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1 - INTRODUCTION

1.1 The Purpose of this Guide

This guide has been produced to educate anyone involved in the day to day use or production of Thermal Sprayed Coatings. It is intended to give advice on best practice and ensure that coatings produced are of the highest standards achievable.
In a document of this type it is impossible to deal with every one of the thousands of coating permutations and combinations that can be produced. The sound practices that are described should help ensure that the end user of the coating is satisfied with his purchase and with its method of production.

1.2 History of Metallisation

Metallizing was first invented in 1910 by Dr Schoop in Switzerland. His first work was carried out by spraying heated metal powder. It was not long before he developed a wire pistol which was the prototype of our present Flamespray Pistols.

Metallisation Ltd was founded in 1922 by a consortium of British Engineers who set up and purchased the rights to the metal spraying process from Dr Schoop. The new company offered a sub-contract service, spraying zinc onto structural steelwork as an anti-corrosion coating.

In 1938 Metallisation came out with its own equipment - the Mark 16 Flame Spray System, which also enabled its contracting service to offer engineering coatings for reclamation applications.

By 1950 an equipment sales division was set up and in 1965 Metallisation produced its first Arcspray System, Acrspray 200.

In 1970 Metallisation Service Limited and Metallisation Limited, as the equipment division was now called, were sold to Cooper Industries, which in turn created a ready made outlet for zinc wire produced by Charles Clifford Limited, another Group Company. Through sustained growth both companies prospered, Metallisation Limited began to export equipment and materials.

In 1979 Metallisation Limited, Metallisation Service Ltd and Charles Clifford

Ltd sold to newly formed holding company, Charles Clifford Industries Ltd. This period saw the contraction of the contracting business and an increase in the equipment manufacturing arm of the group.

In 1981 a new holding company was formed called the Telfos Group. The Contracting service was reduced to one outlet on West Midlands site. During the next ten years Metallisation Limited became accepted in export markets as a leading player.

In December 1991 A successful Management Buy Out of the three businesses was completed through Metallisation Industries Limited, the new holding company. Each of the directors and senior managers involved had an average of 14 years experience and association with the three companies concerned. An essential aspect of the Management Buy Out criteria was that the Company was well funded and operated from a sound financial base.

Since 1991 new equipment has been developed which now cover all aspects from Wire Flamespray, Arcspray, Powder Flamespray, Plasma to High Velocity Oxygen Fuel.

2 - NATURE OF THERMAL SPRAYED COATINGS

2.1 What is a THERMAL SPRAYED COATING ?

Molten spherical particles of metal, ceramic, carbide or blends of these materials are sprayed onto a previously prepared surface where the particles flatten out and instantaneously cool.

The material being sprayed is either in wire or powder form and can be melted and sprayed in one of four different types of heat source:-

Flamespray (wire and powder)
Plasma (powder only)
Arc (wire only)
High Velocity Oxygen Fuel (powder only)

Despite the heat source temperatures varying from 3000 to 15000 degrees centigrade and the melting temperatures of the materials being sprayed, Thermal Spraying can be defined as a cold working process. The component being sprayed will normally never reach 15^{0}C except when applying fused coatings when fusing temperatures in excess of 70^{0}C are experienced.

In general, coatings are harder and contain varying percentages of porosity and oxides in comparison with similar wrought materials.

2.2 Porosity

Inherent in coatings applied by thermal spraying techniques are small pores or voids termed porosity. Their size and distribution within a coating will depend upon the material being sprayed and the process used.

Generally, for Flamespray wire and arc sprayed coatings porosity represents approximately 10% to 15% of the coating volume. In comparison using a very fine type powder via the plasma process, porosity levels can be reduced to less than 1%.

The porosity within the coating can be an advantage in certain applications where lubrication is essential but a problem in corrosive environments or where coatings are used where a seal is required. However various sealing techniques may be employed to eliminate this phenomenon.

2.3 Oxides

During the spraying process the passing of molten particles from the gun to the substrate will oxidise to varying degrees depending upon the heat source, spray distance and particle velocity. Oxidised particles cement together to improve coating integrity and will give an increase in hardness and hence wear resistance.

Special techniques involving spraying under inert atmospheres have been employed to reduce oxide content in specialised applications.

2.4 Bond

The bond to the base material should be considered to be primarily mechanical and occasionally metallurgical, depending upon the material being sprayed, the process used and the base material. For instance, coatings applied by the Powder Flamespray Process which are subsequently fused at red heat temperatures have a full metallurgical bond. In contrast low melting point alloys such as zinc or aluminium applied to plastics bond only mechanically.

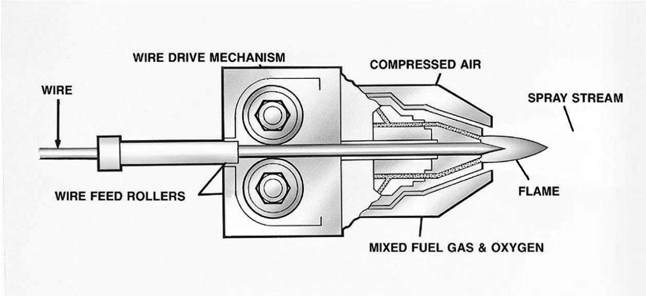
Special bond coat materials containing Nickel Aluminium undergo an exothermic reaction when sprayed creating a metallurgical bond (primarily on ferrous substrates). At a local level the temperature rises to the melting point of the substrate and cause a diffusion bond.

In general the higher the temperature and velocity of the sprayed material, the better the bond.

3 - THERMAL SPRAY PROCESS

3.1 Flamespray

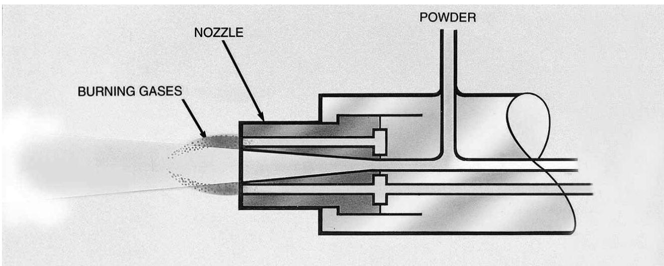
I) Wire



In the Wire Flamespray process, the raw material in the form of a single wire or cored wire, is melted in an oxygen-fuel gas flame. This molten material is atomised by a cone of compressed air and propelled towards the workpiece.
The molten spray solidifies on the component surface to form a dense, strongly adherent coating.

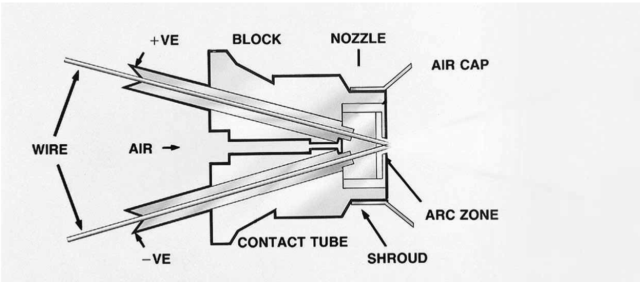
II) Powder

In this process, the raw material in the form of powder, is melted in an oxygen-fuel gas flame. This molten particles are propelled towards the workpiece in the gas stream.
The molten spray solidifies on the component surface to form a dense, strongly adherent coating.
Both metals, plastics and ceramics can be sprayed with this process.



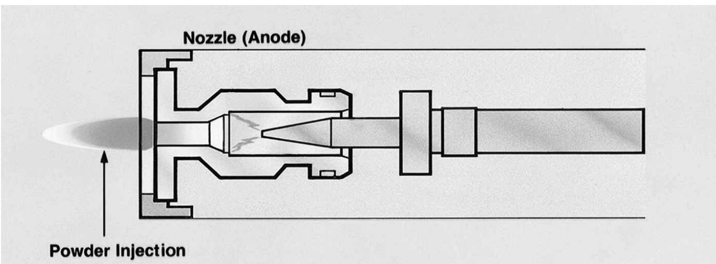
3.2 Arcspray

In the Arcspray process, the raw material in the form of a pair of metallic or cored wires, is melted by an electric arc. This molten material is atomised by a cone of compressed air and propelled towards the workpiece. The molten spray solidifies on the component surface to form a dense, strongly adherent coating. Arcspray deposits possess a higher degree of bond strength than most other thermally sprayed deposits and the use of compressed
air and electricity alone mean more economic coatings.



3.3 Plasma

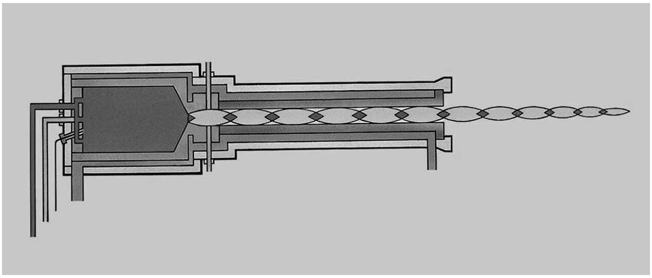
Plasma is the term used to describe gas which has been raised to such a high temperature that it ionises and becomes electrically conductive. In the case of Plasma Spraying, the Plasma is created by an electric arc burning within the nozzle of a plasma gun and the arc gas is formed into a plasma jet as it emerges from the nozzle. Powder particles are injected into this jet where they melt and then strike the surface at high velocity to produce a strongly adherent coating. Almost any material can be sprayed including metals, ceramics and plastics.



3.4 H.V.O.F

Liquid fuel and oxygen are fed via a pre-mixing system and at high pressure into a combustion chamber where they burn to produce a hot high pressure gas stream. This is expanded through a laval type nozzle increasing the gas velocity to around 1500m/sec and the pressure to slightly below atmospheric. At this stage the powder can easily be injected into the gas stream.

This gas stream heats and accelerates the powder particles within the confines of the secondary nozzles so that they impact with tremendous energy upon the substrate material. The Metallisation H.V.O.F System does not melt powders but only softens them. Because less heat is imparted to the particles and dwell times are very short oxidation and decomposition are minimal in H.V.O.F coatings.



3.5 Comparison of Processes

PROCESS	TYPICAL THERMAL ENERGY TEMPERATURE ^{0}C	TYPICAL KINETIC ENERGY PARTICLE VELOCITY M/Sec
Wire Flamespray	3000	50-100
Arc Wire	4000	50-100
Powder Flamespray	3000	20-50
Plasma	15000	50-150
H.V.O.F.	2500	300-700

3.6 Coating Comparison

PROCESS	BOND (Mpa)	POROSITY (%)	OXIDES (%)
Wire Flamespray	5.4 - 27*	10-15	5-15
Arc Wire	13.6 - 50*	10-15	5-15
Powder Flamespray	13.6 - 34*	5-10	5-15
Powder Flamespray (Fused Coatings)	68+	0	1-5
Plasma	34 - 68+	<1-5	<1-5
H.V.O.F.	41 - 95	<1	<1-2

* Ni/Al bond coats used

4 - COMPONENT SELECTION

The term engineering applications covers the field of thermal spraying where material is deposited on machine components to reclaim worn or mis-machined surfaces, and to impart desirable surface characteristics such as wear resistance and improved corrosion resistance to new components in primary manufacture.

The original use of thermal spraying in this connection was for the repair of worn parts, this was soon extended to mis-machined components. In recent years refinement of technique and modern equipment have permitted the salvage of highly stressed components in applications such as gas turbine aircraft engines. In the same manner these techniques and equipment have been used to extend the process into production engineering both in mechanical engineering e.g. spraying fork lift truck masts with bronze to prevent galling, automotive transmission components hardfaced with molybdenum, and in chemical engineering, e.g. spraying mild steel drying rolls with stainless steel and pump shafts with Monel.

The process is also used in many specialised industries such as the manufacture of printing machinery, paper machinery and glass making machinery.

The suitability of the metal spraying process for any particular application may be determined according to the following fundamental principals:-

a) No strength is imparted to the base material by the sprayed metal deposit. It is essential that the component to be sprayed should in its prepared form be able to withstand any mechanical loading to which it will be subject in service, e.g. a crankshaft pin worn below its final regrind limit should not be undertaken, but a crankshaft worn to slightly above its final regrind limit may be restored to original dimensions.

b) If the area to be sprayed on a component or any section of the total area is subject to shear loading in service then it is not a suitable subject, e.g. gear teeth, splines, threads etc., cannot be reclaimed by metal spraying.

c) A point loading with line contact on a metal sprayed deposit will eventually spread the deposit causing detachment. If the deposit is on a moving component with such a loading the deposit failure will occur very rapidly, e.g. needle and roller bearing seating where the bearing elements are in direct contact with the sprayed deposit cannot be treated.

d) If any hardening process such as “Nitriding” have been applied to the surface to be sprayed, then this will require removal.

Subject to the above almost any metal or alloy surface may be sprayed and it is convenient to divide applications into the following types:-

i) Seatings

These are usually bearing seating, gear and pinion seating etc. The bearings or other components may be press fits, interference fits or sliding fits on the seating. Various forms of keyway may be present but all can be metal sprayed satisfactorily using the techniques described later.

ii) Housings

The technique used for treating seating is employed suitably modified for internal diameters.

iii) Location Surfaces

Except in the case of internal or flat surfaces, no complication arises.

iv) Bearing Surfaces

The treatment of bearing surfaces is also quite straightforward. The selection of the metal to be sprayed (see 5 - Coating Selection) will be governed by the type of bearing material in contact with the sprayed surface, e.g. a crank pin running in white metal bearings may be sprayed with many materials, but if it runs in lead/bronze, lead/indium or aluminium alloy shell bearings 60E steel or 103T Cored wire would be used.

v) Bearings

The usual practice where ball or roller bearings are concerned is to spray the seating or housing as described above. Bronze bearings, however, are reclaimable by spraying, and babbit liners can be built up or restored completely in the same way.

vi) Gland Contact Areas, Oil Seal Contact Areas

Gland packing areas may be treated in the normal way but regard should be given to the type of packing and the environment to determine the material used to build up the worn area. Oil seal contact areas are treated in the same manner.

5 - EXAMPLE OF COATING SELECTION

The choice of material to be sprayed depends on the service conditions of the component being treated. The available means of finishing the deposit is also a consideration. For example, if there are grinding facilities available, 60E a 13% Chrome Steel would be the obvious choice, but if not, 57E a free machining variant would have to be used as this can be finished by turning.

All sprayed metals contract whilst cooling. This can be minimised during the spray process (see 8 - Spraying procedure). If the contraction is very great the stress induced may be greater than the cohesion of the deposit and cracking will occur. The contraction rate, however, varies widely with different metals or alloys. For example, 60E (13% Chrome Steel) has one of the lowest contraction rates of all the commercially used materials, whilst 80E (18/8 Stainless Steel) and 30E (Low carbon steel) have the highest.

Modern spraying wires such as 60E and 57E used for machine element work have been developed not only for high wear resistance and free machining properties but also for low contraction rates. Correct selection of the metal to be sprayed can reduce the danger of cracking to a minimum.

The following charts give a range of materials in the current use with their applications, methods of finishing and ranges of deposit thickness. **Refer to Technical Bulletins for all coating recommendations.**

WIRE REF No	MATERIAL	TYPICAL APPLICATION	COATING THICKNESS AFTER FINISHING IN mm	TYPICAL HARDNESS IN ROCKWELL	FINISH
99E	Molybdenum	1. Reclamation of machining error 2. Rectification of worn bearing housing 3. Rectification of press and interference fits 4. Hardfacing new components	0.125-0.375 0.012-0.250 0.125-0.375 0.250	Rc 33 - 60	Ground " " "
60E	CR13 Steel (13% Cr Steel)	Reclamation of all types of bearing surface inside and outside diameter and faces. Usually used where hard-wearing tough deposit required. Such as Class A Service	0.375-3.750	Rc 35	
80E	18/8 Stainless Steel	All surfaces requiring an 18/8 Stainless Steel finish. 1. For reclamation of worn 18/8 stainless components 2. For stainless steel surfacing of new components made of cast iron or mild steel to replace manufacture from solid stainless. Where grinding is applicable	0.375-1.5 1.5	Rb 84	Ground Ground
55E	HM Stainless Steel (18/5 High Manganese Stainless steel)	Used where a high stainless property is required and a turned finish may be necessary. Possesses lower shrink than 80E permitting heavier build up.	0.375-3.750	Rb 92	Ground or turned
57E	FM Chrome Steel (13% CR Low Carbon)	A free machining steel with good wear resistance used for reclamation and salvage requirements on many bearing surfaces. Seating, housings, location surfaces etc.	0.375-3.750	Rb 99	Ground or turned
10E	Aluminium Bronze	An excellent general purpose bronze for all reclamation operations, high wear resistance and good machining properties	0.375-3.750	Rb 82	Generally turned (but can be ground)
15E	Phosphor Bronze	Where specified on components of similar material	0.375-2.000	Rb 70	Turned
70E 71E	Monel	Used where high corrosion resistance is required. Possesses low contraction rate and can be given a superfine turned finish	0.375-3.750	Rb 50	Ground or Turned
05E	Copper	Used for surfacing and reclaiming printing rollers, electrical contacts, slip rings etc.	0.250-3.750	Rb 37	Turned or hand finished
12E 13E 14E	Brass	Used widely as a base coating for rubber bonding	0.250-0.500	Rb 39	As sprayed
02E	Zinc	Used for corrosion protection on steel work, Mould tooling and R.F.I Screening	0.050-2.000	Rh 46	As sprayed
01E 17E 25E	Aluminium & Aluminium Alloys	Used for the reclamation of light alloy components and corrosion protection.	0.250-2.000	Rh 80 Rh 95 Rh 90	Ground or turned

POWDER REF	MATERIAL No's	TYPICAL APPLICATION	THICKNESS LIMITATION IN mm	TYPICAL HARDNESS IN ROCKWELL	FINISH
P404/32 P830/31 P830/06	Aluminium Bronze	Non Ferrous Soft Bearings and Resistant to Cavitation	6.4 " "	Rb 89 Rb 85 Rb 50	Ground / Machined " "
P629/07 P622/06 P627/16	Iron, Nickel and Cobalt	Hard Bearings	None 2.54-6.35 None	Rc 35 Rc 30 - 35 Rb 75	 " Ground / Machined
P226/30 P226/13 P216/38 P220/35	Ceramics	Hard Bearings	0.51-0.63 2.54 0.38 0.51-0.63	Rc 62 - 72 Rc 62 - 64 Rc 70 Rc 61 - 65	Ground " " "
P622/06 P629/07 P626/06 P627/16	Iron, Nickel and Cobalt	Resistant to Abrasive Grains and Hard Surfaces at low Temperatures	2.54-6.35 None " 0.51-0.63	Rc 30 - 35 Rc 35 Rb 80 Rb 75	Ground " Ground / Machined "
P325/10 P325/30 P319/10 P368/05 P315/06	Self Fluxing Alloys	Resistant to Abrasive Grains and Hard Surfaces at High Temperatures 540(C - 815(C (1000(F - 1500(F) Resistant to Cavitation	1.27-1.79 0.38 3.175 1.27-1.79 "	Rc 62 Rc 60 Rc 55 - 60 Rc 50 Rc 30 - 35	 " " " Ground / Machined
P426/38 P423/33 P725/32 P735/31	Tungsten Carbides	Resistant to Fretting at Low Temperature	0.62 " 0.50 0.38	Rc 63 - 66 Rc 64 - 66 Rc 50 - 55 Rc 50 - 55	 " " "
P434/33 P435/33 P436/33 P785/35 P930/27	Chrome Carbides	Resistant to Fretting at High Temperatures 540(C - 815(C (1000(F - 1500(F)	0.62 " " 0.38 "	Rc 55 Rc 53 - 57 Rc 50 Rc 50 Rc 47	Ground " " " "
P255/40 P225/20 P216/30 P220/35 P205/35 P226/30 P226/13	Ceramics	Resistant to Particle Erosion at Low Temperature	0.50 0.80 0.51-0.63 " 0.80-1.0 0.51-0.63 2.54	Rc 65 Rc 65 - 70 Rc 60 - 63 Rc 61 - 65 Rc 55 Rc 62 - 72 Rc 62 - 64	Ground " " " " " "
P815/31 P626/06 P854/35 P868/33	Iron, Nickel and Cobalt	Resistant to High temperature Oxidation	None " 0.38 0.62	Rb 90 Rb 80 Rc 34 Rc 45	N/A " " "

6 - SAFETY

6.1 Introduction

Experience over many years has shown that no serious health or safety problems have resulted from thermal spraying operations, however, like many other industrial processes, malpractice and careless procedure can create hazards for personnel and damage to equipment.

Thermal spraying involves the use of highly concentrated heat sources. The spraying operation also involves the production of metallic dust. This, in certain instances, may present toxic, inflammable or explosive hazards unless suitable precautions are taken.

A separate publication on Health and safety matters is available free of charge on request from Metallisation ltd.

6.2 Compressed Gases

Fuel gas and oxygen cylinders must be treated with care and not be subjected to mechanical shock or undue heating. Acetylene and propane cylinders must always be stored and used in an upright position.

Under no circumstances should oxygen and fuel gas cylinders be stored in the same area. Care should be taken to see that full and empty cylinders are clearly distinguished and kept well apart.

Preferably the storage area should be located so that the cylinders may be readily removed in case of fire. Cylinders should always be stored out of doors and be protected from the rain and direct rays of the sun. To reduce tank pressure to that required by the equipment, pressure regulators must always be fitted to cylinders in use. Only the regulators designed for the gas being used should be fitted to cylinders.

The regulators should be connected to the spraying equipment only by means of the special reinforced rubber hose specified for this service.

Care should be taken to ensure that hoses are securely attached to connectors by means of suitable hose clips. When two lengths of hose must be coupled together, special couplers should be used, never sections of metal tubing. It is important that all hoses be inspected frequently to ensure that they have not become frayed, cut or cracked. Hoses that show any defects must be replaced immediately.

In the case of cylinders of equipment carrying oxygen, it is important that no oil, grease or fatty substance is allowed to come into contact with oxygen cylinders, regulators or filters; otherwise fire or explosion may result. It is important that no grit or other foreign matter is allowed to enter or remain in fittings carrying combustible gases or oxygen.

Care should be taken to ensure that the cylinder valve is fully closed before the regulator is removed.

6.3 Electricity

The open circuit voltage of Arcspray or Plasma spray equipment does not exceed 88 volts DC. The power source, however, will normally be connected to the 220/380/415 volts supply; and it is important that the connection is carried out only by a competent electrician.

During metal spraying metallic dusts are produced and in some cases where the power source is located near the spraying areas, some of this electrically conductive power may enter the unit, thereby short circuiting the high voltage. Adequate ground connections and the correct fuse rating at the junction box must, therefore, be installed.

6.4 Radiant Energy

Electromagnetic radiation includes radio waves, infra-red radiation, visible radiation and ultra-violet radiation.

No ill effects appear to have arisen from exposure to infra-red radiation, nor are they considered likely to do so, as exposure will generally not be intense.

Visible radiation is similarly unharmful, though exposure of the eyes to light of high intensity should be avoided. The effect of ultra-violet radiation is well known, as it is the sunburn producing constituent of solar radiation. The brilliant blue light from an electric arc has a high concentration of ultra-violet radiation. The effect of looking at the arc with unprotected eyes is an intensely painful burning sensation in the eyes, which those who have suffered do not forget. The pain is due to a burn of the conjunctiva, the delicate membrane covering the eye, and is referred to as “arc-eye” or “arc-flash”.

It is essential that sources of ultra-violet should be screened, not only from the persons working the equipment, but also from those nearby. The persons working with the process should also wear protective glass, not plastic, visors or goggles with side shields. Note: plastic lenses could soften / melt if to close to the Plasma.

6.5 Dusts Fires and Explosions

Firmly divided materials and metal dusts constitute a potential fire and explosion hazard, unless due precautions are taken.

When metal spraying is in progress, some of the metal droplets do not become deposited on the workpiece but settle on the floor of nearby surfaces.

In general, it is considered that the finer the dust, the greater the risk of explosion; but it is fair to point out that in metallurgical industries, extremely fine metal powders are made in large quantities and are handled without difficulty. Measures should be taken at all times, however, to keep down to a minimum the amount of accumulated dust by regular cleaning of spraying areas and removal of dust accumulation on walls, doors, ledges, beams and joists.

Aluminium is especially hazardous, pyrophoric and explosive; and should not be sprayed without proper ventilation i.e. exhaust duct sizing to prevent powder dropout and an approved wet or dry collector.

Adequate ventilation should also be provided to reduce the possibility of dust accumulation in spraying rooms or confined spaces, the dust removed should be collected in suitable dust collectors outside the building. All ductwork should have adequate access for cleaning.

During cleaning, ventilator fans should be kept running to prevent the creation of high concentration dust clouds in the ducts, and no naked light or source of ignition should be permitted in the area.

No welding or repair of ventilating equipment should be done, unless the equipment has been thoroughly cleaned free from dust.

All fans, motors, casing and ducts should be electrically grounded.

Before commencing to spray, consideration must be given to walls, floors, or nearby objects of waste material so as to assess the risk of fire. All combustible materials should be removed from the vicinity of the spray stream, or if this is impossible, it should be protected by metal or fire resistant sheets. Tarpaulin should not be used for this purpose. Suitable fire extinguishing apparatus should always be ready at hand.

It is important to check after work is completed that no smouldering materials pass unnoticed.

6.6 Toxic and Respiratory Hazards

Inhalation of dust and fumes

This is by far the most important route of absorption of chemical substances into the body. The weight of air inhaled in the course of a day is about 27 kilos; and if it contains any dust, fumes or gas, the amount absorbed can be considerable. Certain substances exert a local action on the lung itself; for example, silica dust produces silicosis, while others such as lead and benzol are absorbed from the air spaces into the blood and are able to exert their toxic action throughout the body. Absorption of poisons in this way deprives the body of the protective action of the liver, as the freshly oxygenated blood from the lungs is returned to the heart and is pumped immediately through the arteries, with the result that any toxic substance taken up into the blood can produce its effects even on remote organs.

Strictly speaking, fumes are condensed solid particles, but the term is used loosely to include vapours and condensed vapours (fogs and mists) as well as the minute particles of materials which are often oxidised during the condensation process. Their action is often the same as, or more severe than, the dust of the same material.

The lung in a healthy person is capable of dealing with a certain amount of dust, the amount varying with the chemical nature of the dust and duration of exposure. Large quantities of dust of any kind can ultimately produce damage to the lung, but we are concerned more particularly with dust which, in relatively small concentrations, can produce either damage to the lung or be absorbed into the body from the lung. The higher the concentration in particles per cubic foot, the more severe is likely to be the effect.

Harmful effects may occur from a single massive exposure in the case of certain toxic or irritant dust and fumes, but with the majority of dusts the effect comes on slowly over months or years. Occasional exposure causes trouble less rapidly than regular or continual exposure.

With the use of Extraction and or Breathing apparatus the amount of exposure can be drastically reduced. The ideal solution would be to remove the operator from the spraying environment through automation.

6.7 Noise Hazards

Noise is sound which is both unnecessary and objectionable. Excessive noise has a number of effects on people. For instance, it can reduce productivity, cause tension and nervousness, slow reaction times and cause hearing impairment.

Noise is measured by measuring the energy (pressure) of the sound waves with a meter consisting of a microphone, amplifier and readout.

The meter reads in decibels (dBA). In perceiving loudness, the ear has a range of approximately 130 decibels. Typical noise levels in various environments are indicated in Table 1.

TABLE 1

EQUIPMENT	CONDITIONS		dBA
Arc Spray Pistols	Steel	24 volts/200 amps	106
		32 volts/500 amps	116
	Zinc	19 volts/100 amps	104
		19 volts/200 amps	106
	Aluminium	36 volts/1000 amps	120
Powder Flamespray Pistols	Acetylene		90
		With Air Jet Cooling	110
Wire Flamespray Pistols 1/8" and 3/16"Wire	Acetylene		114
	Propane		118
Plasma Spray Pistol	Argon	38volts/1000amps	128
	Argon/Hydrogen	70volts/600 amps	132
	Argon/Nitrogen	50volts/1000amps	131
H.V.O.F	Liquid Fuel / Oxygen		129
Typical Grit Blasting Equipment			80-85
Typical Exhaust Equipment			< 90

Wherever there is a possibility of a noise problem, measurements should be made. Without an accurate sound level survey, there is no certainty a problem exists.
The physiological effect of noise is caused by its loudness and duration. The louder the noise, the shorter the permissible exposure to it.

An equal amount of additional noise raises the sound level by only 3 dBA. For example, two 80 dBA machines produce a noise level of 83 dBA. An increase from two to three 80 dBA machines will increase the noise from 83 to 86 dBA.

If an added noise is less than the existing noise, it has a negligible effect on the total noise. If the added noise is between 0-10 dBA louder, 3dBA will be added to the total noise. If the added noise is more than 10 dBA louder than existing, the total noise will be essentially the value of the added noise.

Controlling Noise and Exposure

There are three categories of exposure to thermal spray noise; operators, nearby works and transients. Consideration must be given to protecting all of them against the effects of the noise.
Engineering and administrative controls can be used to reduce noise, or reduce exposure to noise.

Engineering controls are:
1. Location of equipment
2. Change operating parameters
3. Isolate equipment acoustically
4. Insulate work area
5. Provide operator hearing protection

Location of equipment

The greater the distance from the source of noise, the lower the sound pressure level.

In a large room with no sound-reflecting surfaces, the sound pressure level decreases 6 dBA for each doubling of distance. In actual practice, which usually includes reflective surfaces, the reduction with the distance will be somewhat less.

Table 3 indicates typical reduction with distance in a free field.

TABLE 3

Distance from source (Meters)	dBA Theoretical Reduction
10	0
3	10
10	20
30	28

Change Spray Gun Operating Parameters

A 3 to 4 dBA reduction in the noise of combustion wire and powder guns can be achieved by lowering the flow of gases and air flows. Less heat will be produced, so the spray rate must be reduced. The resulting coating, compared with a normally sprayed coating, is less dense, softer and has a coarser texture.

With plasma, noise can be reduced by lowering the amperage. A corresponding reduction in spray rate is required. Decreasing gas flows will reduce noise, make less heat available and reduce coating quality.
Arc spray noise can be reduced by lowering the amperage (spray rate), voltage or flow of atomising air, or all. If all are lowered, the effect on the coating will be similar to those described above. If the spray rate is lowered and the atomising air flow is not lowered, the as-sprayed coating will have a finer as-sprayed texture and the coating will be denser and contain more oxides with some materials.

Isolate Equipment

Equipment noise can be isolated by moving it away from the affected personnel, or by enclosing it in an acoustically insulated enclosure.

Insulate Work Area

Very significant noise reduction can be obtained by blocking the path of transmission of the noise. This can be done by lining the work area with sound absorbing materials.

Provide Hearing Protection

Under the Health and Safety Regulations the law permits that suitable personal protective equipment be used.

6.8 General Considerations

Metal Spraying Equipment

The following associated safety rules must be observed when using metal spraying equipment.

Install and set up the equipment in accordance with the manufacturerís recommendations.

Ensure that all hoses connections and nozzles are tight, and maintain hoses and fittings in good condition. Before fitting regulators to cylinders, ensure that the threaded socket is clean by momentarily opening the valve and “blowing-out”.

Always start, adjust and shut off the equipment strictly in accordance with the procedure detailed by the manufacturer.

Handle the spraying gun carefully, and never let it be pointed towards other persons, combustible materials or gas cylinders.

Make full use of protective clothing and respiratory equipment where necessary.

Ensure that adequate ventilation is provided. If by special circumstances adequate ventilation cannot be provided, suitable respiratory protection should be worn by operators and any other persons in the spraying area.

When arc or plasma spraying, or when spraying molybdenum or similar high melting point materials, tinted goggles or a visor should be worn to protect the eyes from the high intensity light and ultra-violet radiation. Glass, not plastic, must be used as protection.

Publications

No safety standards have been adopted for Thermal Spray equipment as yet. Some of the relevant publications are:-

International Acetylene Association "Safe practices for installation and operation of welding and cutting equipment".

Metallisation Technical Bulletin "5.1.4"

Metallisation Publication "Health & Safety - Thermal Spraying"

7- SURFACE PREPARATION

7.1 Preparation

If any one stage in the "building up" process can be described as the most important, it is without doubt preparation. In common with all types of deposition and surface coating work whether it be welding, electroplating, vitreous enamelling or painting, unsatisfactory preparation can be disastrous. 90% of coating failures investigated have been a direct result of poor or inadequate surface preparation.

a) Preliminary Inspection

All components must be inspected to ensure that no surface condition exists which could interfere with any subsequent operation.

(a) Worn or mis-machined components should be examined for cracks, previous deposits and a hardness check performed.

(b) In production engineering where the metal spraying operation is part of the flow line process, dimensional inspection will naturally be carried out before spraying.

b) Degreasing

If the surface of the component shows any trace of grease this should be removed. Castings which are contaminated with oil or grease should be heated to approximately 300^0C by suitable torch or in a furnace.

c) Preliminary Machining

In some cases no preliminary machining will be required and preparation of the surface in the chosen manner may be commenced immediately. This is particularly the case in the restoration of mis-machined surfaces where the surface to be reclaimed is a seating, housing or location surface. However, in the case of a worn surface the worn area must be pre-machined to ensure a uniform concentric deposit for both internal and external diameters. The method is described in detail in the following pages.

7.2 Pre-Machining

Applicable to machine element work such as shafts.

In general, the component is prepared by undercutting the area to be sprayed using conventional machining techniques. EG. Turning or Grinding. The amount of base material removed will be dependant upon the material to be applied and the final dimension of the component.

The geometry for such undercuts and other types of machine preparation are shown in the following diagrams;

Undercuts should have a straight shoulder or preferably a 45^0 chamfer. Sharp corners should be replaced with radii of approximately 0.5mm (.020") see fig 1.

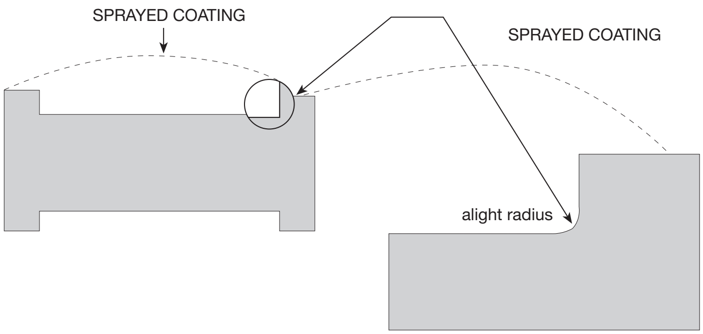


Fig 1

The type of undercutting shown in fig 2 should **NOT** be used as this will cause a poor bond and a porous area at the shoulder.

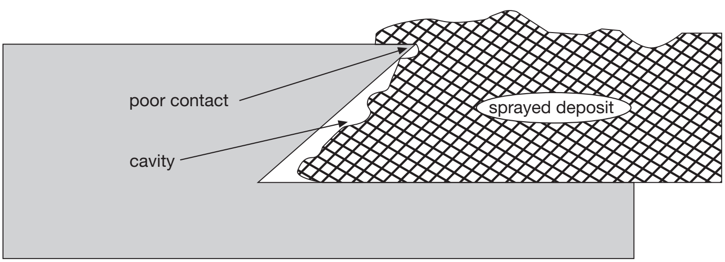


Fig 2

If possible, a shoulder should be left at the end of the shaft.
However if this is not possible, then the coating should be wrapped around the end of the shaft. With a typical undercut of 0.5mm x 0.5mm (.020î x .020î) see fig 3.

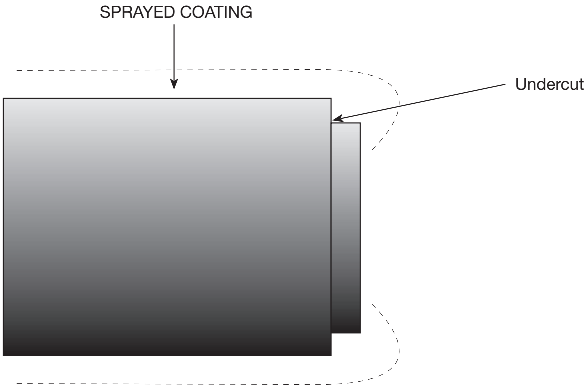


Fig 3

For the reclamation of badly worn parts and to avoid deep shoulders a stepped undercut may be used fig 4.

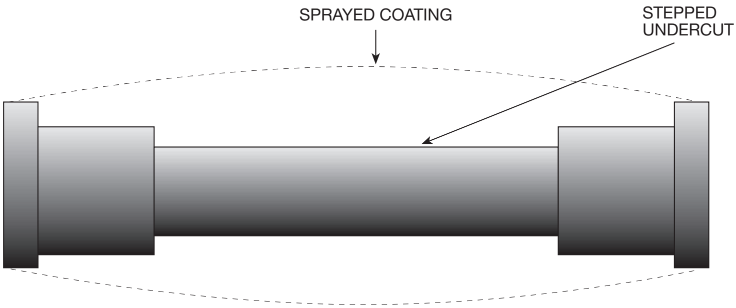


Fig 4

Using this method avoids any undue stresses that may cause cracking and also reduces the amount of material sprayed.

Cutting fluids should not be used on machine preparation as contamination to the previously degreased part may result.

Surface finish is not critical, ideally the rougher the finish the better the bond.

If any hardening process such as “Nitriding” have been applied to the surface to be sprayed, then this will require removal.

Degree of Machining

The degree of pre-machining determines the thickness of the finished machined deposit. The optimum thickness of the sprayed deposit is determined by the type of component and its duty and the contraction rate of the chosen metal. The component type and service conditions are the major factors in determining deposit thickness.

Machining Allowance

The sprayed deposit thickness is the final deposit thickness plus a machining allowance. This depends on the diameter of the component and whether it is to be ground or turned, but normally it will range from 0.125mm (0.005”) on radius for a 25.4mm (1”) diameter ground finish, up to 0.5mm (0.020”) for a 254mm (10”) diameter and above turned finish.

It is important to appreciate that if a deposit fails to machine to final dimensions through lack of metal, the whole deposit must be removed and the complete operation recommenced.

Keyways

If the edges of a keyway are in reasonable condition, it should be masked off immediately before spraying with a dummy key as described in section 8 - Spraying Procedure (Masking for Spraying).

If damage has occurred to such an extend that the refitting of a key would not be satisfactory, no reliance should be made on the sprayed deposit to rectify the damage. In this event another keyway should be cut if this is permissible and the existing keyway filled in, or alternatively the keyway may be reclaimed by welding.

Having determined the depth of pre-machining in accordance with the above recommendations and maintained the type of profile discussed, the machining may be commenced without the use of lubricant or cutting fluid.

7.3 Degreasing

Purpose

To remove oil and grease from the surface and the pores of the substrate

Especially important if the component has been in service.

Options

1. Flood with cold solvent

2. Vapour degrease

3. Special cleaning may be required if the component has been crack detected to remove the dye penetrate.

   E.G. Soak in white spirit

4. On porous castings that have been absorbed oil in service, methods 1, 2 and 3 may not be satisfactory.

   Pre-heating the component to between 260^{0}C and 370^{0}C and maintaining this temperature until oil ceases to come to the surface or until all smoking stops will satisfactorily clean the component.

After degreasing, it is important that the area to be sprayed is not handled or allowed to become contaminated.

7.4 Gritblasting

General method of preparation for machine element work, irregular shaped components, flat surfaces and Anti-Corrosion.

The purpose of gritblasting is to remove surface oxides and roughen surface to provide a mechanical key for the coating.

Sand Blasting does not produce the profile required and can contaminate the surface.

Shot blasting peens the surface rather than producing a profile.

Prior to gritblasting, components should be degreased to prevent contamination media and masked where areas not to be sprayed need to be protected.

Methods of Masking

1. Gritblasting tape
2. Mechanical masks

Gritblasting Media

1. Metallic grit - normally angular chilled iron.

Commercial quality - least expensive
Hard sharp angular fragments, giving bright etched finish
However grit breaks down quickly causing excessive machine wear and contamination if not frequently changed

Recommended grades of grit available:-

G17	Fine	for thin coatings less than 0.250mm (.010”).
G24	Medium	General purpose Engineering and Anti-Corrosion.
G34	Coarse	for heavy deposits greater than 1.25mm (.050”).

Blasting pressure normally required with this grit between 3.45 - 6.90 Bar (50-100psi).

2. **Non Metallic grit** - Aluminium Oxide

Fused aluminium oxide grit for optimum hardness and durability.

Can be used on light gauge work and plastics without causing distortion.

Grades of grit available :-

< 36 mesh	for thin coatings less than 0.250mm (.010") where little or no finishing will be carried out.
36 mesh	for coatings under 0.750mm(.030") which require to be finished.
> 36 mesh	for heavy deposits over 0.750mm(.030").

Blasting pressure normally required with this grit between 1.72 - 3.45 Bar (25-50psi).

3. On Site Blasting

There are two types of grit available for on site blasting, Garnet and Copper Slag. These are of the disposable type and are only used once.

Operator Notes

Pressure blast or suction blast machines may be used for either grit depending upon the grade used, the coverage rate required and the amount of surface contamination on the component.

Ensure that the compressed air used is clean and dry to avoid contamination of the grit and component.

Ensure correct pressure whilst blasting in order to prevent distortion of the component.
(Especially on light gauge work and plastics).

Do not over blast - this will flatten the peaks generated by the grit blast and therefore result in a poor bond.

Maintain quality and size of grit - be aware of contamination.

Metallic grit will round off, becoming blunt. Thereby reducing the necessary cutting action.

Non-metallic grit will reduce in size but maintain a sharp edge.

Blasting distance is approximately 150mm (6”) and blasting angle 5-10 degrees from the perpendicular.

Ensure the component is dust free after blasting. (Use a clean dry air supply).

Never handle the surface or allow it to become contaminated after blasting.

Spray as soon as possible after blasting, ideally within 2 hours and definitely before any visible oxidisation occurs on the prepared surface.

7.5 Rough Thread Preparation

Rough cutting or Rough Thread preparation consists essentially of cutting a thread form on the area to be sprayed.
This process increases the surface area and roughens it up, there by adding to the mechanical bond of the Thermal Sprayed coating.
This type of preparation correctly carried out gives a very high bond strength, and has the advantage that it may be done in the lathe immediately after the pre-machining operation , without necessitating the removal of the component and subsequent re-setting for spraying. Which is necessary when gritblast preparation is used.
It must be emphasised that the cutting must be rough, as a conventional smooth thread is virtually useless.

The tool should be ground with a 90^0 inclusive angle a slight radius at the top and a relief angle
of 5^0, see Fig 5.

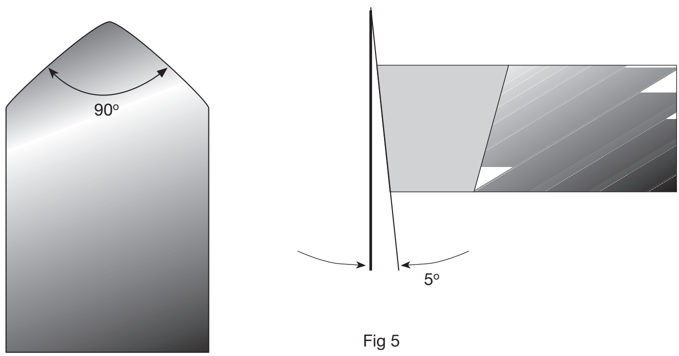


Fig 5

The tool should be mounted in the conventional manner and set so that it enters the surface between 0.5mm (1/64”) and 1mm (1/32”) below centreline according to the diameter being treated (this produces a torn and jagged cut). No cutting fluid or other lubricant is used and the cut should be taken with one traverse of the tool which should be fed into full depth immediately. Between 10 and 12 threads per cm (24 & 30 T.P.I.) should be used, the greater numbers for small diameters, e.g. a 12mm (1/2”) diameter shaft would require 12 thread per cm (30 T.P.I.) The surface speed should be the lowest possible for the traverse speed selected, the whole purpose being to produce a torn and jagged thread form. The illustration in Fig 6 shows an example of this type of preparation.

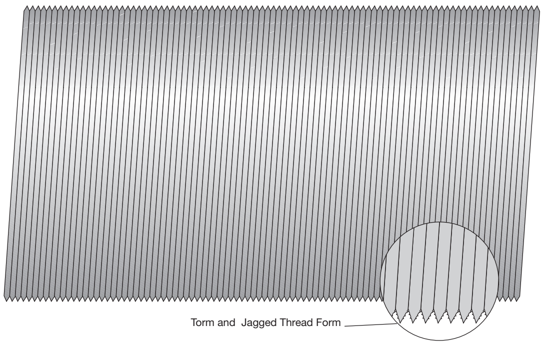


Fig 6

In internal diameters a modification of the thread form is desirable and a buttress thread should be used with an included root angle of 60^0 see Fig 7. This permits the spray to enter the thread fully without risk of bridging.

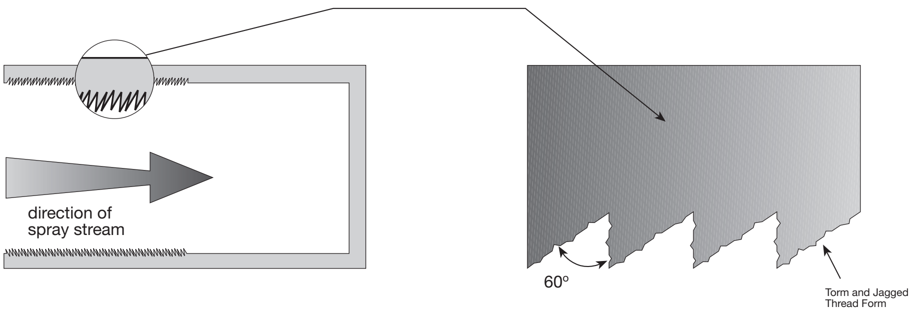


Fig 7

7.6 Bond Coat Materials

Certain materials will bond to clean surfaces that have not subsequently been prepared by either gritblasting or Rough threading.

These materials generally contain Nickel and Aluminium which when sprayed, will create an exothermic reaction causing particles to become superheated and will metallurgically bond with the substrate material.

These materials (T405-1 for Wire Flamespray, 75E for Arcspray and P636 for the powder processes) are applied as bond coats (thickness approximately 0.125mm (.005”)) prior to spraying the desired top coat material.

A Metallisation 99E molybdenum wire coating Flame sprayed will exhibit self bonding properties but will not bond to bronze, copper, chrome and nitrided surfaces (unless the nitrided area is removed).

There are other Metallisation materials which have these self bonding properties plus additional coating qualities. EG Selfbonding Stainless, Bronze etc. These materials are commonly referred to as one steps. (Metallisation 83E for Wire Flamespray, 79E for Arcspray and the P600 series when powder spraying).

Bond strengths will be improved if prior to spraying a bond coat or one step material the surface is either gritblasted or thread cut.

It is recommended that in the engineering environment a Bond Coat should always be used.

See Technical Bulletins for Material Parameters.

7.7 Summary of Surface Preparation Methods

Method	-	Processes
1.	-	GRITBLAST
2.	-	PRE-MACHINING PLUS BOND COAT
3.	-	GRITBLAST PLUS BOND COAT
4.	-	ROUGH THREAD PLUS GRITBLAST
5.	-	ROUGH THREAD PLUS BONDCOAT
6.	-	ROUGH THREAD PLUS GRITBLAST PLUS BONDCOAT

Applications

All these surface preparation methods have their place, e.g Grit Blast for a anticorrosion coating on a steel structure. However the recommend method where possible would be, rough thread plus grit blast plus bondcoat for most applications.

Method 1:- used for thin coatings less than 1.25mm (.050”) (however this will depend on grit size used) on irregular shaped components where bond coats are not applicable.

Method 2:- used for coatings less than 1.25mm (.050”) on machinable bases where bond coats are applicable and grit blasting is not available.

Advantage - quicker than Method 1

Method 3:- used on irregular shaped components that cannot be prepared by machining. Can also be used for machine element work but will require resetting after gritblasting.

Method 4:- used for thick coatings in excess of 1.25mm (.050”) on machinable bases where bond coats are inapplicable e.g.Copper substrates.

Method 5:- is a quicker alternative to Method 4 where bond coats are applicable.

Method 6:- the most expensive method with the least risk of subsequent coating failure through lack of adhesion.

8 - SPRAYING PROCEDURE

8.1 Masking for Spraying

Masking previously used for gritblasting may not be suitable due damage by the gritblasting procedure or the heat of the thermal spraying process, especially plasma.

However, Metallisation Sprayshield Masking Compound will withstand both a light gritblast preparation and the heat from the spraying process.

Other forms of masking include;

1. Mechanical
2. Sprayshield Black
3. Rubber / Silicon
4. Metalspray Tape

To prevent build up of the sprayed material on mechanical masks it is wise to coat them with sprayshield (brush or spray on liquid coating)

Consideration must be given to the technique used in removing gritblasting masks and applying spraying masks. It is critical that the surface to be sprayed does not become contaminated.

Where keyways are to be treated a false key should be manufactured in graphite and inserted in the keyway as indicated in Fig 8.

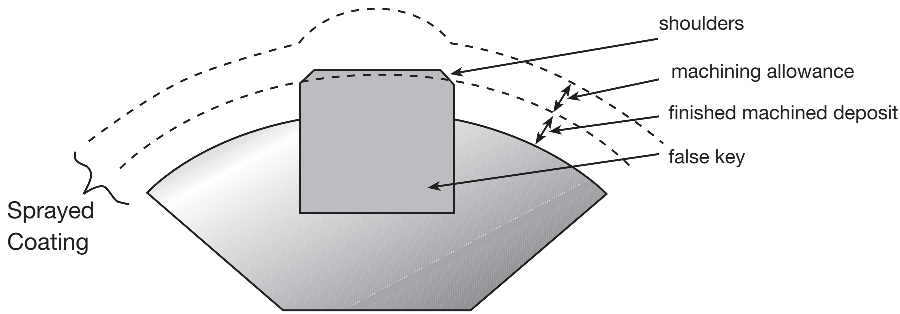


Fig 8

Graphite keys are much preferred since they are easy to remove. False keys of brass, bronze, etc. may be used provided proper care is taken to provide suitable taper to ensure ease of removal.

Oil holes are usually closed with a rubber plug as in Fig 9 or a tapered metal insert (Graphite is not normally used).

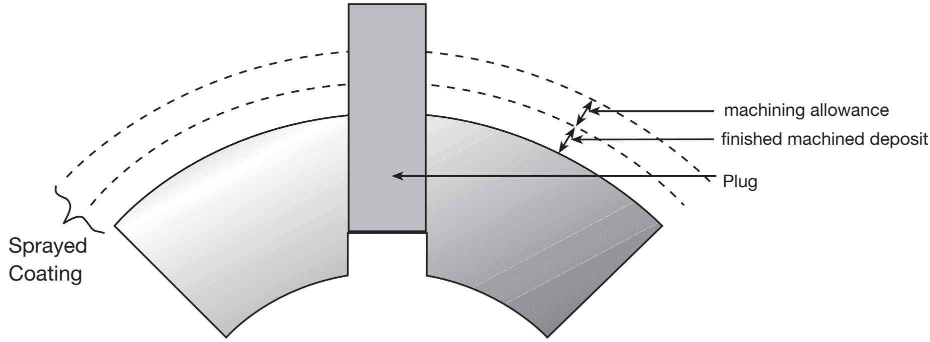


Fig 9

Surface oil ways may be filled with a copper strip as indicated in Fig 10 or be re-cut after spraying.
Other materials can be used if enough depth is avaliable to hold the insert in.

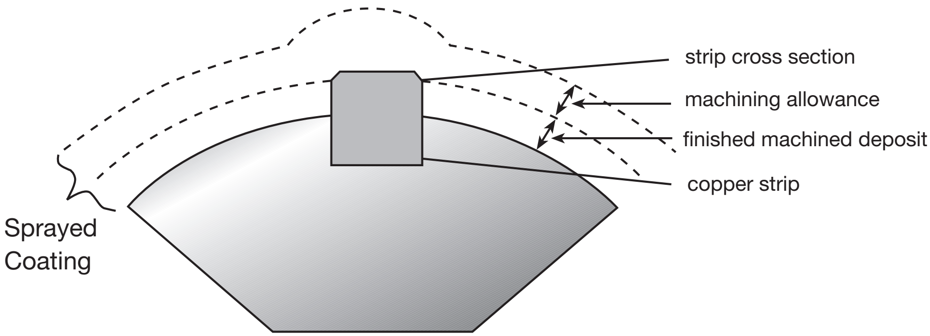


Fig 10

In masking, two important rules must be observed.

a) The masking should never intrude on the area to be sprayed

b) It should never interfere with the correct access of the spray stream. All masking should finish 1.6mm (1/16”) outside the sprayed area.

8.2 Pre-Heating

Pre-Heating is not always used (e.g Arcspray). However it can be used to advantage in certain applications to assist in reducing moisture and Thermal stresses etc.

Purpose

a) To remove surface moisture and prevent condensation forming

b) To reduce thermal stress by reducing the difference in the coefficient of expansion between the component and the hot particles

c) To assist in any metallurgical bonding

Normal pre-heat temperature is between 90^{0}C and 120^{0}C depending on the oxidation
characteristics of the base material.

> ***EG. Copper and Magnesium Alloys should not be pre-heated. Aluminium should only be pre-heated indirectly to approximately 50^{0}C***

Be aware of surface oxidation when using a flamespray gun to pre-heat.

Always increase the distance between gun and component and traverse quickly.

Use the heat from the flame to pre-heat not the flame itself.

Other methods of pre-heating

Oxygen - Fuel heating torch
Furnace (Production)
Induction Coil (Production)

8.3 Spraying

Unless hand spraying, the sprayed operation will generally be carried out in a lathe specifically set aside for spraying or with the aid of a traverse unit e.g Met Scan. Although if permissible it can be carried out in the machine tool used for the preliminary machining. However the abrasive nature of the sprayed particles could soon damage a good machine tool.

In either case, the pistol will be mounted on the specially designed tool post, except where the sprayed area is too small or large when manual spraying is the only choice.

It should be emphasised, however, that mechanical traversing should be employed wherever possible. This gives controlled deposits and minimises loss through overspray. Care must be taken to ensure that the necessary traverse can be obtained without fouling hoses or wire.

General Recommendations

a) Always try to spray perpendicular to the surface. However a maximum angle of 45^0 may be tolerated.

b) Maintain spray distance within the tolerance laid down in the Technical Bulletins.

c) Observe coating temperature during spraying, trying to maintain the pre-heat temperature if applicable. Maximum temperature recommended is 150 degrees centigrade.

d) Observe spraying area environment.

   Airborne dust should not be permitted to be drawn into the spray stream. This can lead to unreacted particles being present in the sprayed coating. This is of particular importance when spraying bores or deep pockets.

   Dust entrapment can be reduced and even eliminated with a correctly design extraction system.

e) Observe safety precautions (see section 5 Safety);
   Dust
   Noise
   Radiation
   Heat
   Rotating Components

f) Ensure process parameters are maintained during spraying
Spray Rate
Gas Flows
Air Pressure
Rotational Speed
Etc

g) The spraying operation should be carried out with the minimum of interruption preferably as a continuous process. It should be commenced as quickly as possible after the preparation and there should never be a delay of more than two hours between preparation and spraying. Certain standards will permit up to 4 hours between preparation and spraying.

Wherever possible when dealing with flat surfaces and non-continuous deposits the preparation and spraying zone should be overlapped or wrapped over the edge of the substrate.

At all times before spraying, prepared surfaces must be protected from dirt, moisture or contamination by handling.

8.4 Traverse & Rotational Speeds

These are dependant upon the material being sprayed, the process used and the shape of component being sprayed.

Reference should always be made to the relevant material Technical Bulletin for guidance on deposit per pass and surface Meters per Sec (feet per minute).

Traverse rate and rotational speeds may be calculated from the following formula;

1 . Rotational Speed (Metric)	1 . Rotational Speed (Imperial)
$\text{R.P.M.} = \frac{60 \text{ X } S}{(\text{ X } D}$ S = Surface Meters Per Second D = Diameter in Meters π = 3.14159 EXAMPLE: 0.1 m Diameter Shaft at 0.5 Surface meters per second $\text{R.P.M.} = \frac{60 \text{ X } 0.5}{\pi \text{ X } 0.1} = 94$	$\text{R.P.M.} = \frac{12 \text{ X } S}{(\text{ X } D}$ S = Surface Feet Per Minute D = Diameter in Inches π = 3.14159 EXAMPLE: 4” Diameter Shaft at 100 Surface feet per minute $\text{R.P.M.} = \frac{12 \text{ X } 100}{\pi \text{X } 4} = 100$
2. Traverse Rate (Metric)	**2. Traverse Rate (Imperial)**
Traverse Rate / Minute = R.P.M x * Band Width e.g Plasma Spray R.P.M = 94 Band Width = 4mm Traverse Rate = 376mm/Minute = 94 x 4	Traverse Rate / Minute = R.P.M x * Band Width e.g Plasma Spray R.P.M = 100 Band Width = 1/8” Traverse Rate = 12î / Minute = 100 x 1/8”

* Refers to spray band width e.g Plasma = 4mm approx, Wire Flamespray = 15mm approx, Arcspray = 50mm approx and High Velocity Oxygen Fuel = 6mm approx. (Depending upon Gun set-up, spray material and distance)

Deposition rates should be approximately 0.075mm to 0.150mm (.003” to .006”) per pass for general metallic materials. However, some materials with low spray rates, especially ceramics and carbides, traverse and rotation speeds should be increased to allow a reduction per pass of between 0.00125mm to 0.050mm (.0005” to .002”) depending upon the material.

Too slow traverse will cause;

Local hot spots (stresses in a coating)
Surface oxidation (laminated effect)

Generally, it is good practice to traverse the gun as fast as possible. Should a spiral appear on the component during spraying the traverse rate should be reduced until it disappears.

8.5 Cooling

Cooling may be essential during spraying to prevent the coating and component from
overheating and to allow continuous spraying especially when applying a thick coating.

It is advisable to keep the temperature as close to the pre-heat temperature as possible. Never allow the temperature to exceed 150^{0}C

Large components are unlikely to need additional cooling, but with thin section components cooling is essential.

Air is perfectly suitable providing it is clean and dry.

An Air Siphon can be used to direct air onto the workpiece. This unit converts high pressure low volume air into high volume low pressure air by siphoning in ambient air.

Air jets may be fitted to Powder Flamespray and Plasma Guns and can be used to cool the coating directly adjacent to the spray cone.

Compressed air is generally used to atomise molten particles in both the wire combustion and arc processes. For this reason, coatings applied by these techniques do not tend to over heat as much as the other processes.

CO_2 cooling can also be used particularly for the Plasma and H.V.O.F processes.

8.6 Sealing

Thermal sprayed coatings have a porous structure. In many applications, the porous nature of these sprayed coatings is an advantage. Coating porosity helps to retain lubricants which, in machine element build-up and repair coatings, prevent wear. However, there are some cases where it is best to seal up the pores of the sprayed coating, such as where thin coatings are used or where a corrosive agent is active. Porosity can be a disadvantage when the sprayed components are exposed to damaging environments, such as sea water, steam, dilute acids, corrosive gases and elevated temperatures. Coating porosity can entrap corrosive elements, setting up an electrochemical attack of both the coating and the underlying substrate. This could lead to coating and/or bond failures.

Where ceramic materials are utilised for their di-electric properties, sealing of the coating helps to maintain di-electric constants. If left unprotected, coating porosity could lead to the absorption of moisture and contaminants, resulting in the formation of unwanted conductive paths in the coating.

General Comments

As a general rule, all sealers should be applied after spraying and after finishing. The part should be below 80^{0}C before applying the sealer, this will prevent rapid evaporation of the solvent or premature curing of the sealer.

All sealers should be cured prior to finishing. The heat generated during machining may cause premature and non-uniform curing of the sealer. Grinding un-cured sealers may clog the grinding wheels. It is recommended that a light coat of sealer be re-applied after finishing to assure optimum sealing. For maximum resistance to corrosion, all sealers must be fully cured before placing into service.

Sprayseal M has been developed by Metallisation as a deep penetration sealant for engineering coatings. It overcomes the problems of viscous sealants (which only penetrate 100 or so microns and are consequently removed by machining or wear) and low viscosity sealants which either run out of the pores or fail to completely seal them. Sprayseal M will completely seal thick metallic coatings, although with some materials, adequate time must be allowed for full penetration. Because Sprayseal M requires free metal as a curing activator, special procedures must be adopted when it is used on inert or ceramic coatings, otherwise full curing may not take place quickly. Refer to Technical Bulletins for full details.

8.7 Finishing

Much has been written on the finishing of sprayed metal and many very specific recommendations have been given. In practice, satisfactory results have been obtained with grinding wheels slightly different from those specified below, whilst the materials not recommended for turning have in fact been turned with quite satisfactory results. If the general recommendations given are followed closely, excellent results will be obtained. It may be found in practice that variations of these recommendations give acceptable results, if so these may be adopted.

Grinding

All sprayed metal can be ground and this is the preferred finishing method. Wet grinding using a soluble cutting oil and wheels of medium hardness with vitrified bond are particularly recommended. Silicon carbide or bauxite grit may be used with a size of 30-50 Grit.

Refer to Technical Bulletins on individual materials for finishing recommendations.

Work surface speed should be 0.4 - 0.5 M/sec (80 -100 ft/min) and wheel speeds in accordance with the manufacturers instructions.

When starting grinding, the overspray must be removed before the main operation commences, by grinding outwards from the sprayed area. After a few cuts the overspray will fall away from the masking compound.

A low traverse speed is recommended with a light cut and any overheating must be strictly avoided.

It is important that the wheel be dressed frequently to avoid the glazing particularly liable to occur with sprayed metals.

If a very high finish is required, a 300 grit wheel will give a buffing action with minimum stock removal.

Turning

When grinding is not practicable, certain metals may be finished by turning as indicated in the coating selection table section 5.

Turning of sprayed metal is very similar to turning a cast material. Carbide tipped tools should always be used.
In practice, tipped tools recommended for grey cast iron give good results.

A typical tool profile is shown in Fig 11.

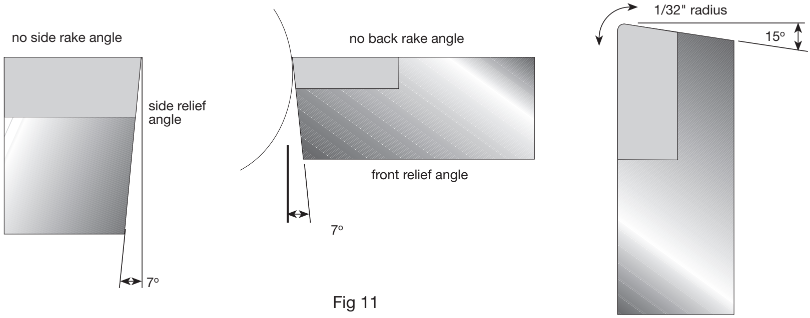


Fig 11

Overspray should be removed by machining outwards from the sprayed area as described for grinding.

Work surface speed should be about 0.3 M/sec (60 ft/min) for sprayed steels. Aluminium Bronze and Copper require a surface speed of approximately 1.26 M/sec (250 ft/min).

Cuts must be light, not exceeding 0.125mm (0.005”) and the traverse speed should be between 0.100mm and 0.150mm (0.004” and 0.006”) per revolution.

Although coolants are not generally recommended for tipped tools, paraffin applied with a brush will assist the cutting action.

Hand Finishing

The finishing of sprayed deposits by hand is sometimes necessary.

Example (1) The hardfacing deposit of molybdenum applied to the stretch bead area of a press die must be finished by hand grinding and stoning.

Example (2) On large flange areas such as high pressure joints on steam turbines the same procedure applies, unless a machinable metal has been used, such as 57E in which case it can be finished by filing and hand scraping.

Lapping

Sprayed metal deposits lend themselves to normal lapping procedures.

If these general recommendations are followed, no trouble should be experienced in finishing sprayed metal.

Superfinishing

Sprayed ceramics can be finished to 5 - 7µ“Ra with this specialised process.

8.8 Spray Process Variables

Typicial Factors Affecting Coating Quality

	FLAME WIRE	FLAME POWDER	ARC	PLASMA	H.V.O.F
POROSITY	Spray Distance, Angle of Spray, Wire Feed, Atomising Air.	Spray Distance, Angle of Spray, Air Jets, Powder Feed Rate.	Spray Distance, Angle of Spray, Wire Feed, Arc Voltage, Nozzle Air.	Spray Distance, Angle of Spray, Gas Flows, Kw, Powder Feed Rate.	Spray Distance, Angle of Spray, Chamber Psi.
OXIDISATION	Spray Distance, Overheating, Wire Feed, Atomising Air, Condition of Flame.	Spray Distance, Overheating, Air Jets, Condition of Flame,. Powder Feed Rate.	Spray Distance, Overheating, Wire Feed, Nozzle Air, Arc Voltage.	Spray Distance, Overheating, Gas Flows, Kw, Powder Feed Rate.	Spray Distance, Overheating, Chamber Psi, Fuel / Oxygen Ratio.
BOND STRENGTH	Spray Distance, Overheating, Atomising Air, Angle of Spray, Pre-Heating.	Spray Distance, Overheating, Angle of Spray, Air Jets, Powder Feed Rate, Pre-Heating.	Spray Distance, Overheating, Angle of Spray, Wire Feed, Arc Voltage, Nozzle Air.	Spray Distance, Overheating, Angle of Spray, Gas Flows, Kw, Powder Feed Rate.	Spray Distance, Overheating, Angle of Spray, Chamber Psi, Fuel / Oxygen Ratio.
DEPOSIT EFFICIENCY	Spray Distance, Angle of Spray, Atomising Air.	Spray Distance, Angle of Spray, Air Jets, Powder Feed Rate.	Spray Distance, Angle of Spray, Arc Voltage, Nozzle Air,	Spray Distance, Angle of Spray, Gas Flows, Kw, Powder Feed Rate. Carrier Gas Flows.	Spray Distance, Angle of Spray, Chamber Psi, Fuel / Oxygen Ratio, Powder Feed Rate, Carrier Gas Flows.

NOTE:- Always refer to Metallisation Technical bulletins or The Pistol Manual for the correct material spraying parameters.

Flame and Arc Systems

1. **Poor preparation:-** Causing reduced bond strength due to:

    i) Insufficient Degreasing
    ii) Poor quality grit
    iii) Incorrect grit size
    iv) Surface contamination

2. **Insufficient pre-heat:-** Causing an increase in coating stress resulting in reduction in bond strength.

3. **Overheating:- during:**

    i) Preheat, causing oxidised surface resulting in a reduction in bond strength
    ii) Spraying, causing an increase in coating stress and oxide content

4. **Condition of flame:-** (combustion processes)

    i) Oxidising, causing oxide rich coating hence increased hardness & wear resistance.
    ii) Reducing, causing fewer oxides hence lower hardness

5. **Spray Distance:-** Controls particle temperature and velocity. Dwell time of particle in the heat source is important. Particles need to be at their hottest and highest velocity prior to impact. Incorrect distance will cause reduced bond strength, unreacted particles within the coating and will reduce deposit efficiency, if the spray distance is allowed to increase or decrease over the recommended for the material being sprayed.

6. **Angle of spray:-** Should be perpendicular to the surface being sprayed. As the angle to the surface is reduced the coating exhibits more porosity, reduced bond strength and has a rougher appearance.

7. **Wire Feed:-** Excessive wire feed (long wire tip) with Flamespray will cause larger molten particles resulting in coarser coating and higher porosity. With the Arc Spray process the wire feed is related to the arc current therefore slow wire feed will cause small particles and fast wire feed will cause larger and hotter particles. Adjustment of the gun voltage will also have a similar effect.

8. **Atomising air:-** Pressures effect particle size (higher the pressure the finer the spray) but the lower the deposit efficiency of the process.

9. **Powder Feed:-** Excessive powder feed can result in unreacted particles contained within the coating, reduction in bond strength and interparticle cohesion and coating hardness.

1. Parameters

For each material, reference should be made to the relevant Technical Bulletin or Gun Instruction Manual for the correct spraying parameters.

2. Gas Flows (Particle Velocity)

If the primary gas flow is too high, particle velocity will be too high. The dwell time will be reduced and therefore the particle will not have received sufficient heat to melt properly

Result: Poor deposit efficiency
Unreacted particles in coating
Poor bond
Soft porous coatings

If gas flows are too low, the particle dwell time in the flame will be too long causing the fines to over-heat and burn out.

There will also be less kinetic energy imparted to the particle.

Result: Poor deposit efficiency
Poor bond
Increase in porosity
Increase in oxides

3. Kilowatts (Volts x Amps)

Too high	Particle will overheat	Result:	Oxidised coating Poor deposit efficiency.
Too low	Reduced heat in plasma	Result:	Unreacted particles Poor deposit efficiency. Poor bond Soft porous coating

4. Powder Feed Rate

Too high Result: Unreacted particles
Poor deposit efficiency
Poor bond
Soft porous coatings

Too low Result: Particles will overheat
Oxidised coating
Poor deposit efficiency

If powdered materials are allowed to become damp, ensure that they are dried prior to spraying as this will affect their powder feed rate.

Depending on the material, drying can be achieved in an oven at approximately 50^{0}C for one hour.

5. Carrier Gas (Powder Feed Unit)

Too high Result; Powder carried through plasma flame, hence this causes Target point deviation (spray does not run parallel with the flame) and Poor deposit efficiency

Too low Result; Powder bounces off plasma flame, hence this causes Target point deviation (spray does not run parallel with the flame) and Poor deposit efficiency

6. Spray Distance

Particles need to be in an optimum condition (temperature & velocity) for bonding to the base material and each other.
Any variation of spray distance from that which is stated will affect;

i) Bond strength
ii) Deposit efficiency
iii) Unreacted particles

High Velocity Oxygen Fuel

1. Parameters

For each material reference should be made to the relevant Technical Bulletin or Gun Instruction Manual for the correct spraying parameters.

2. Chamber Pressure (Particle Velocity)

If the Chamber Pressure is too high, particle velocity will be too high. The dwell time will be reduced and therefore the particle may not have received sufficient heat to melt or soften correctly.

Result: Poor deposit efficiency
Unreacted particles in coating

If chamber pressure is too low, There will be less kinetic energy imparted to the particle.

Result: Poor deposit efficiency
Poor bond
Increase in porosity
Increase in oxides

3. Liquid Fuel / Oxygen Ratio

Too high	Particle will overheat	Result:	Oxidised coating (Substrate Overheating) causes Nozzle Blockage
Too low	Reduced heat	Result:	Unreacted particles causing Poor deposit efficiency and a Poor bond

4. Powder Feed Rate

Too high Result: Unreacted particles causing Poor deposit efficiency and Nozzle Blockage

Too low Result: Spraying time increased

If powdered materials are allowed to become damp, ensure that they are dried prior to spraying as this will affect their powder feed rate.

Depending on the material, drying can be achieved in an oven at approximately 50^{0}C for one hour.

5. Carrier Gas (Powder Feed Unit)

Too high Result; Powder carried through Gas stream, hence the particles are not heated correctly, causing Poor deposit efficiency and Nozzle Erosion

Too low Result; Powder bounces off Gas stream, hence the particles are not heated correctly, causing Poor deposit efficiency and Nozzle Erosion

6. Spray Distance

Particles need to be in an optimum condition (temperature & velocity) for bonding to the base material and each other.
Any variation of spray distance from that which is stated will affect;

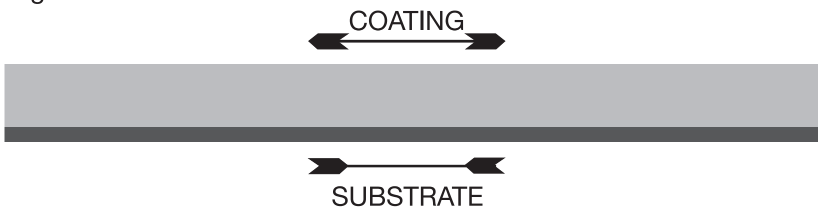
- i) Bond strength
- ii) Deposit efficiency
- iii) Unreacted particles
- iv) Particle Oxidisation

8.9 Coating Stresses

Sprayed particles cool upon impact and shrink therefore creating stresses within the sprayed coating.

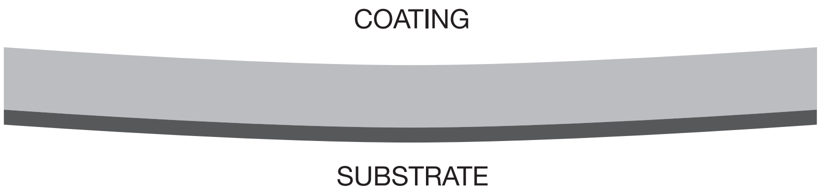
Immediately, the particles cool on the substrate they contract. However since the coating is bonded to the substrate the contraction is restrained and the coating is therefore stretched to tension.

Coating in tension.

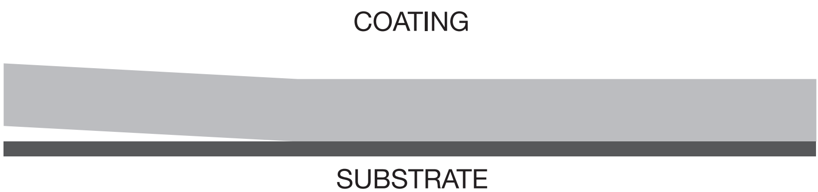


Substrate in compression

When a thick coating is applied to a thin section of base material, the coating stresses can distort the substrate causing it to curl up.



If an excessively thick coating of a highly stressed material is applied to a rigid substrate the tension in the coating is sometimes greater than the bond and causes the coating to lift at the edges.

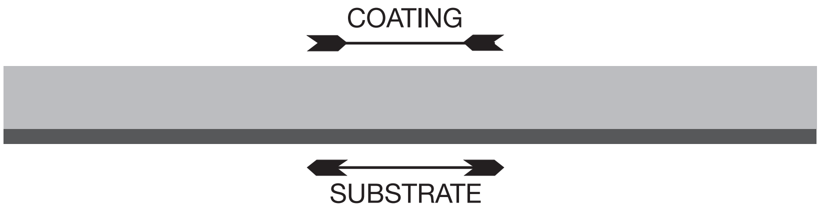


Although this effect would only be observed with an excessive thick coating of high shrink materials, any coating stress will detract from the bond and it is therefore better to eliminate it.

Pre-heating the substrate before applying the coating will expand the base material. Then applying the coating maintaining the pre-heat temperature and then allowing the coating to cool naturally will cause the substrate and coating to contract and thus reduce the coating tension.

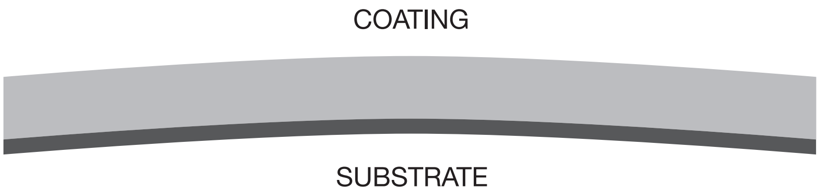
This coating stress is more critical when applying coatings to flat surfaces or internal bores.
With Metallisation H.V.O.F sprayed coatings the opposite stresses occur due to the high velocities involved .This translates to a high kinetic energy for each particle.

Coating in compression.



Substrate in tension.

When a thick coating is applied to a thin section of base material, the coating stresses can distort the substrate causing it to curl down.



This has the added advantage of increasing the bond strength of the coating.

9 - CALCULATING COSTS

9.1 Requirements

The following information lists the basic data necessary to calculate the coating costs, material usage and spraying times.

This information only relates to the cost of spraying and does not include;

The cost of machining - preparation or finishing

The cost of masking for grit blasting or spraying.

The cost of surface preparation

The cost of sealing.

The cost equipment depreciation, Overheads etc

The above costs are based and assessed by practical engineering and accounting experience.

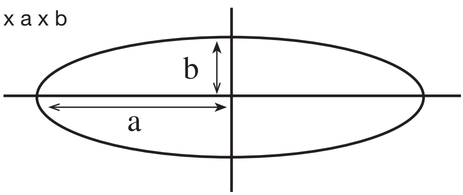
Calculating Sprayed Area

When estimating surface area, an allowance for loss at the edges must be made. It is good practice to add 25mm (1”) to each dimension where there is an edge to compensate for this loss. This also applies when spraying a shaft, in this case, add 25mm (1”) at each end.

An important factor to take into account is the normal variation in coating thickness between the thinnest spot and thickest spot. If a minimum coating thickness is specified be sure to spray the coating thick enough so that no spot will be thinner than the specified minimum.

Formulae

Circumference of a Circle	=	$2 \times \pi \times$ radius
Area of a Circle	=	$\pi \times$ radius ^{2}
Flat Area	=	Length x Width
Area of a Cylinder (Open Ends)	=	$2 \times \pi \times$ radius x Length
Area of a Cylinder (Close Ends)	=	$2 \times \pi \times$ radius x Length + $2 \times \pi \times$ radius ^{2}
Area of a Cone (Excluding Base)	=	$\pi \times$ radius at base x Length
Area of a Cone (Including Base)	=	$\pi \times$ radius at base x Length + $\pi \times$ radius ^{2}
Area of a Sphere	=	$4 \times \pi \times$ radius ^{2}
Area of a Ellipse	=	$\pi \times a \times b$



9.2 Calculating Costs for all the Processes

Calculating coating costs can be aided by referring to the respective Technical Bulletin on the material in question.

In general, the following procedure is :-

1. Quantity of Material Required:

Coverage Rate	=	Kg / Sq.M / 100 microns
Quantity	=	Coverage x Area x Thickness / 100 microns
+ 15% (or similar)	=	Allowance for overspray

2. Cost of Material:

Cost	=	Quantity x Price
Price	=	* / Kg

* Cost of material is available from METALLISATION or its DISTRIBUTOR and must be periodically checked in case of metal market fluctuations.

3. Spraying Time:

Spray Rate	=	Kgs / Hour (Check equipment operating manual for details)
Time	=	$\frac{\text{Quantity}}{\text{Spray Rate}}$

4. Labour Cost:

Labour Rate	=	* / Hour (Estimate rate including overheads)
Cost	=	Rate x Spraying Time

5. Energy:

Consumption Rate	=	* / Kwh(Electricity) and / or * / Hour (Gases)

6. Compressed Air:

Consumption Rate	=	* / Hour
Cost	=	Rate x Spraying Time

7. Consumable Spares:

Consumption Rate	=	* / Kg of material sprayed
Cost	=	Rate x Material Quantity

* = Going rate at time of costing

Note: This calculation excludes Surface Preparation, Equipment Depreciation, Component Handling, Coating finishing, Etc.

10 - TABLES

10.1 Conversion Chart

lbs/Hour - Oz/Min - Kgs/Hour - grms/min

1Kg = 2.2046 lb
1lb = 453.6 grms.
1lb/hour = 7.56 grms/min.
1lb/hour = 0.267 oz/min.

lb/hour	oz/min	Kg/hour	grms/min	lb/hour	oz/min	Kg/hour	grms/min
0.5	0.133	0.2268	3.78	10.0	2.67	4.5360	75.60
0.75	0.200	0.3402	5.67	10.5	2.80	4.7628	79.38
1.0	0.267	0.4536	7.56	11.0	2.937	4.9896	83.16
1.5	0.401	0.6804	11.34	11.5	3.071	5.2164	86.94
1.75	0.467	0.7938	13.23	12.0	3.204	5.4432	90.72
2.0	0.530	0.9072	15.12	12.5	3.338	5.6700	94.50
2.5	0.668	1.1340	18.90	13.0	3.471	5.8968	98.28
3.0	0.801	1.3608	22.68	13.5	3.605	6.1236	102.06
3.5	0.935	1.5876	26.46	14.0	3.738	6.3504	105.84
4.0	1.068	1.8144	30.24	14.5	3.872	6.5772	109.62
4.5	1.202	2.0412	34.02	15.0	4.005	6.8040	113.40
5.0	1.330	2.2680	37.80	15.5	4.139	7.0308	117.18
5.5	1.469	2.4948	41.58	16.0	4.272	7.2276	120.46
6.0	1.602	2.7216	45.36	16.5	4.406	7.4844	124.74
6.5	1.736	2.9484	49.14	17.0	4.539	7.7112	128.52
7.0	1.869	3.1752	52.92	17.5	4.673	7.9380	132.30
7.5	2.003	3.4020	56.70	18.0	4.806	8.1648	136.08
8.0	2.136	3.6288	60.48	18.5	4.940	8.3916	139.86
8.5	2.270	3.8556	64.26	19.0	5.073	8.6184	143.64
9.0	2.400	4.0824	68.04	19.5	5.207	8.8452	147.42
9.5	2.537	4.3092	71.82	20.0	5.340	9.0720	151.20

10.2Hardness Comparison Table

		ROCKWELL				ROCKWELL	
BRINELL 10mm Ball 3000Kg	FIRTH or VICKERS 120Kg	C Scale 120 Cone 150Kg	B Scale 1/16 Ball 100Kg	BRINELL 10mm Ball 3000Kg	FIRTH or VICKERS 120Kg	C Scale 120 Cone 150Kg	B Scale 1/16 Ball 100Kg
800	—-	72	—-	276	278	30	105
780	1220	71	—-	269	272	29	104
760	1170	70	—-	261	261	28	103
745	1114	68	—-	258	258	27	102
725	1060	67	—-	255	255	26	102
712	1021	66	—-	249	250	25	101
682	940	65	—-	245	246	24	100
668	905	64	—-	240	240	23	99
652	867	63	—-	237	235	22	99
626	803	62	—-	229	226	21	98
614	775	61	—-	224	221	20	97
601	746	60	—-	217	217	19	96
590	727	59	—-	211	213	18	95
576	694	57	—-	206	209	17	94
552	649	56	—-	203	201	16	94
545	639	55	—-	200	199	15	93
529	606	54	—-	196	197	14	92
514	587	53	120	191	190	13	92
502	565	52	119	187	186	12	91
495	551	51	119	185	184	11	91
477	534	49	118	183	183	10	90
461	502	48	117	180	177	9	89
451	489	47	117	175	174	7	88
444	474	46	116	170	171	6	87
427	460	45	115	167	168	5	87
415	435	44	115	165	165	4	86
401	423	43	114	163	162	3	85
388	401	42	114	160	159	2	84
375	390	41	113	156	154	1	83
370	385	40	112	154	152	—-	82
362	380	39	111	152	150	—-	82
351	361	38	111	150	149	—-	81
346	352	37	110	147	147	—-	80
341	344	37	110	145	146	—-	79
331	335	36	109	143	144	—-	79
323	320	35	109	141	142	—-	78
311	312	34	108	140	141	—-	77
301	305	33	107	135	135	—-	75
293	291	32	106	130	130	—-	72
285	285	31	105	—-	—-	—-	—-

NOTE : The above Hardness Comparison Table is for guidance only.

10.3Thermal Spraying Terminology

Abrasive. Material such as crushed chilled cast iron, crushed steel grit, aluminium oxide, silicon carbide, flint, garnet, of crushed slag used for surface roughening.

Abrasive Blasting. See preferred term Blasting.

Absorb. To take in and engulf wholly.

Acoustic Room. A soundproof enclosure, containing thermal spraying and sometimes related auxiliary equipment. Its design and construction prevent any unacceptable process noises from interfering with normal work in the environment surrounding the enclosure.

Adhesion. A binding force that holds together molecules of substances whose surfaces are in contact or near proximity.

Adhesive Strength. The magnitude of attractive forces, generally physical in character, between a coating and a substrate. Two principle interactions that contribute to the adhesion are van der Waals forces and permanent dipole bonds.

Air Cap. A device for forming, shaping and directing an air flow pattern for the atomisation of wire or ceramic rod.

Air Cooler. A device used to direct compressed air to prevent overheating of the thermal spraying deposit or the substrate.

Air Filter. Mechanism for cleaning air of contaminants such as water, oil, and solid matter.

Alumina. A chemical compound (aluminium oxide); a ceramic used in powder or rod form in thermal spraying operations. May also be a blasting medium.

Anchoring. A supplemental method of locking the thermal spray deposit to the substrate by screw heads, studs, or similar means.

Anode. The electrode is maintained at a positive electrical potential. In typical plasma thermal spraying gun designs, this is the front electrode, constructed as a hollow nozzle and usually fabricated from copper. In electric arc thermal spraying guns, one feed wire is the positive electrode.

Arc. A luminous discharge of electrical current crossing the gap between two electrodes.

Arc Chamber. The confined space within the plasma thermal spraying gun enclosing the anode and cathode, in which the arc is struck.

Arc Spraying (ASP). A thermal spraying process using an arc between two consumable electrodes of surfacing materials as a heat source and a compressed gas to atomise and propel the surfacing material to the substrate.

Atomisation. (1) The division of molten material at the end of the wire or rod into fine particles. **(2)** The process used in the manufacture of powder.

Backfire. The momentary recession of the flame into the spray gun, followed by immediate reappearance or complete extinction of the flame.

Blasting. A method of cleaning or surface roughening by a forcibly projected stream of sharp angular abrasive.

Bond Coat. A preliminary (or prime coat) of material that improves adherence of the subsequent spray deposit.

Bond Strength. The force required to pull a coating free of a substrate, usually expressed in kPa (psi).

British Thermal Unit (BTU). A unit of measure for heat (equal to 1055 J).

Build-up. A surfacing variation in which surfacing metal is deposited to achieve the required dimensions.

Carbide. A chemical compound formed between carbon and a metal or metals; examples are tungsten carbide, tantalum carbide, titanium carbide, chromium carbide.

Carburizing Flame. A standard term for a reducing flame.

Carrier Gas. The gas used to carry powdered material from the powder feeder or hopper to the gun.

Cast. The twist warp or curvature of a metal wire.

Cathode. The electrode maintained at a negative electric potential. In a plasma gun it is usually the rear electrode, conically shaped, and fabricated from tungsten or thoriated tungsten.

Cermet. A physical mixture of ceramics and metals; examples are alumina plus nickel and zirconia plus nickel.

Cladding. A surface variation that deposits or applies surfacing material, usually to improve corrosion or heat resistance.

Clad Metal. A laminar composite consisting of a metal, with a metal of different chemical composition applied to one or two sides.

Closed Loop Control. A method to continuously monitor and control thermal spray parameters to assure repeatability of the process and coatings.

Coalesce. To grow or come together; fuse; unite

Coating. (1) The act of building a deposit on a substrate, (2) the spray deposit.

Coating Density. A standard term for spray deposit density ratio.

Cohesive Strength. (1) A measure of the cohesive bond within a coating, as opposed to coating-to-substrate bond (adhesive strength), (2) the tensile strength of a coating, usually expressed in kPa (psi).

Coating Stress. The stresses in a coating resulting from rapid cooling of molten material or semi-molten particles as they impact the substrate. Coating stresses are a combination of body and textural stresses.

Coefficient of Thermal Expansion. The ratio of the change in length per degree rise in temperature.

Composite Coating. A coating consisting of two or more dissimilar spray materials which may or may not be layered.

Compressed Air Mask. A force feed type of face mask with a suitable regulator worn by the thermal spraying operator to provide a fresh air supply.

Cone. The conical part of an oxyfuel gas flame next to the orifice of the tip.

Contact Tube. A device which transfers current to a continuous electrode.

Control Console. The instrument unit from which the gun is operated and operating variables are monitored and controlled.

Controlled Atmosphere Chamber. An enclosure or cabinet either filled with an inert gas or evacuated to below atmospheric pressure in which thermal spraying can be performed to minimise, or prevent, oxidation of the coating or substrate.

Cord. A plastic tube filled with powder and extruded to form a compact, flexible layer level wound wire-like “cord”.

Cospray. Thermal spraying of two or more dissimilar materials through a single gun using multiple powder injection ports.

Critical Resolved Shearing Stress. The shearing stress on the slip plane necessary to produce slip (threshold value).

Cylinder Manifold. A multiple header for interconnection of gas or fluid sources with distribution ports.

Defect. A discontinuity or discontinuities that by nature or accumulated effect (for example, total crack length) render a part or product unable to meet minimum applicable acceptance standards or specifications. This term designates rejectability.

Degrease. To remove oil or grease from the surface of the workpiece. See Solvent Greasing.

Deliquescent. The process of melting or becoming liquid by absorbing moisture from the air.

Density. The mass or quantity of matter of a substance per unit volume, expressed as grams per cubic centimetre, or pounds per cubic inch.

Deposit. A standard term for thermal spraying deposit.

Deposition Efficiency. The ratio, usually expressed in percent, of the weight of spray deposit to the weight of the material sprayed.

Deposition Rate. The weight of material deposited in a union of time.

Dessicant. A chemical used to attract and remove moisture from air or gas.

Detonation Flame Spraying. A thermal spraying process variation in which the controlled explosion of a mixture of fuel gas and oxygen is utilised to melt and propel the material to the workpiece.

Dewpoint. Temperature at which moisture will condense from humid vapours into a liquid state.

Discontinuity. An interruption of the typical structure of a coating, such as a lack of homogeneity in the mechanical, metallurgical, or physical characteristics of the material. A discontinuity is not necessarily a defect. See also Defect and Flaw.

Dovetailing. A method of surface roughening involving angular undercutting to interlock the spray deposit.

Dwell Time. The length of time the spray material is exposed to the heat zone which produces and sustains a molten condition.

Ear Protection. COSH, or other safety agency approved devices for the reduction of sound audible to the outer ear.

Edge Effect. Loosening of the adhesion bond between the spray deposit and the substrate at the workpiece edges.

Edge Loss. Spray deposit lost as overspray resulting from spraying near the edge of the workpiece.

Elastic Modulus. The ratio of stress, within the proportional limit, to the corresponding strain.

Electrode. A component for the electrical circuit through which current is conducted to the arc. See Anode and Cathode.

Enclosure. See preferred term Acoustic Room.

Exhaust Booth. A mechanically ventilated, semi-enclosed area in which air flow across the work area is used to remove fumes, gases and solid particles.

Eye Protection. Proper helmets, face masks or goggles which are required to be used to protect the eyes from ultra-violet and infra-red radiation during thermal spraying operations.

Face Shield (eye protection). A device positioned in front of the eyes and over all or a portion of the face to protect the eyes and face. See also Hand Shield and Helmet.

Feed Rate. A non-standard term for spray rate.

Filter Glass. (eye protection). An optical material that protects the eyes against excessive ultra-violet, infra-red and visible radiation.

Fines. A material finer than a particular mesh size under consideration.

Flame Spraying (FLSP). A thermal spraying process in which an oxyfuel gas flame is the source of heat for melting the surfacing material. Compressed gas may or may not be used for atomising and propelling the surfacing material to the substrate.

Flashback. A recession of the flame into or back of the mixing chamber of the thermal spraying gun.

Flashback Arrestor. A device to limit damage from a flashback by preventing propagation of the flame front beyond the location of the arrestor.

Flaw. An undesirable discontinuity. See Defect.

Flow Meter. A device for indicating the rate of gas flow in a system.

Fretting. Surface damage resulting from relative motion between surfaces in contact under pressure.

Fuel Gases. Gases such as acetylene, natural gas, hydrogen, propane, and other fuels, and hydrocarbons, usually used with oxygen for heating.

Furnace Fusing. The melting together of the spray deposit and the substrate which results in coalescence. The furnace offers the advantages of controlled heating, cooling and protective atmosphere.

Fused Spray Deposit. A self-fluxing spray deposit which is subsequently heated to coalescence within itself and with the substrate.

Fusion. The melting together of filler metal and metal (substrate), which results in coalescence.

Fusion Temperature. In thermal spraying, during the fusing of self-fluxing coatings, the narrow temperature range within which the coating surface exhibits a glassy or highly reflective appearance.

Galvanic Corrosion. Corrosion caused by spontaneous current between two dissimilar conductors in an electrolyte or between two dissimilar conductors in dissimilar electrolytes. If the two dissimilar metals are in contact, the reaction is referred to as couple action.

Gas Cylinder. A portable container used for transportation and storage of a compressed gas.

Gas Regulator. A device for controlling the delivery of gas at some substantially constant pressure.

Gradated Coating. A thermal spraying deposit composed of mixed materials in successive layers which progressively change in composition from the constituent material lot the, substrate to the surface of the sprayed deposit. Also referred to as graduated or graded coating.

Gravity Feed. A process by which powder is fed into a thermal spraying gun by gravity.

Grit. See preferred term Abrasive.

Grit Blasting. See preferred term Blasting.

Grit Size. The particle size and distribution of abrasive blasting grains. Usually expressed by Society of Automotive Engineers numbers, such as SAE G25.

Gun. A non-standard term for thermal spraying pistol.

Gun Extension. The extension tube attached in front of the thermal spraying gun to permit spraying within confined areas or deep recesses.

Hand Shield. A protective device for shielding the eyes, face and neck. A hand shield is equipped with a filter plate and is designed to be held by hand.

Hardfacing. A surfacing variation in which surfacing metal is deposited to reduce wear.

Helmet. A device designed to be worn on the head to protect eyes, face and neck from arc radiation, radiated heat, spatter or other harmful matter.

HVOF/HVAF (High Velocity Oxygen Fuel/High Velocity Air Fuel). A high velocity flame spray process.

Inert Gas. A gas which does not normally combine chemically with the substrate or the deposit. Typical examples are argon and helium.

Injection Angle. Angle at which powder is injected into flame. Powder injected at 0° is injected perpendicular to the flame. Positive angles indicate injection in direction of flame; negative angles in direction against flame.

Interface. The contact surface between the spray deposit and the substrate.

Ion. An atom or group of atoms forming a molecule that carries a positive or negative charge as a result of having lost or gained one or more electrons.

Keying. A non-standard term for mechanical bond.

Lamination. A thin layer, as in the overlaid particles in a thermal spray deposit.

Low Pressure Plasma Spray. See preferred term Vacuum Plasma Deposition.

Manifold. See Cylinder Manifold.

Mask. A device for protecting a substrate surface from the effects of blasting or adherence of a spray deposit.

Matrix. The major continuous substance of a thermal spraying coating as opposed to inclusions or particles of materials having dissimilar characteristics.

Mechanical Bond. The adherence of a thermal spraying deposit to a roughened surface by the mechanism of particle interlocking.

Metallizing. See preferred term Thermal Spraying.

Metallurgical Bond. The principal bond that holds metals together and is formed between base metals and filler metals in all processes. This is a primary bond arising from the increased spatial extension of the valence electron wave functions when an aggregate of metal atoms is brought close together.

Neutral Flame. An oxyfuel gas flame in which the portion used is neither oxidising nor reducing. See also Oxidising Flame and Reducing Flame.

Nontransferred Arc. An arc established between the electrode and the constricting nozzle. The workpiece is not in the electrical circuit.

Nozzle. (1) A device which directs shielding media, (2) a device that atomises air in an arc spray gun, (3) the anode in a plasma gun, (4) the gas burning jet in a rod or wire flame spray gun.

Nozzle Accumulation. Surfacing material deposited on the inner surface and on the exit end of the nozzle.

Open Circuit Voltage. The potential difference applied between the anode and cathode prior to initiating the arc.

Overspray. The excess spray material that is not deposited on the part being sprayed.

Oxide. A chemical compound, the combination of oxygen with a metal forming a ceramic; examples - aluminium oxide, zirconium oxide.

Oxidising Flame. An oxyfuel gas flame having an oxidising effect (excess oxygen).

Oxyfuel Gas Spraying. A non-standard term for flame spraying.

Parameter. A measurable factor relating to several variables; loosely used to mean a spraying variable, spraying condition, spray rate, spray distance, angle, gas pressure, gas flow, etc.

Parent Metal. A non-standard term for substrate.

Partial Size. The average diameter of a given powder or grit granule.

Particle Size Distribution. Classification of powdered materials as determined by various testing methods defining the particle sizes and quantities in a given sample.

Particle Size Range. See preferred term Particle Size Distribution.

Particle Stress. Residual stresses within an individual sprayed particle.

Pass. A single progression of the thermal spray device across the surface of the substrate.

Pistol. See Thermal Spraying Gun.

Plasma. A gas that has been heated by an electric arc to at least a partially ionised condition, enabling it to conduct an electric current.

Plasma Gas. The gas introduced into the arc chamber and ionised by the arc to form a plasma.

Plasma Spraying (PSP). A thermal spraying process in which a non-transferred arc is utilised as the source of heat that ionises a gas which melts and propels the coating material to the workpiece.

Plenum Chamber. The space between the inside wall of constricting nozzle and the electrode.

Porosity. Cavity type discontinuities within a sprayed coating (voids).

Postheating. The application of heat to an assembly after a thermal spraying operation.

Powder. Material manufactured into finely divided particles. When explicitly blended for thermal spraying, powder falls within a specific mesh range, usually finer than 120 mesh (125 microns). Fine powder is usually defined as having particles smaller than 325 mesh (44 microns).

Powder Alloy. Powder prepared from a homogeneous molten mixture of elements, and sometimes entrapped carbides or metal oxides. All of the particles have approximately the same composition.

Powder Blend. A heterogeneous mixture of two or more alloy powders.

Powder Clad (Wire Clad). Powder or wire wherein one alloy is encapsulated in another; a composite.

Powder Composite. Two or more independent materials, combined to form a single integrated unit. May be either chemically clad or mechanically agglomerated.

Powder Feeder. A device for conveying powdered materials to thermal spraying equipment.

Powder Feed Gas. See preferred term Carrier Gas.

Powder Feed Rate. The quantity of powder introduced into the hot, gaseous stream per unit of time.

Powder Flame Spraying. A thermal spraying process variation in which the material to be sprayed is in powder form; all oxyfuel gas processes. See Flame Spraying (FLSP).

Powder Injection. Feeding of a powder through a powder port into a thermal spray flame.

Powder Metallizing. A non-standard term for powder flame spraying.

Powder Port. Internal or external orifice through which powder is injected into flame or plasma.

Preheat. The heat applied to the base metal or substrate immediately before spraying.

Preheat Temperature. A specified temperature that the substrate is required to attain immediately before material deposition.

Primary Gas. The major constituent of the arc gas fed to the gun to produce the plasma; usually argon or nitrogen.

Procedure. The detailed elements of a process or method used to produce a specific result.

Protective Atmosphere. A gas envelope or vacuum surrounding the part to be thermally sprayed, with the gas composition controlled with respect to chemical composition; dewpoint, pressure, flow rate, etc. Examples are inert gas, combusted fuel gases, hydrogen and vacuum.

Protective Barriers. Curtains or portable fireproof canvas shields, sometimes required to enclose work areas, where there is a possibility of the spray stream being misdirected, or where the glare of the arc or flame could injure unprotected eyes.

Protective Clothing. Leather or metal coated articles designed to prevent burns from ultraviolet radiation or misdirected particles.

Pseudo Coating. Thermal spraying of two dissimilar materials through a spray pistol.

Quench Rate. The speed at which a sprayed particle cools upon striking the surface of the substrate.

Reducing Flame. A gas flame having a reducing effect (excess fuel gas)

Regulator. See Gas Regulator.

Residual Stress. Stress remaining in a structure or member as a result of thermal or mechanical treatment or both. See Coating Stress.

Root Mean Square (RMS). A method of defining the average roughness of a surface. It is the square root of the sum of all individual measurements divided by the number of measurements.

Rough Threading. A method of surface roughening which consists of cutting threads with the sides and tops of the threads jagged and torn.

Screen. One of a set of sieves, designated by the size of the openings, used to classify and sort powder to particle size.

Seal Coat. Material applied to infiltrate and close the pores of a thermal spraying deposit.

Secondary Gas. The minor or second constituent of the arc gas fed to the gun to produce plasma.

Self-Bonding Materials. Those materials that exhibit the characteristics of forming a metallurgical bond with the substrate in the as-sprayed condition.

Self-Fluxing Alloys. Surfacing materials that "wet" the substrate and coalesce when heated to their melting point, without the addition of an externally applied flux. These alloys contain boron or silicon, or both, as fluxing agents.

Shadow Mask. A protective device that partially shields an area of the work, thus permitting some overspray to produce a feathering at the coating edge.

Shear Stress. The stress on the slip plane produced by external loads tending to slide adjacent planes with respect to each other in the direction parallel to the planes.

Shielding Gas. Protective gas used to prevent or minimise atmospheric contamination. See also Protective Atmosphere.

Shrinkage Stress. A non-standard term for residual stress.

Sieve. See preferred term Screen.

Sieve Analysis. A method of determining particle size distribution, usually expressed as the weight percentage retained upon each of a series of standard screens of decreasing mesh size. See also Particle Size Distribution.

Solvent Degreasing. The removal of oil, grease and other soluble contaminants from the surface of the workpiece by immersion in suitable cleaners.

Spalling. The flaking or separation of a sprayed coating.

Spray. A moving mass of dispersed liquid droplets or heat softened particles.

Spray Angle. The angle of particle impingement, measured from the surface of the substrate to the axis of the spraying nozzle.

Spray Booth. See term Exhaust Booth.

Spray Deposit. The coating or layer of surfacing material applied by a thermal spraying process.

Spray Distance. The distance maintained between the thermal spraying gun nozzle tip and the surface of the workpiece during spraying.

Spray Dry. A method for making thermal spray powder, especially ceramic powder, by spraying a slurry into a heated chamber and drying it to powder.

Spray Rate. The rate at which surfacing material passes through the gun.

Spraying Sequence. The order in which different layers of similar or different materials are applied in a planned relationship, such as overlapped, superimposed, or at given angles.

Stabilising Gas. The arc gas, ionised to form the plasma, is usually introduced into the arc chamber tangentially. The relatively cold gas chills the outer surface of the arc stream, tending to constrict the plasma, raise its temperature, and force it out of the anode (nozzle) in a steady, relatively unfluctuating stream.

Substrate. Any material to which a thermal spraying deposit is applied.

Superfines. Extra small, minute powder particles, usually less than five microns in size.

Surface Feet Per Minute (SFPM). Linear velocity of the thermal spray gun as it traverses the length of the workpiece. Also, the circumferential velocity of the substrate.

Surface Preparation. The operations necessary to produce a desired or specified surface condition.

Surface Roughening. A group of methods for producing irregularities on a surface. See also Dovetailing, Rough Threading and Blasting.

Surface Coating. The application by thermal spraying of a layer or layers of material to a surface to obtain desired properties or dimensions, as opposed to making a joint.

Surface Coating Material. The material that is applied to a substrate during surface coating.

Thermal Spraying (THSP). A group of processes in which finely divided metallic or non-metallic surfacing materials are deposited in a molten or semi-molten condition on a substrate to form a spray deposit. The surfacing material may be in the form of powder, rod, cord or wire. See also Arc Spraying, Flame Spraying and Plasma Spraying.

Thermal Spraying Gun. A device for heating and directing the flow of a surfacing material.

Thermal Stress. Stress resulting from non-uniform temperature distribution.

Throughput. The weight or length of spray wire or rod melted in a unit of time.

Torch. A device used for fusing sprayed coatings; it mixes and controls the flow of gases.

Torch Fusing. The use of a torch to heat and melt a fusible spraying deposit to produce coalescence.

Transferred Arc. An arc established between the plasma torch and the workpiece. The workpiece is part of the electrical circuit. Can be reversed to pre-heat and clean a substrate surface.

Traverse Speed. The linear velocity at which the thermal spraying gun traverses across the workpiece during the spraying operation.

Undercutting. A step in the sequence of surface preparation involving the removal of substrate material.

Vacuum Plasma Deposition (VPD). A thermal spraying process variation utilising a plasma gun confined to a solid enclosure. The enclosure is evacuated and the spraying performed under low pressure, usually below 10 Toff.

VPS, Low Pressure Plasma Spray (LPPS). VPS underwater plasma spraying.

Water Wash Booth. The forcing of exhaust air and fumes from a spraying booth through water so that the vented air is free of thermal sprayed particles or fumes.

Wire Feed Speed. The rate of speed at which the wire is consumed.

Wire Flame Spraying. A thermal spraying process variation in which the surfacing material is in wire form. See Flame Spraying (FLSP).

Wire Metallizing. See preferred term Wire Flame Spraying.

Wire Straightener. A device used for controlling the cast of coiled wire to enable it to be easily fed into the gun.

Workpiece. The object or surface to be coated. See preferred term substrate.

10.4Examples of Typical Applications

Light Engineering Applications

Metallisation Equipment and Materials are employed in many light engineering applications. As the examples below indicate, uses range from salvage and reclamation to the provision of wear and corrosion resistance. In many cases, reclamation coatings may give much longer lives than the original materials. These examples indicate merely a typical selection of the vast range of light engineering applications.

Each coating system is selected for a specific application and careful attention is paid to the component material and size, the operating conditions, the deposit thickness required and the facilities available. Details of surface preparation, bond coats and deposit thickness have been omitted below for clarity of presentation.

APPLICATION	COATING		REASON FOR USE
Lathe Beds	Gas	99E	Resist sliding wear and abrasion
Machine Slideways	Gas	99E	Reclamation
Press Tool Slideways	Gas	99E	Reclamation and improved wear resist-ance
Coining Press Slide	Arc	15E	Provide reduced friction
Honing Tool Slide	Gas	99E	Improved wear resistance on side sliding edge
Slideway Support Plate	Arc	60E	Improved wear resistance
Press Tools	Gas	99E	Reclaim wear due to sliding steel shaft
Machine Tool Arbor	Gas	99E	Wear resistance on bearing aligning arbor
Drilling Spindles	Gas	P225	Wear resistance and low friction at high speeds
Armature Shafts	Arc	60E	Reclamation of journals
Electric Motor Spindle	Arc	60E	Reclamation
Motor Cages	Arc	05E	Provide electrical conductivity
Worm Gears	Arc	15E	Reclamation of OD of bosses
Welding Rod Tips	Arc	15E	To improve arc striking
Welding Electrode Holders	Gas	P255	Insulation and protection against spatter
Bearing Housings	Various Coatings		Reclaim bearing locations and extended life
Pulley Seats	Gas	99E	Salvage and reclaim
Compressor Pistons	Various materials depending on original compressor bore components. For reclamation.		
Clutch Discs	Arc	60E/05E	Reclamation
Press Brake Cranks	Arc	60E	Reclamation
Brake Cam Shafts	Arc	60E	Reclamation

APPLICATION	COATING		REASON FOR USE
Brake Test Rolls	Gas	60E + P205	High friction and wear resistance
Drive Shafts	Arc	15E	Wear resistance and low friction on road
			sweeper brush drive shaft
Impeller Blades	Arc	60E	Abrasion resistance
Impeller Blades	Gas	99E	Abrasion resistance
Impeller Journals	Arc	60E	Reclamation and improved wear resistance
Turbine Casings	Gas	P205	Abrasion resistance
Valves	Gas	P205	Abrasion resistance
Cooking Utensils	Arc	80E	Wear resistant base for PTFE coating
Plastic Pipe Joint Casings	Arc	55E	Key for PTFE coating
Plastic Pipe Joint Dies	Arc	55E	Heated surface for gas pipe welding
Forming Rolls	Gas	P325	Wear resistance
Pump Shafts	Gas	P325	Wear and corrosion resistance
Pump Sleeves	Gas	P325	Wear and corrosion resistance
Pump Shaft Journals	Arc Gas	60E + P216	Reclamation and corrosion resistance
Rotary Seals	Gas	P225	Seal Surface
Cup Seals	Gas	P225	Seal Surface
Glass Shearing Blades	Gas	P325	Increased life of blade edges
Explosive Packing Plungers	Gas	P505	Reduced manufacturing cost and increased life

Transport Industry Applications

Metallisation Arc and Gas Spraying Equipment and Materials are extensively used in all areas of road, rail, sea and air transport to reclaim and salvage over-machined or worn parts, to provide friction and wear control on new parts, to prevent corrosion and to reduce tooling costs.

Road and Rail Applications	
Diesel Engine Frames	Arcsprayed on worn body parts Aluminium or Al-Si to required thickness. To repair wear damage and extend life
Camshaft Housings	Arcsprayed on bore surfaces Aluminium Silicon. To salvage over-machined articles
Pistons	Arc or gas sprayed on diameter Material and thickness depends on piston material. To reclaim wear damage
Piston Rings	Gas sprayed on outside diameter. Molybdenum to .25mm. To confer wear and scuff resistance
Cylinder Liners	Gas sprayed on outside diameter. Alumina to .3mm To resist corrosion and cavitation erosion.
Valve Seats	Gas sprayed on seat ring. Alumina to .15mm. To provide oxidation resistance.
Valve Stems	Gas sprayed on collet friction area. Molybdenum to .25mm. To provide wear and scuff resistance.
Camshafts	Gas sprayed in various areas. Molybdenum as required. To salvage worn or over machined articles.
Crankshaft Locating Diameters	Arcsprayed in various areas 75E+60E to 0.3mm. To salvage mis-machined components
Crankshaft Journals	Arcsprayed 75E+60E as required (up to 1.5mm). To salvage over-machined parts and to reclaim worn components.
Crankshaft Pulley	Gas sprayed. Molybdenum as required. Salvage or reclaim.
Water Pumps	Gas spray gland area on pulley boss. Molybdenum as required. To provide wear resistance.
Syncromesh Cones	Gas sprayed on friction area. Molybdenum to .3mm. To provide wear resistance.
Syncromesh Blocking Rings	Gas sprayed on friction area. Molydenum to .25mm. To provide wear resistance.
Gear Selector Forks	Gas sprayed on contact areas. Molybdenum or bronze to .25mm. To provide friction and wear resistance.
Rear Axles	Arc sprayed on end bearing fittings. 75E and 30E as required. To reclaim worn or mis-machined parts.

Road and Rail Applications	
Stub Axles	Arc sprayed on end bearing fittings. 75E and 30E as required. To reclaim worn or mis-machined parts.
Half Shafts	Arcsprayed where necessary. 30E to required thickness. To utilise undersize forgings.
King Pins	Arcsprayed on bearing surfaces 60E to required thickness. To recover over-machined parts.
Brake Cylinders	Arcsprayed inside bore. 75E up to 1mm. To recover wear damage.
Brake Drums	Arcsprayed on friction area. 75E and 60E as required. To reclaim wear damage.
Brake Discs	Arcsprayed on friction areas of light alloy discs. 60E/05E composite of various steels. To provide lightweight disc brakes on cranes, motorcycles etc.
Clutch Plates	Arcsprayed 05E/65E composite to reclaim wear damage and heat checking
Tank Wheels	Arcsprayed on rim area of light alloy wheels. 10E and 65E as required. To provide easily salvaged wear resistant surfaces.
Torsion Bars	Arcsprayed over surface of railway torsion bars. Aluminium to reduce stress corrosion.
Exhaust Manifolds	Arcsprayed on exterior surface. Aluminium to .15mm. To provide oxidation and corrosion resistance.
Exhaust Pipes	As above
Chassis Components	Arc or gas sprayed outside and inside. Zinc or aluminium to .1mm and sealed. To provide corrosion resistance
Freight Truck Bodies	As above
Tooling Applications	
Press Tools	Gas sprayed on worn areas. Molybdenum as required. To repair wear damage.
Plastic Moulding Tools	Arcsprayed on to suitable patterns. Zinc or Tin Zinc plus Zinc to 3mm. To provide low cost tooling for seats, steering wheel bosses, trim, body panels, lighting cluster, spoilers etc., made of SMC, DMC, Polyurethane, Expanded Polyurethane RIM.

Marine Applications

Spraying is used extensively by military forces and in limited instances on civil ships. However, some classification societies are reluctant to grant widespread approval for spraying.

The following examples indicate where spraying has been used for reclamation and in some cases, for original equipment.

APPLICATION	COATING AND REASON FOR USE
Tailshaft	Arcspray on shaft areas 75E + 15E
Tailshaft Bearing Areas	Arcspray 15E
Tailshaft Bearing Areas	Arcspray 30E to build up plus flamespray P225 for wear resistance.
Propellor Shaft	Flamespray molybdenum plus 60E on journals
Intermediate Shaft	Arcspray 15E on area in way of loose coupling. Arcspray 15E on gunmetal liners
Secondary Propulsion	Arcspray mainshaft with 70E Arcspray piston and rings with 15E
Turbo Hydraulic Pump	Arcspray rotor shaft with 75E + 60E
Main Circuit Pump	Arcspray turbine rotor shaft with 75E + 60E
Pumping Station	Flamespray piston guide with 15E and 45E.
Madden Pump	Arcspray water cylinder with 75E + 15E
Bilge Pump	Flamespray shaft with molybdenum + 60E
Turbo Blower	Flamespray sequential nozzle valve with molybdenum + 60E
Draught Blower	Arcspray rotor shaft, gear shaft and impeller shaft with 75E + 60E
Air Conditioning Compressor	Arcspray crankshaft with 75E + 60E
Generator	Arcspray armature shaft pedestal bearing journal with 75E + 60E
Steering Gear Hydraulic Cylinder	Arcspray cut off rings with 75E + 10E Arcspray piston and cut off rings with 15E
Rudder	Flamespray cross head pin with 75E + 70E. Flamespray stock and steering ram with 99E + 60E
Hydroplanes	Flamespray stock with 75E + 70E. Flamespray pistol with 75E and phosphor bronze. Arcspray head pin with 75E + 70E. Arcspray connecting rod with 75E + 70E.
Hydroplane Yokes	Arcspray pins with 75E + 70E
Hydroplane Tiller	Arcspray journals with 75E + 70E
Hydroplane Mainshaft	Arcspray journals with 75E + 70E
Hydroplane Hydraulic Cylinder	Arcspray piston and cut-off rings with 75E + 10E
Hydraulic Ram	Arcspray piston with 75E + 10E Stabiliser Flamespray hydraulic cylinder with 99E + 80E stainless
Air Loaded Hydraulic ACC Equipment	Arcspray guide rings with 75E + 15E

APPLICATION	COATING AND REASON FOR USE
Sidelocking Cylinder	Flamespray ram with 99E + 55E stainless
Hydraulic Gravity Davit	Arcspray operating lever housing with 15E
Hydraulic Anchor	Flamespray windlass housing with 99E + 55E Stainless
Power Loading Gear	Arcspray winch end covers with 75E + 70E
Capstan	Arcspray drive shaft with 15E
Hoist and Traverse Winch	Flamespray body clutch with 99E + 60E
Winches	Arcspray pivot shaft with 10E Arcspray vertical shaft with 10E
Gear Wheel	Flamespray shaft with 99E and 60E
Washing Machines	Flamespray shafts with 99E + 55E
Radar Mast	Flamespray cross head and casing with 99E + 70E
Short Mast	Arcspray body gland with 15E Arcspray lifting pins with 75E + 15E
AKU Mast	Flamespray head with 99E + 55E stainless
The following are general examples of metal spraying for corrosion in marine transport applications.	
Weather Decks	Arc or flamespray with zinc
Radar Masts	As above
Bridge Superstructures	As above
Ships Holds	As above
Storage Tanks	As above
Liquid Cargo Tanks	As above
Steam Pipes	Arcsprayed aluminium
Exhaust Pipes	As above
Aircraft Carrier Decks	Arcsprayed aluminium on aircraft launch areas
Steam Valves	Arc or flamesprayed aluminium
Boiler Skirts	As above
Ladders	As above
Instrument Stands	As above
Lifeline Stanchions	As above
Diesel Exhaust Stacks	Arcsprayed aluminium. Also gives heat resistance
Missile Exhaust Deflectors	As above. Also gives heat resistance
Helicopter Deck Tiedowns	Arc or flamesprayed aluminium
Steam Riser Valves	As above
Helicopter Landing Decks	Arcsprayed aluminium. Also gives non-skid surface
Deck Walkways	Arcsprayed aluminium. Also gives non-skid surface
Gun Turrets	Arcsprayed aluminium. Also protects against corrosion from burning propellant and flame resistance
Tub Snorkel Cages	Arc or flamesprayed aluminium
Mini-Sub Hulls	Flamesprayed with zinc

Electrical Engineering Applications

Metallisation Equipment and Materials are used in the electrical industries to apply surface coatings for a variety of applications. The traditional uses of the process (for corrosion protection, component salvage and reclamation and wear resistance) are complemented by the ability to apply sprayed coatings to almost any substrate material in order to confer insulating, resistive and conductive properties.

APPLICATION	COATING	REASON FOR USE
Steel Mill Tinning Rolls	Arc 05E 40mm	Sprayed over entire low alloy surface to provide high contact carrying capacity
Railway Coach Axles	Arc 05E 6mm	For electrical conductivity on central brush path
Electrical Motor Armature Shafts	Arc Steels 25mm	Reclaim wear damage
Bearing Housings	Arc Steels 12mm	As above
Slip Rings	Gas 99E	Reclaim worn periphery
Slip Rings	Arc or Gas 05E	Reclaim contact area
Commutators	Arc or Gas 05E	As above
Arc Furnace Electrodes	Arc 01E .3mm	Prevent oxidation
Electrode Holders	Gas P255 .3mm	Electrical insulation and splatter protection
Induction Heating Coils	Gas P255	Electrical insulation
Buzbars	Gas Brazing Alloy	Accurate emplacement of bronze prior to joining
Foil Wound Capacitors	Arc 02E or 07E 25/3mm	Provides easily soldered or welded surfaces on end faces
Carbon Resistors	Gas Brass .25mm	Often fully automated. Applied to end faces for joining on direct electrical contact
Carbon Resistors	Gas 01E .25mm	Electrical contact between resistors in arrestor stock
Carbon Resistors	Gas P255 .25mm	Electrical insulation on periphery of above parts
Bridge Rectifiers	Gas 14E .05mm	Electrical contact
Radar & Microwave Reflectors	Arc or Gas 02E or 01E 3mm	Sprayed onto former and then backed with resin to provide free-standing parabolic or hyperbolic reflectors and collectors
Valves	Gas 01E .1mm	Outer gas envelope sprayed to provide reflector and earthing screen
Computer Housings	Arc 02E .1mm	Screening against radio frequency on electro-magnetic interference
Electronics Housings	As above	As above

APPLICATION	COATING	REASON FOR USE
GRP MInesweeper	Arc Multilayer	To prevent stray transmission radiation from radio room
Hospital Radiography Rooms	Gas 02E .15mm	To prevent electromagnetic interference
Strain Gauges	Gas P255 .25mm	Sprayed beneath and on top of gauges to fix in position
Aircraft Wing Surfaces	Arc or Gas Copper Alloy .15mm	Interior surfaces sprayed to provide anti-static earthing screening
Aircraft Control Surfaces	As above	As above
Aircraft Air Intake Nacelles	As above	As above
Aircraft Fuselage	Arc 01E	Applied to CFRP skin, wing webs & fuel tanks to provide lightening conductor
Domestic Heating Trays	Arc or Gas 01E	Circuit pattern to provide resistive heating circuit
Domestic Cookers	As above	As above
Lightening Arrestors	Gas 01E .25mm	To provide electrical conductivity between carbon resistors in arrestor stock
Lightening Arrestors	Gas P255 .25mm	To insulate periphery of above components

Heavy Engineering Applications

Metallisation Equipment and Materials are vital to the heavy engineering industry. Scrapping heavy items of capital plant because wear or corrosion has damaged less than 1% of the material is unacceptably expensive. The additional loss of production whilst new articles are made (often more than 13 weeks) would be even more costly; so too, would the cost of holding spares to accommodate unscheduled breakdowns. The examples below show some of the areas where Metallisation Technology has been used to save money, increase product life and improve productivity. Many of the savings are worth more than £10,000.00 each.

In each case, careful attention is paid to the article and its operating conditions, the deposit thickness required and the coating and finished facilities available. Preparation details, bond coatings and deposit thickness have been omitted from the table for the sake of clarity.

APPLICATION/ WHERE USED	COATING	REASON FOR USE
Drilling Mandrels - Oil Production Platforms	Arc 60E	Reclamation
Hydraulic Rams - Mining	Arc 60E	Reclamation
Pit Props - Mining	Arc 60E	Better wear resistance reduced friction
Jack Piston - Mining	Gas 99E + 60E	Reclamation
Hydraulic Motor Pistol - Mining	Gas 99E + 60E	Reclamation
Driving Head Shaft - Coal Ripper	Arc 60E	Reclaiming bearing area and keyway
Rock Crusher - Quarry	Arc 60E	Reclamation, better wear resistance
Brake Drums - Earth Movers	Arc 60E	Reclamation, better wear resistance
Brake Disc - Crane	Arc 60E/05E	Reduce unsprung weight
Wire Barrel - Crane	Arc 10E+30E	Salvage to .25in radial thickness
Fixed Axle Bearing - Crane	Arc 60E	Salvage
Bearing Housing - Crane	Arc 30E	Salvage
Gear Box Housing - Crane	Arc 30E	Salvage
Clutch Disc - Crane	Arc 30E	Reclamation
Lifting Hook - Crane	Arc 05E+10E	To create non-sparking surface
Brake Drum - Fork Lift Truck	Arc 60E	Reclamation
Lifting Forks - Fork Lift Truck	Arc 05E+10E	Non-sparking surface
ClayCar Wheel - Steelworks	Arc 60E/30E	Reclaim OD
ClayCar Shaft - Steelworks	Arc 60E/30E	Reclalim journals
Coke Shaker Plate - Steelworks	Arc 60E	Provide wear resistance
Sand Shaker Plunger - Foundry	Arc 60E	Repair abrasion major savings
Cogging Mill Shaft - Steelworks	Arc 30E/60E	Bearing surface reclaimed
Cogging Mill Shaft - Steelworks	Arc 30E/60E	Reclaim contact surface of universal joint
Run Out Roll - Steelworks	Arc 60E	Reclaim surface thickness 12mm
Blower Fan Shaft - Steelworks	Arc 60E	Reclaim of carbon ring gland seal areas

/........................Heavy Engineering Applications

APPLICATION/WHERE USED	COATING	REASON FOR USE
Taper Rolls - Aluminium Works	Arc 60E	Reclaim taper surface
Roll Bearing - Aluminium Works	Arc 15E	Reclamation
Hydraulic Rams - Steelworks	Arc 60E	Reclaim wear damage
Hydraulic Rams - Aluminium Works	Arc 55E	Reclaim wear damage
Tube Checking Mandrel - Steelworks	Arc 60E	Improve wear resistance
Pillar Support Bearing - Tube Punch in Steelworks	Arc 15E	Reclaim worn ID
Wire Reeling Drums - Rope Works	Arc 60E	Reclaim worn surface
Wire Drawing Cords - Wire Mill	Arc 60E	Improve wear resistance
Centre Column - Brickworks	Arc 60E	Reclamation of journals on forming machine
Hydraulic Pumps - Steel/Aluminium Works	Arc 75E	Reclaim pump bodies
Hydraulic Pumps - Steel/Aluminium Works	Arc 60E	Reclaim piston diameter
Hydraulic Pumps - Steel/Aluminium Works	Arc 15E	Reclaim piston diameter
Yankee Dryer Drums - Paper Industry	Arc 60E	Reclaim roll face saving up to £40,000.
Printing Rolls - Printing Industry	Arc 60E	Reclaim journals
Plate Cylinders - Printing Industry	Gas 60E	Reclamation
Compression Cylinders - Printing Industry	Arc 60E	Reclamation

/........................Heavy Engineering Applications

APPLICATION/WHERE USED	COATING	REASON FOR USE
Blanket Cylinders - Printing Industry	Arc 60E	Reclamation
Gluing Rolls - Paper Industry	Arc 80E	Reduce manufacturing costs
Pump Bodies - Paper Industry	Arc 55E	Reclamation
Pump Sleeves - Paper Industry	Gas P325	Improve wear and corrosion
Rolls - Textile Industry	Arc 55E	Wear and corrosion resistance
Weaving Shuttles - Textile Industry	Arc 60E aluminium shuttles	Improve wear resistance of low weight
Compression Cylinder - Chemical Industry	Gas P225	Low friction wear resist surface for hydrogen chloride compressor
Pump Casing - Sugar Beet Mill	Gas 99E + Blue Corrundum	Provide abrasion and corrosion
Crusher Rolls - Sugar Cane Mill	Arc 60E	Reclaim diameters up to 75mm
Crusher Roll Journal - Sugar Cane Mill	Gas 60E	Reclamation
Crusher Roll Bearing - Sugar Cane Mill	Arc 15E	Reclamation
Crusher Roll - Grain Mill	Arc 60E	Increase life 2-3 times
Crusher Roll - Tobacco Mill	Arc 55E	Improved wear and corrosion resistance
Pulp Roll - Wood Pulp Mill	Arc 80E of pulp	Reduce cost and prevent rust straining
Chilling Cylinder - Soap Factory	Arc 60E	Reclamation and improved wear resistance
Turbine Casing - Hydro-electric Station	Gas 99E	Restore dimensions to casting.

Protecting Steelwork in Inland Aquatic Environment

Inland waterways and water carrying systems do not usually affect steelwork as rapidly as do marine environments. Nevertheless, water is a naturally corrosive medium for steel and attack may be accelerated by dissolved salts leached from the ground or present as a result of industrial pollution. In many cases, care must be taken to ensure that protection systems do not pollute potable water supplies. The following examples show some of the uses of sprayed zinc or aluminium in these applications:-

APPLICATION/ WHERE USED	COATING	COMMENT
Lock Gates - Paris	02E - 150 µ	Gates treated in 1922 were sound in 1962
Lock Gates - Great Ouse River	02E - 100 µ	
Lock Gates - Bedford	02E - 100 µ	
Lock Structures - Great Ouse River	02E - 100 µ	
Sluice Gates - Paper Mill	02E - 100 µ	
Sluice Gates - Bedford	01E - 100 µ	
Flood Gates - River Nene	01E - 100 µ	32 gates have been treated in this scheme
Reservoir Sluices - Anglia River Authority	02E - 100 µ	
Reservoir Covers - Anglia River Authority	02E - 100 µ	
Bridge Caissons - France	02E -150-200 µ	
Water Pipeline - Clunie Hydro-Electric	02E	
Water Pipeline - Birmingham Main Supply	02E	Pipeline is almost 100 miles long
Water Treatment Vessels - NW Water Authority	02E	
Water Tower - Fylde	02E	
Water Storage Tanks - Various Users	02E or 01E - 100 µ	
Barge Hulls - Various Rivers and Canals	02E - 100 µ	
Jet Pump Dredger - Quarry Lake	02E - 100 µ	Dredger is 132 ft long x 22 ft wide x 15 ft above water line
Medium Girder Bridges - Various Rivers	01E - 100 µ	Aluminium portable bridges treated to prevent stress corrosion
Drum Gates - Kilmorack Dam	02E - 150 µ	
Radial Gates - Kilmorack Dam	02E - 150 µ	

Protecting Steelwork against Corrosion in Rural or Indoor Situations

In rural or indoor locations, steelwork corrodes less rapidly than when exposed to more aggressive industrial or marine environments. Nevertheless, in such situations, structures are expected to last for many years (often more than 50 years) and inspection opportunities are limited. Also, indoor conditions often create serious condensation problems which may lead to very rapid corrosion. Zinc and aluminium metal sprayed coatings provide excellent long term protection in these situations. Typical examples include:-

APPLICATION	COATING	COMMENTS
Radio Masts	02E	Often inaccessible for regular inspection and maintenance of point systems.
Radar Towers	02E	
Television Masts	02E	
Water Towers	02E	
Road Signs	02E or 01E	Sprayed coating provides good base for reflective paints
Motorway Bridges	02E or 01E	May suffer pollution from diesel exhaust fumes
Railway Bridges	02E or 01E	
Footbridges	02E or 01E	
Medium Girder Bridges	01E	Sprayed to prevent stress corrosion of aluminium bridges
Mining Headgear	02E	
Lighting Column	02E	
Prefabricated Factory Unit	02E	
Farm Buildings	02E	
Farm Produce Containers	02E or 01E	May also suffer corrosion from animal and vegetable fluids
Farm Gates and Fencing	02E	
Electrical Switch Boxes	02E	Serious risk of condensation corrosion
Swimming Pool Structures	02E	Serious risk of condensation corrosion
Brewery Structures	02E	
Pasteurising Plant Structures	02E	
Window Frames	02E	
Doors	02E	
Bed Frames	02E	
Washing Machine Drums	02E	Must withstand hot water and detergents

Protection Against Corrosion in Marine and Coastal Situations

Metallisation Arc and Flame Spray Equipment have been used extensively for many years (since 1922) to spray zinc and aluminium for the protection of structural steelwork exposed to the windborne saltspray or in immersion conditions experienced in coastal and marine locations. BS 5493 indicates that properly applied metal coatings will outlast paint systems in these situations. Structures used from the North Sea to highly humid areas have been successfully treated. Below are listed a small selection and subsequent sealant/paint treatment are made to suit the specific application. Details are available from Metallisation Limited.

APPLICATION	COATING	COMMENTS
Humber Bridge Deck	02E	
Forth Road Bridge	02E	
Severn Road Bridge	02E	
Bosphorus Bridge - Turkey	02E	Environment also very humid
Lighting Columns	02E or 01E	Environment often industrially polluted
Aberdeen Dock Bridge	01E	Bridge is made of aluminium
Ro Ferry Terminal - Pembroke Dock	01E	
Ro Ferry Terminal - Stranraer	01E	
Sea Water Mains Pipe	01E	
Hull Tidal Barrier	01E	
Thames Tidal Barrier	01E	
Steelwork for Prefabricated	02E	Environment also very humid
Buildings - Dubai		
Drilling Rig Catwalks	02E	
Flare Boom Handrails	02E	
Flare Booms	01E	Aluminium also resists heat temperature corrosion
Diving Gas Bottles	01E	Special post spray treatment applied to prevent incendive spark hazard
Helicopter Landing Platforms	01E	
Diving Decompression	01E	
Chambers		
Diving Bells	01E	
Trawler Hulls	02E	
Miniature Submarine	02E	

APPLICATION	COATING	COMMENTS
Firefighting Tug	01E	Snorkel cage treated
Ship Holds	02E	
Ship Storage Tanks	02E	
Liquid Cargo Tanks	02E	May also be subject to chemical attack
Ships Catwalks	01E	Special application technique used to produce rough non-slip surfaces for
Ships Ladders	01E	added personnel safety.
Radar Towers	02E	
Ships Weather Decks	02E & 01E	
Lifeline Stanchions	01E	
Helicopter Tiedown	01E	
Aircraft Carrier Decks	01E	Must also withstand heat from aircraft exhausts
Missile Exhaust Deflector	01E	Must also withstand heat from aircraft exhausts
Naval Gun Turret	01E	Must withstand blast heat and attack from propellant chemicals
Submarine Bow	02E	
Steam Pipes	01E	
Steam Valves	01E	
Steam Rigger Valves	01E	
Diesel Exhaust Stacks	01E	Must also withstand heat and combustion
Boiler Skirts	01E	product corrosion

Protection of Steelwork Against High Temperatures

Since Metallisation first patented aluminising to protect steelwork from high temperature oxidation aluminium, nickel-chromium alloys and ceramics have been widely used to protect steelwork (and other materials) against the effects of high temperatures. The examples below indicate the wide use of thermal spraying in such applications.

ARTICLE TREATED	PROTECTIVE SYSTEMS	COMMENTS
Cupola Stacks	01E:150 µ Arc	Used in Iron Foundry
Cupola Spark Arrestors	01E:150 µ Arc	Used in Iron Foundry
Chimneys External	01E:150 µ Arc	CEGB Standby Stations
Chimneys Internal	01E:150 µ Arc	CEGB Standby Stations
Exhaust Duct Exteriors	01E:100 µ Arc	BSC Advanced Processes Laboratory
Exhaust Duct Interiors	01E:130 µ Arc	BSC Laconby
Exhaust Gas Stacks - Exterior and Interior	01E:125 µ Arc	Heysham Nuclear Power Station
Exhaust Gas Stacks - Exterior and Interior	01E:150 µ Arc	RR Olympus Engines for Australia Power Station
Gas Turbine Exhaust Ducts	01E:150 µ Arc	RAE Farnborough
Exhaust Silencer	01E:150 µ Gas	Power Station in Finland
Vehicle Exhaust Pipes	01E:100 µ Gas	Must also withstand industrial and
Vehicle Exhaust Manifold	01E:130 µ Gas	Protects against thermal shock on sports
Naval Diesel Exhaust Stacks	01E:150 µ Gas	
Missile Exhaust Deflector	01E:150 µ Gas	Also protects against salt spray
Aircraft Carrier Decks	01E:150 µ Gas	Also protects against salt spray

/................ Protection of Steelwork against High Temperatures

ARTICLE TREATED	PROTECTIVE SYSTEMS	COMMENTS
Naval Gun Turret	01E:250 µ	Also protects against salt spray and projectile propellant attack. Specially burnished to reduce chemical attack
Boiler Skirts	01E:150 µ	
Flare Booms	01E:Arc	Also protects against industrial pollution and marine corrosion
Combustion Systems	85E:250 µ + 01E:100 µ	Protects up to 1100 SYMBOL 176 \f "Symbol"C in presence of high sulphur fuels
Crane Structures	01E:150 µ	Used over furnace areas to protect against heat
Arc Furnace Electrodes	01E:25-100 µ	To protect carbon anodes
Furnace Skewbacks	P255	To protect base against erosion
Crucibles	P255:250 µ	To eliminate silicon contamination of molten product
Crucibles Internal/External	P255:100 µ	To prevent erosion by molten aluminium
Sprues - Internal/External	P255:250 µ	To prevent erosion by molten aluminium
Ladles - Internal/External	P255:250 µ	To prevent erosion by molten aluminium
Furnace Furniture	01E:250 µ	Oxidation protection
Thermocouples	P255:50-100 µ	To electrically insulate and prevent molten metal attack
Thermocouples	85E:150-300 µ	To attach thermocouple to test article
Strain Gauges	P255	To attach gauge to test article

Protection against Corrosion in Polluted Industrial Situations

Metallisation Equipment and Materials have been used for 70 years to protect structural steelwork against corrosion in industrially polluted areas. The systems: metal, thickness and sealant, are chosen to suit each particular application. The correct system can give protection for up to 50 years with maintenance at 20-25 years. Below are shown a small but typical selection of successful examples.

APPLICATION	COATING	COMMENT
Pierre La Port Bridge Canada	02E	Spray treatment selected because - original paint system showed signs of failure after 5 years.
Clifton Suspension Bridge - Bristol	02E	Before selecting metal spraying, this famous old bridge was in danger of being condemned.
Motorway Bridges	02E or 01E	Arcsprayed coatings withstand collision impacts better than other systems.
Railway Bridges	02E or 01E	
Foot Bridges	02E or 01E	
Port Talbot Steelworks - Steel Structures	01E	Sprayed in 1947 it was in good condition in 1980. It must also withstand salt spray and above the furnace level, chemical pollution
Brewery Roof Structure	02E	
Swimming Pool Structure	02E	
London Mosque Dome Structure	02E	
Street Lighting Columns	02E or 01E	
Electrical Switchgear Covers	02E	
Ventilation Fan Blades	02E	
Radio Towers	02E	
Radar Towers	02E	
Floodlight Towers	02E	
Aircraft Maintenance Platforms	02E	
Crane Structures	02E or 01E	Aluminium preferred where cranes operate in chemical works or above furnaces where corrosion and heat may be added problems.

APPLICATION	COATING	COMMENT
Freight Containers	02E	In tropical climates these must also withstand high levels of heat and humidity
Vehicle Trailer Chassis	02E	In tropical climates these must also withstand high levels of heat and humidity
Gas Cylinders	02E	Specially constructed automatic spraying plant equipment available for treating the large quantities
LPG Bottles	02E	Specially constructed automatic spraying plant equipment available for treating the large quantities
Oil Storage Tanks	02E	
Gas Holders	02E	
Storage Tans	02E or 01E	
Water Treatment Vessels	02E	
Sewage Purification Plant	02E	
Road Sweeper Bodies	02E	Previously painted bodies had too short a life
Refuse Collection Vehicles	02E	In Singapore the entire state fleet of the vehicles has been treated over the last few years
Ash Hoppers	01E	The coating must also withstand considerable abrasion
Fasteners	02E	A very thin deposit protects and provides non-seizing components
Railway Wagon Torsion Bars	01E	Used to prevent stress corrosion
Medium Girder Bridges	01E	The aluminium alloy structure is sprayed to prevent stress corrosion
Chimneys	01E	The coating must also withstand heat and chemical attack
Galvanised Tube Seams	02E	Sprayed zinc replaces the galvanised layer which is destroyed during welding. Applied to automatic plant.
Ammunition Boxes	02E	Must withstand rough handling
Jerry Cans	02E	Must withstand rough handling

Protection of Steelwork against Chemical Attack

Chemical attack presents the designer with one of the most difficult problems. Each case must be carefully considered in isolation since almost every situation is slightly different from others and the incorrect selection of materials may be disasterous. In addition, there are usually other problems such as wear or heat to be considered. It is usually advisable to evaluate test samples before finally selecting the protective system. The selection of typical examples shown below demonstrate the wide range of situations in which Metallisation Protective Systems have been successful. Only one or two cases of untreated coatings are employed. Most applications demand the use of a suitable sealant and/or additional paint system. These have been omitted from the table for the sake of clarity.

ARTICLE PROTECTED	CORROSIVE MEDIUM	ADDITIONAL PROBLEMS	PROTECTIVE SYSTEM
Steelwork Structure	Furnace Fumes	Heat & Salt Corrosion	150 µ 01E
Crane Structures Corrosion	Furnace Fumes	Heat & Natural	150 µ 01E
Cat Walks	Various Chemicals	Non-Slip Properties	Required
Carbon Anode Hangers	Furnace Fumes	Attachment to Anode	1-2mm 06E
Ships Holds	Various Liquids	Salt Corrosion	02E
Ships Storage Tanks	Various Liquids	Salt Corrosion	02E
Liquid Cargo Tanks	Various Liquids	Salt Corrosion	02E
Aircraft Carrier Decks	Jet Exhaust Fumes	Salt Corrosion & Heat	150 µ 01E
Missile Exhaust Deflectors	Missile Exhaust Fumes	Salt Corrosion & Heat	150 µ 01E
Naval Gun Turret Residue & Propellant	Ammonical Copper	Heat & Salt Corrosion	250 µ 01E Burnished Fumes 01E
Sewage Plant Components	Sewage		
Abbatoir Equipment	Animal Body Fluids	Abrasion	02E
Abbatoir Catwalks	Animal Body Fluids	Abrasion	02E
Food Canning Machinery	Animal Body Fluids	Sliding Wear	60E/61E
China Clay Plates	H2SO4	Heat, Abrasion	100 µ 01E Filter 02E or 01E

ARTICLE PROTECTED	CORROSIVE MEDIUM	ADDITIONAL PROBLEMS	PROTECTIVE SYSTEM
Ammonia Process Plant	Various Media		99E + 150-200 μ
"Finned Tube" Seams	Petrochemicals		100 μ -500 μ 02E
St.St.Tank	HNO3		150 m 01E- burnished
Steel Tank	Glycol Ethers		01E
Steel Tank	Acetates		01E
Steel Tank	Ethanolamine		01E
Storage Vessel	Methylene Chloride		02E or 01E
Storage Vessel	MEK		02E or 01E
Storage Vessel	Toluene		02E or 01E
Steel Tank	Genkleen Degreasant		02E
Barrels	Petroleum Leading		02E
Storage	Mud	Abrasion	175 μ 01E
Ash Hoppers	CoolAsh	Abrasion	150 μ 01E
Valve Body	Various Acids		P255
Nickel Injectors	Chlorine Gas		P255
Agitator Boss	Various Media	Abrasion	80E
Pump Impellor Bearing	Plating Bath Residues	Reclamation	85E + P215
Pump Sleeves	Strong Acids	Abrasion	Fused P325 Alloy
Pump Plungers	Strong Acid Slurries	Abrasion	Fused P325 Alloy

10.5 Materials Reference Chart

Wires

Ref No	Material
01E	Aluminium
02E	Zinc
04E	Babbit
05E	Copper
06E	Nickel
07E	Tin/Zinc 70/30
08E	Tin/Zinc 80/20
09E	Tin/Zinc 60/40
10E	Aluminium Bronze 92/8
12E	Brass 60/40
13E	Brass 70/30
14E	Brass 80/20
15E	Phosphor Bronze
17E	Aluminium/5% Silicon
18E	Tin
21E	85/15 Zinc Aluminium
24E	Moulding Alloy HD
25E	Aluminium/5% Magnesium
30E	Low Carbon Steel (Arc)
31E	Low Carbon Steel (Flame)
35E	0.25% Carbon Steel
45E	0.80% Carbon Steel
55E	18/5 Stainless Steel
57E	FM Chrome Steel
60E	13% Chrome Steel
65E	High Chrome Manganese Steel
70E	Monel (30% NI)
71E	Monel (67% NI)

Wires continued

Ref No	Material
75E	Nickel Alloy
78E	Fecral
79E	Ichrome
80E	18/8 Stainless Steel
81E	312 Stainless Steel
82E	308L Stianless Steel
83E	NICRFE
84E	Stainless 316
85E	Nichrome 80/20
86E	NiCrAl
99E	Molybdenum

Cored Wires

Ref No	Material
101T	Ni Al/Mo
102T	Hi C Martensitic Steel
103T	FeCrB
104T	FeCrC
105T	FeCrMoAl
110T	FeCrTiC
111T	WC/Co in Steel
120T	CuSN
450/1T	NiAl Flamebond

Powders

Nickel Base Self Fluxing Powders

Ref No	Material
P315/06	NiCrBSi Machinable Hardfacing Alloy
P319/10	NiCrBSi Hardfacing Alloy
P320/16	NiCrBSi Hardfacing Alloy
P324/10	NiCrBSi Hardfacing Alloy
P325/10	NiCrBSi Hardfacing Alloy
P325/30	NiCrBSi Hardfacing Alloy
P335/06	NiCrBSi Hardfacing Alloy
P421/32	NiCrBSi Hardfacing Alloy
P422/33	(Wc-12Co) NiCrBSi Hardfacing Alloy
P505/30	50% Wc-12%Co Aggregate. Blended matrix of BiCrBSi Alloy
P505/30P	50% Wc-12%Co Aggregate. Blended matrix of BiCrBSi Alloy
P515/03	35% Wc-8%Ni Aggregate. Blended matrix of BiCrBSi Alloy
P531/06	35% Wc/Co Aggregate. Blended matrix of BiCrBSi Alloy
P532/06	80% Wc-12%Co Aggregate. Blended matrix of BiCrBSi Alloy

Cobalt Base Self Fluxing Powder

Ref No	Material
P368/05	CoNiCrBSi Alloy

Pure Metal Powders

Ref No	Material
P407/32	Copper 99%
P835/16	Copper 99% +
P836/23	Nickel 99.5%
P836/33	Nickel 99.5%
P845/16	Aluminium 99% +
P845/23	Aluminium99% +
P899/25	Molybdenum 99% +

Nickel Base Powders

Ref No	Material
P405/33	Nickel Chrome Molybdenum Iron
P406/33	Nickel Chrome Iron Molybdenum
P446/16	Nickel Chrome Tungsten Molybdenum
P448/33	Nickel Aluminium 95/5
P615/10	Nickel Chrome Aluminium
P622/06	Nickel Chrome Molybdenum Aluminium
P623/06	Nickel Chrome Alloy/Aluminium
P626/06	Nickel Chrome Molybdenum Aluminium Iron
P627/16	Nickel Aluminium Molybdenum
P635/15	Nickel Aluminium 80/20
P636/16	Nickel Aluminium
P636/16P	Nickel Aluminium
P815/12	Nickel Chrome (80/20) Alloy
P815/31	Nickel Chrome (80/20) Alloy
P815/35	Nickel Chrome (80/20) Alloy
P816/10	Nickel Chrome Iron Alloy
P855/10	316 Stainless Steel
P865/33	431 Stainless Steel
P870/24	Nickel Chrome Tungsten Molybdenum

Iron Base Powders

Ref No	Material
P408/33	Iron Chrome Molybdenum
P628/07	Iron Aluminium Molybdenum
P629/07	Iron Aluminium Molybdenum
P652/08	Nickel Iron Aluminium
P850/10	Low Carbon Steel
P865/10	Iron Chrome Nickel

Aluminium Base Powders

Ref No	Material
P852/10	Aluminium Silicon (88/12)

Cobalt Base Powders

Ref No	Material
P427/33	Cobalt Molybdenum Chrome
P854/23	Cobalt Nickel Chrome Tungsten Alloy
P854/35	Cobalt Nickel Chrome Tungsten Alloy
P866/32	Cobalt Molybdenum Chrome Alloy
P868/33	Cobalt Molybdenum Chrome Alloy

Copper Base Powders

Ref No	Material
P404/32	Aluminium Bronze
P830/06	Aluminium Bronze
P830/31	Aluminium Bronze
P624/10	Aluminium Bronze
P857/23	Copper Nickel Alloy
P858/23	Copper Nickel Indium

Molybdenum Base Powders

Ref No	Material
P881/31	Molybdenum Self Fluxing Alloy Blend
P885/20	Molybdenum Self Fluxing Alloy Blend

Cermet Powders

Ref No	Material
P903/29	Magnesium Zirconate/Nickel Chrome Alloy
P910/20	70% Alumina 30% Nickel Aluminide
P941/09	Zirconium - Magnesium Oxide

Chromium Carbide Base Powders

Ref No	Material
P434/33	Chrome Carbide 25 (Ni 20Cr)
P435/33	Chrome Carbide 7 (Ni 20Cr)
P436/33	Chrome Carbide 50 (Ni 20Cr)
P437/33	Chrome Carbide 20 (Ni 20Cr)
P770/11	Chrome Carbide
P785/12	75% Chrome Carbide 25% Nickel Chrome
P785/35	75% Chrome Carbide 25% Nickel Chrome
P930/27	Chrome Carbide - Nickel Aluminium

Tungsten Carbide Powders

Ref No	Material
P423/33	Tungsten Carbide 12% Cobalt
P424/33	Tungsten Carbide 12% Cobalt
P425/35	Tungsten Carbide 17% Cobalt
P426/38	Tungsten Carbide 17% Cobalt
P715/23	Tungsten Carbide 12% Cobalt
P725/32	Tungsten Carbide 12% Cobalt Aggregate
P735/31	Tungsten Carbide 17% Cobalt
P735/36	Tungsten Carbide 17% Cobalt
P939/20	Tungsten Carbide 12% Cobalt

Aluminium Oxide Base Powders

Ref No	Material
P205/35	Grey Alumina 94%
P205/39	Grey Alumina 96%
P216/30	Aluminium Oxide 87% Titanium Dioxide 13%
P216/38	Aluminium Oxide 87% Titanium Dioxide 13%
P220/35	Aluminium Oxide 60% Titanium Dioxide 40%
P255/30	White Alumina 98.5%
P255/40	White Alumina 99.5%

Chromium Oxide Base Powders

Ref No	Material
P225/20	Chrome Oxide 98%
P225/33	Chrome Oxide 99%
P226/13	Chrome Oxide, Silica Titanium Dioxide
P226/30	Chrome Oxide, Silica Titanium Dioxide

Titanium Oxide Base Powders

Ref No	Material
P235/31	Titanium Oxide 99%

Zirconium Oxide Base Powders

Ref No	Material
P245/12	8% Yttria Stabilisd Zirxonia
P245/23	8% Yttria Stabilisd Zirxonia
P246/22	20% Yttria Oxide 80% Zirxonium Oxide
P265/25	93% Zirxonium Oxide
P265/31	93% Zirxonium Oxide
P275/31	24% Magnesium Oxide Zirxonium Oxide

Copper Base Abradables

Ref No	Material
P105/12	Aluminium Bronze Polyester 90/10

Aluminium Base Abradab les

Ref No	Material
P106/09	Aluminium Polyester
P960/08	Aluminium Graphite 60/40
P961/01	Silicon/Aluminium 30% Graphite
P963/04	Aluminium/Graphite 40/45

Nickel Base Abradables

Ref No	Material
P901/06	Boron Nitride Nickel Chrome Cermet
P955/18	Nickel Graphite 75/25
P955/19	Nickel Graphite 75/25
P958/18	Nickel Graphite 85/15
P959/10	Nickel Graphite 80/20
P962/03	Nickel Chrome Aluminium Bentonite
P964/02	Nickel Chrome Aluminium Bentonite

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