15 | 0.19 | 0.21 | 0.23 | 0.27 | 0.31 | 0.35 | 0.38 | 0.42 | 0.46 | 0.50 |
| 10 | 0.20 | 0.25 | 0.28 | 0.30 | 0.35 | 0.40 | 0.45 | 0.50 | 0.55 | 0.60 | 0.65 |
| 8 | 0.25 | 0.31 | 0.34 | 0.38 | 0.44 | 0.50 | 0.56 | 0.63 | 0.69 | 0.75 | 0.81 |
| 6 | 0.33 | 0.42 | 0.46 | 0.50 | 0.58 | 0.67 | 0.75 | 0.83 | 0.92 | 1.00 | 1.08 |
| 5 | 0.40 | 0.50 | 0.55 | 0.60 | 0.70 | 0.80 | 0.90 | 1.00 | 1.10 | 1.20 | 1.30 |

Example: Table 5

Powder Price $\text{£}2.75$ per kg
 S.G. 1.5
 DFT 50μ
 Coverage (100% utilisation) $13.3m^2/kg$

Example: Table 6

Coverage $13.3m^2/kg$
 Powder Price $\text{£}2.75$ per kg
 Cost $\text{£}0.21/m^2$

Powder Coatings

14. Testing Procedures

There are certain specific tests for powder and for the cured coating. The powder as delivered to the end user cannot be adjusted as with a solvent based paint and therefore extremely strict quality control must be exercised by the powder manufacturer during all stages of the manufacturing process. This will ensure that all powders are of a consistent high quality. There are a number of general test procedures on powders and coating performance which are applicable to all powders in addition to those special tests required for specific customers to meet particular conditions.

Powder Test Procedures

Particle size distribution - There are a number of techniques which can be utilised to determine particle size distribution. These vary widely and because thermosetting powder particles are of irregular shape and size different results between the various techniques arise. However, for practical purposes, these differences need not be regarded as of major significance at the present time.

Sieve analysis

This is the simplest, most versatile and fastest technique and does not require highly skilled personnel nor calculations. It can separate broad fractions quickly and for thermosetting powders appears adequate at present for providing the powder in 'cuts' appropriate for the application method.

In the simplest form a series of sieves, of different sieve meshes, set in an automatic shaker can be used. However, this has limitations especially with fine powders in that the fine meshes tend to become blocked extremely quickly.

An air-jet sieve in which an air-jet is used to 'blow' the powder on the sieve mesh, can separate the powder particles rapidly and keep the mesh from blinding up (becoming blocked).

The Alpine air-jet sieve can be used to determine the particle size distribution using sieves which can give particle size cuts from 125 μ to 10 μ .

Sedimentation techniques

These include the Andreasen pipette, Backman and Shimadzu sedimentation balance and photosedimentometer. All these techniques involve dispersion of powder in a liquid, usually water containing a percentage of a powder wetting or dispersing agent and allowing the powder particles to settle out over a time period.

As the powder particles settle out a trace records the weight over this time. From the trace recorded on a graph as the particles settle out the particle size distribution can be calculated.

Coulter counter

In this method a dilute dispersion of powder particles in an electrolyte is made to pass through a narrow orifice. The change in electrical resistance of the electrolyte as the particle passes is used to estimate the volume of the particle.

The figure derived is the equivalent spherical volume and the method gives no guidance as to the shape of the particle.

Laser light diffraction techniques

In this method a sample of powder suspended in an air stream is passed across the path of a laser light beam. The angle(s) at which the beam is diffracted from a particle is determined by its diameter. The diffracted beams impinge on a series of concentric sensors. The energy absorbed by each of these sensors is fed to a computer which gives a print-out of particle size distribution.

Powder dry flow - This, as stated previously, is important in the handling and transport of the material through the powder feed lines during application and recovery. To a certain extent this is dependent on the particle size distribution of the powder but other factors such as the resin characteristics, pigment & extender loadings and other additives can have a pronounced effect. There are several methods of determining the flow characteristics of a powder:

Angle of repose

This method entails allowing a quantity of powder to fall on to a horizontal collecting plate to form a cone. The angle assumed by the side of the cone is an indication of the dry flow characteristics of the powder.

SAMES flowmeter (method Afnor)

This consists of a fluidising bed in the form of a vertical transparent plastic cylinder. In the side of the cylinder is a small outlet which can be closed by means of a plug. Dry compressed air can be fed through the fluidising plate at a controlled rate and pressure. A sample of the test powder (250g) is introduced into the cylinder and the air supply switched on. The height to which the powder rises is measured; the air supply is switched off and the powder allowed to settle and stabilise and the height is again measured. The air is again switched on and during the fluidisation the plug removed for 30 seconds; the powder escaping through this orifice in this time is collected and weighed.

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14. Testing Procedures

If h_1 = Fluidised height of powder
 h_0 = Settled powder height
 m = Mass of powder collected in 30 seconds
then the index of fluidisation, r , is given by:
$$r = (h_1 \div h_0) \times m$$

The index of fluidisation can give a guide to the dry flow characteristics of a powder but the results should be treated with caution.

Powder storage - It is important that the powder should not cake or form lumps during bulk storage especially when subjected to warm conditions. Nor should chemical reaction between resin and curing agents proceed during storage otherwise the application properties, flow and gloss can be affected.

Storage tests are usually carried out by placing a known amount of powder in a container and storing containers over a given period in an oven maintained at a constant temperature (in the range 30-40°C). It is usual to apply a weighted disc, eg. 100g, to the surface of the powder during the test. No blocking, caking or change in reactivity of the powder should be in evidence after 1 month's storage under these conditions.

Moisture content - This can influence the blocking and dry flow characteristics of the powder.

1. The simple direct method of determining moisture content is to heat a small, weighed quantity of powder in an oven at 105°C to constant weight. Unless the powder is spread in a thin uniform layer, this method can give very inaccurate results owing to entrapment of volatiles.
2. An alternative method is to dry a weighed amount of the powder for 8 days in a desiccator over phosphorus pentoxide, then re-weigh.

Mass loss on heating - A known weight (ca. 0.5-1.0g) of powder is heated at 200°C for 15 minutes and allowed to cool in a desiccator. The weight loss is calculated as a percentage of initial powder weight. This mass loss may be significant in the case of powders where volatile materials are evolved, eg. caprolactam in the case of polyurethanes.

Specific gravity - This is vital in order to calculate the covering power of the powder and hence the actual coating cost per unit area covered at a given film thickness.

Two methods for its determination are available:

- ✓ Displacement of a non-solvent liquid of known specific gravity.
- ✓ Gas pycnometer.

Displacement method

An analytical balance, 500cm³ measuring flask, petroleum ether and a sample of powder are required to carry this out and the following procedure should be used:

The sample of powder, say 50g, is weighed out into a 500cm³ measuring flask of known weight and the volume made up to the mark with petroleum ether. If the contents of the full flask weigh, say 378g, the weight of the petroleum ether is calculated by deducting the weight of the powder, ie. 378g less 50g = 328g. If the specific gravity of the petroleum ether is measured as 0.7, its volume can now be calculated as follows:

$$\text{Volume} = \frac{\text{weight}}{\text{specific gravity}} = \frac{328}{0.7} = 468.8\text{cm}^3$$

It then follows that the powder in the slurry has a volume of 31.2cm³ (ie. 500cm³ less 468.8cm³). The specific gravity of the powder is therefore given by:

$$\text{SG} = \frac{50}{31.2} = 1.6$$

However, the above method is not wholly satisfactory. For many modern powders it is very difficult to find a liquid which will sufficiently displace the air from the powder without exerting some solvent effect.

Gas pycnometer

This is a much more accurate and rapid method. This is a specialised piece of apparatus which can operate with either air or helium although the air-operated version is much cheaper and adequately accurate. The apparatus measures directly the volume of air displaced by a known weight of powder and the test takes only 2-3 minutes to perform.

Gel time - The gel time of a powder is useful as an indication of:

- ✓ Curing speed.
- ✓ Consistency of powder quality.
- ✓ Chemical instability on storage.

A marked reduction in gel time after the storage test outlined above would indicate that reaction in the powder had occurred, which would have an adverse effect on the applied powder film.

The apparatus used for determining the gel time consists of a heating block which can be maintained at the required temperature (usually 180-200°C) to an accuracy of ±1°C. A small quantity (ca.0.25g) of powder is placed in the centre of the heated plate and a stop-clock started. The molten mass is manipulated with a small wooden spatula. When threads can no longer be pulled from the mass with the spatula, the elapsed time is recorded as the gel time.

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14. Testing Procedures

Ash content - A sample of powder is weighed out into a porcelain dish which is placed into a cold furnace which is gradually heated to calcining temperature. (Heating should be slow so that no powder escapes at the beginning with the entrapped air). After cooling, the dish is re-weighed.

Other quality control procedures - These include infrared spectroscopy and differential scanning calorimetry. Both these methods are valuable in monitoring powder quality.

Cured coating procedures - As with solvent-based industrial paints, the cured coating of each production batch must be checked for a wide range of characteristics before despatch to end user.

For **Interpon** thermosetting powders, three types of substrates are generally employed, depending on the test requirements:

- Untreated steel
 - Lightweight iron phosphated steel
 - Lightweight zinc phosphated steel
- (Panels are available from proprietary suppliers))

The powder is spray applied electrostatically and cured at the appropriate temperature for the specified time at a controlled film thickness.

The usual tests conform to BS3900. For specific applications, eg. architectural aluminium extrusion, tests must conform to BS4842. Very often end users issue their own test specifications.

Information relating to methods of determination of particle size of powders can be obtained from:

- BS410 Test sieves
- BS2955 Glossary of terms relating to powders
- BS3483 Methods for testing pigments for paints

Methods for paint testing can be obtained from BS3900, 'Methods of Test for Paint'.

Powder Coatings

15. Troubleshooting

Powder Application Problems

| Trouble | Possible Causes | Solution |
|--|---|--|
| Poor charging - inadequate powder film thickness or poor coverage | High voltage source not providing enough KV at charging electrode | a) Check if high voltage source is on. Systematically check continuity from voltage source to electrode, including cable, resistors and fuses. b) Replace missing or broken electrode. c) Clean electrode insulated by powder build-up or impact fusion. |
| | Poor Ground | Check ground from conveyor rail (or rub bar when used) through hanger to part. All contact areas must be free of powder build up, heavy grease and other insulating materials. |
| | Powder delivery rate is too high | Reduce powder delivery rate until material is adequately charged. |
| | Excessive moisture in powder booth air | Moisture in humid air will tend to dissipate the charge on the powder particles. Control the humidity in the powder spray area. |
| | Powder too fine | a) Maintain consistent blend of virgin and recycled powder. b) Check particle size of powder. Contact your powder supplier. |
| | Powder type or formula | Some powder formulations charge better than others and some formulas are designed for thin film application. Contact your powder supplier |
| | Powder delivery air too high. Powder blowing by part. | Turn down air setting or move gun position farther away from part. |
| Poor penetration - powder will not coat Faraday cage area (holes, grooves, channels, inside corners & recesses) | Powder delivery too low | Turn up powder delivery air settings. |
| | Poor ground | Check ground. Refer to 'Poor ground' above. |
| | Incorrect powder spray pattern | a) Adjust powder spray pattern b) Try alternative nozzle selections. |
| | Voltage too high | Turn voltage setting down so that surfaces closer to gun do not repel powder from corners. |
| | Powder delivery velocity too high | Turn air setting down so powder air stream does not blow powder into corners. |
| | Poor gun placement | Adjust gun position so powder cloud has a direct path to recessed areas. |
| Back ionisation - powder layers are repelled from part | Voltage too high | Turn down voltage settings. |
| | Gun positioned too close to part. | Change gun placement farther away from part. |
| | Poor ground | Check ground. Refer to 'Poor ground' above. |
| | Excessively heavy powder build up | Refer to 'Powder delivery rate is too high' above. |
| Powder feed surging or spitting - interrupted powder feed | Insufficient air pressure or volume | Check air supply. Determine if air supply piping to equipment is large enough. Enough air volume must be provided so that air pressure to powder feed does not drop. |
| | Hoses, kinked, flattened or too long | Check powder feed hose routing & condition. Refer to 'Obstruction of powder delivery system' in 'Powder Supply Problems' section on page 30. |
| | Hoses, powder pumps or suction tubes | a) Clean hoses, powder pumps & guns. b) Check air supply for moisture. c) Check powder delivery settings. d) Check coating area relative humidity & temperature. e) Check powder delivery system for vacuum leaks. |
| | Incorrect powder delivery | a) Check powder delivery settings. b) For low powder delivery rates, increase powder transport air function settings. c) Replace powder hose with smaller diameter hose. |
| | Incorrect feeder hopper fluidising | a) Adjust fluidisation air pressure. b) Check porous fluidising membrane for clogging or defects. c) Refer to 'Powder fluidisation/air blowing large holes through powder surface' in 'Powder Supply Problems' section on page 30. |
| | Low powder level | Add powder |

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15. Troubleshooting

Powder Supply Problems

| Trouble | Possible Causes | Solution |
|---|---|--|
| Poor blowing out of hopper | Fluidisation air pressure too high | Adjust air regulator to lower pressure to fluid bed. |
| | Insufficient hopper ventilation | a) Check hopper vent for plugging. b) Check vent assist device for obstruction and proper air supply. |
| No air percolating through powder surface | Insufficient air pressure | Check hopper fluidisation air supply. Increase air pressure as required. |
| | Plugged membrane | Check membrane for plugged pores from dirty or oily air supply. |
| | Obstructed membrane | Check bottom of hopper for obstructions. |
| | Compacted powder on membrane | Manually loosen powder and fluidise well with clean, dry air. |
| Poor fluidisation/air blowing large holes through powder surface | Powder level too low | Add powder until hopper is filled to proper level. |
| | Packed or moist powder | a) Manually loosen powder and fluidise well with clean dry air. b) Check compressed air and booth air for high humidity or oil content. c) Powder sieving may be required. |
| | Obstructed membrane | Check bottom of hopper for obstructions. |
| | Plugged or broken membrane | a) Check membrane for plugged pores or oil contaminated air supply, cracks or holes. b) Check for proper seating of membrane/leaking around edges. |
| | Powder particle size | a) Maintain consistent blend of virgin & recycled powder. b) Check particle size of powder in hopper. |
| | Insufficient fluidising characteristics of powder | Contact your powder supplier. |
| Plugged hoses and/or powder pumps from impact fusion build up | Normal build up | Clean or replace parts. |
| | Air pressure too high | a) Reduce powder hose length. b) Turn down air settings on pumps & guns. |
| | Moisture in air supply | Check air supply for clean, dry oil free air. |
| | Composition of powder feed hoses | Check hoses. Contact your equipment supplier. |
| | Worn powder pumps and worn parts | Replace all worn parts. |
| | Powder particle size | a) Maintain consistent blend of virgin & recycled powder. b) Check particle size of powder in hopper. Contact your powder supplier. |
| | Powder type or formula | Some powder types are more susceptible to impact fusion. Contact your powder supplier. |
| | Kinked or flattened hoses | a) Avoid sharp bends and restrictions in the hose. Protect hoses from external abrasion & abuse. b) Replace if permanently deformed. |
| | Powder hose too long or has too many sharp bends | Reduce powder hose length, modify hose runs. |
| Insufficient powder feed | Powder not fluidising | Refer to 'No air percolating through powder surface' & poor fluidisation/air blowing large holes through powder surface' above. |
| | Obstruction of powder delivery system | a) Check suction tubes, powder pumps, hose & gun. b) Check air supply. Adjust air settings to pump & guns. c) Check powder supply for contamination. |
| | Powder hose too long or has too many sharp bends. | Reduce powder hose length; modify hose runs. |
| | Low air pressure | Check air supply. Adjust air settings to pump and guns. |

Powder Coatings

15. Troubleshooting

Booth & Recovery Equipment Problems - General

| Trouble | Possible Causes | Solution |
|---|---|--|
| Part surface contamination | Powder or contamination falling in spray booth from conveyor or hangers | Clean conveyor regularly for continuously before it enters powder spray booth. Strip hangers as needed. |
| | Contamination from parts entering spray booth | Check cleaning and pretreatment equipment for proper operation. Ensure proper part drying before part enters spray booth. |
| | Contamination from plant air circulated through spray booth | Isolate spray booth area. Preferably enclose in a room with filtered humidity controlled air. Maintain positive pressure in coating room. Inspect nearby operations as possible contamination sources; correct as necessary. |
| | Contamination from compressed air supply | Check compressed air supply system. |
| | Powder sieve screen torn, missing | Replace sieve screen. |
| | Inoperable powder sieve | Repair sieve or sieve control circuitry or replace if necessary |
| Poor powder containment. Inadequate air flow through spray booth | Primary filter media binding | a) Clean or replace filter media as required. b) Check ambient air humidity in coating area. c) Check filter media air pulse operation. d) Check for moisture/oil in compressed air supply. |
| | Final filters clogged | Check primary filter media for powder leakage. Service, repair or replace as needed. |
| | Use of compressed air for booth cleandown | Refer to operations manual for proper cleaning procedures. |
| | Improper powder gun placement/alignment | Correct as necessary, position guns away from openings. |
| | Room draughts leading to powder drifting from booth. | Map airflow in powder booth area. Minimise draughts to eliminate powder drift. |
| | Blocked airflow | a) Check air volume control damper adjustment. b) Check fire safety device for proper operation. |
| | Inadequate blower operation | Check for proper operation. |
| Cross contamination of recycled powder | Inadequate booth/recovery equipment cleaning | Clean equipment per equipment supplier recommendations. |
| Booth Turbulence | High powder containment air velocity | Contact equipment supplier. |
| Powder recovery percentage below equipment specification | Insufficient air volume/velocity | Refer to 'Poor powder containment. Inadequate air flow through spray booth' above. |
| | Poor system seals | Verify and correct any air leaks. |
| | Too high a percentage of powder fines | Contact your powder and equipment suppliers. |