03. ADHESION OF PROTECTIVE COATINGS AND SURFACE PREPARATION

1. INTRODUCTION

With any applied coating, the quality of the surface preparation is the most important factor in determining whether the coating will perform for its expected design life. With paint coatings in particular, almost all failures are due to poor surface preparation. Longer maintenance free performance is being demanded of protective coatings, and environmental and heritage issues increasingly impact upon surface preparation technology. The specification and quality assurance of surface preparation thus require as much attention as the priming and top coating systems. There are no shortcuts to good surface preparation and the costs premature failure render the savings associated with cheap surface preparation insignificant.

2. INITIAL SURFACE CONDITION

SURFACE PREPARATION

Rust is an oxide of iron formed by the action of air and water. It is voluminous and occupies one and three-quarter times the volume of the steel from which it originated. Rust forming under a paint coating or through breaks in the coating, can burst through and may creep under the coating resulting in flaking so that repair is both difficult and costly.

Proper surface preparation is essential for the success of any protective coating scheme. The importance of removing oil, grease, old coatings and surface contaminants (such as mill scale and rust on steel, laitance on concrete and zinc salts on galvanized surfaces) cannot be over emphasised.

These steel bridge railings have been abrasive blasted prior to coating but have flash-rusted, requiring further surface treatment prior to coating

The performance of any paint coating is directly dependent upon the correct and thorough preparation of the surface prior to coating.

The most expensive and technologically advanced coating system WILL fail if the surface pre-treatment is incorrect or incomplete.

DEGREASING AND PRELIMINARY SURFACE PREPARATION

Organic Solvents

Aliphatic and aromatic solvents will remove most process oil and grease. It is not always appropriate to use these solvents because of fire, pollution or occupational health hazards. Statutory environmental requirements will generally require recovery of used solvents and solvent degreasing is best suited to controlled static manufacturing operations.

Detergent Degreasers

Spray or dip application is the best method for using detergent degreasers. There are many types of detergent degreasers. Many are alkaline and most require rinsing with clean water after application. Galvanizing plants use hot (70°C) caustic degreasing tanks for paint removal as well as degreasing. Containment of the detergent cleaning residues is a mandatory requirement as strict controls on such industrial waste products are now almost universal.

Steam Cleaning

Steam cleaning is well suited to small parts or machinery. Steam alone is unlikely to dislodge the lubricants used to grease working machinery. For more highly efficient steam cleaning of oil and grease from work¬ing machinery, a detergent is typically added. Operating conditions may be between 690-1,034 KPa and 60-71° C

Newer Methods
Among the newer methods available for grease and oil removal from working machinery are ice blasting, carbon dioxide pellet blasting, abrasive blasting with rubberized pellets, and blasting with a sodium bicarbonate slurry.

- *Ice Blasting* – Ice crystals generated within the blasting equipment are used as the abrasive media. Ice blasting is well suited to the removal of contaminants from softer substrates such as aluminium or brickwork that would be damaged by conventional abrasives.

- *Carbon Dioxide Blasting* - The principle of operation of this method involves solidification and ero¬sion/abrasion of oil or grease from the structure. The operating conditions are typical of abrasive blasting with nozzle pressures at or near 550 KPa. Feed rates for the CO^2 are mea-sured as a few kg per minute. The primary benefit claimed for this method is that the clean up required is very limited because the CO^2 sublimes to a gas after hitting the substrate, leaving only the removed oil and grease behind.

- *Rubber Pellet Blasting* - Blasting with pellets of rubbery polyurethane foam has been identified as a versatile method for a number of cleaning oper¬ations. Like CO^2 blasting, this method is said to dramatically reduce the need for clean-up of fractured abrasive. The principle involves the sponging of the oil or grease from the surface into pores on the foam pellets. The pellets change shape when they hit the metal surface, and grease or oil is squeezed into the pores of the rubbery foam. Operating conditions are quite mild, with nozzle pressures around 30-60 psi 200-400 kPa being common..

- *Sodium Bicarbonate Slurry Blasting* - Several types of this method exist. A super-saturated slurry of baking soda in water is projected at the work piece with nozzle pressures of 85 100 psi (586-690 kPa).

Rust and Scale Removal
The various methods of preparing steel for subsequent painting are given in Australian Standard 1627 Parts 0 to 10, issued by the Standards Association of Australia, with reference to pictorial standards depicted in Aust. Standard 1627.9 . It is strongly recommended that the appropriate Standard be stated to define clearly the degree of surface preparation required. Australian Standard 2312-1994, Guide to the Protection of Iron and Steel Against Exterior Atmospheric Corrosion also provides a comprehensive guide to surface treatment in Section 5 of that Standard.

These galvanized conveyor frames are be-ing brush-blasted prior to the application of a heavy-duty paint coating. This is a very effective surface treatment for painting over galvanized surfaces.

It is essential to remove all oil, grease, drilling and cutting compounds and other surface contaminants prior to further surface preparation or painting of the steel. The most common method is by solvent washing, followed by wiping dry with clean rags. The wiping clean is critical, because if this is not carried out thoroughly the result of solvent washing will simply spread the contamination over a wider area. Proprietary emulsions, degreasing compounds and steam cleaning are also commonly used. Recommended procedures are described in Australian Standard 1627. Part 1 and in the above section of this article.

Processes like hot dip galvanizing and use in-line pretreatment systems that remove all organic contaminants from the steel surface by immersion in hot caustic soda solution prior to pickling off of the mill scale and rust

Hand Tool Cleaning

Hand tool cleaning is defined as a method of preparing new, corroded or previously painted steel surfaces prior to painting by removing loose mill scale, loose rust and loose paint by using hand wire brushing, hand sanding, hand scraping hand chipping or a combination of these methods. Preliminary cleaning of large deposits of oil or grease, soluble fluxes and fume deposits from areas adjacent to weld runs should be carried out by solvent or detergent cleaning, detailed in Australian Standard 1627 Part 1 or by fresh water washing as appropriate.

Three standards of surface preparation are defined:

Class 1: is produced by "light wire brushing' to at least as good as Standard St 1 Of AS1627.9.
Class 2: is produced by "thorough scraping and wire brushing", and heavy rust scale first removed by hand hammering, The prepared surface to he at least as good as Standard St 2 of AS 1627.9.
Class 3: is produced by "very thorough scraping and wire brushing", any heavy rust scale being first removed by hand hammering. The prepared surface to be at least as good as Standard St 3 of AS1627.9.

Hand tool cleaning should only be specified for normal atmospheric exposures and interiors when the painting system includes a primer of good wetting ability. Hand cleaning will not remove all residues of rust, nor will it remove firmly adherent mill scale, and particularly corrosive salts such as chlorides and sulfates.

These highway safety rail posts have suffered 100% failure of their powder coating because of inadequate pre-treatment of the hot dip galvanized surface to which they have been applied.

Power Tool Cleaning

When removal of rust and mill scale is required, other Australian Standards; Power Tool Cleaning 1627.2, Blast Cleaning 1627.4, or Pickling 1627.5 should be considered.

(a) Power Tool Cleaning is defined as a method of preparing new, corroded or previously painted steel surface prior to painting by removing loose mill scale, loose rust, loose paint and all welding scale with power impact tools, power grinders, power sanders, power wire brushes or a combination of these tools. Tightly adhering mill scale and rust In deep pits will not normally be removed by this method of cleaning. Care should be taken not to polish the metal surface as this may reduce the key for subsequent coating.

(b) All surfaces to be coated shall be cleaned by the use of power-driven tools according to Australian Standard 1627 Part 2. Reference is made to Pictorial Standards of original unpainted surfaces of Australian Standard 1627.9 and to painted surfaces with varying amounts of visible rust, the amount rated typified by the Reference Standards of Australian Standard 1580 Method 481,3.

(c) Three standards of preparation are defined -

Class 1: is produced by power wire brushes only
Class 2: is produced by power impact tools followed by a light wire brushing
Class 3: is produced by power impact tools or power sanders, followed by light wire brushing.

Flame Cleaning

Flame cleaning is affected by the use of high velocity, high temperature oxy-fuel gas flames over the surface to be treated. It is slightly more effective than power rod cleaning and covered by Australian Standard AS1627, Part 3. It is expensive and has inherent risks of fire and explosion, and of possible distortion to light gauge steel. It is generally used for cleaning corroded and previously painted steel.

The hot dip galvanizing process uses chemical pretreatment. Close control of the pre-treatment chemistry ensures reliable galvanized coating application.

Pickling

Pickling may be carried out by any of the methods using either acid, alkaline or electrolytic baths, or in combination, provided adequate precautions are observed to:

(a) Ensure sufficient inhibitor has been added to minimise attack on the base metal when pickling in acid solutions. NOTE: Hydrochloric acid is much less aggressive on the base steel than sulfuric and generally does not require an inhibitor if used at concentrations under 15%.

(b) Acid pickling or cathodic treatment methods are not used on steel having a tensile strength greater then 800 MPA. This precaution is necessary to prevent hydrogen absorption and subsequent embrittlement that may result in fracture due to hydrogen cracking.

The pickled steel must be thoroughly rinsed of residual acid and will require passivation treatment with phosphate or other appropriate medium to prevent re-rusting. This is not required for hot dip galvanizing as the steel is normally fluxed and galvanized immediately after pickling.

Blast cleaning

By far the most effective method for removal of mill scale, rust, and old coatings is through the use of abrasives such as slag, grit or shot transported by high pressure air. There are four commonly used grades of blast cleaning, and the approximate equivalents between the various International Standards are as follows:

Aust. Std 1627.4	US Spec SSPC NACE	British Std BS4232	Swedish Std SIS 05-5900
White metal	Class 3	SP-11 NACE-1	1st Quality Sa 3
Near white metal	Class 2½	SP-3 NACE-2	2nd Quality Sa 2½
Commercial blast	Class 2	SP-2 NACE-3	3rd Quality Sa 2
Brush blast	Class 1	NACE-4	Sa 1

Australian Standard 1627.4 describes the correct practice to be followed in abrasive blast cleaning and details the various qualities of blast. All surfaces should be cleaned free of oil and grease before blasting. Australian Standard 1627 Part 9 provides pictorial representations of four different rust grades on steel that has been previously rusted as well as new steel. Pictorial representations are then given showing the appearance of each when blasted to any of the four classes of preparation.

The grade of blasting suitable for a particular coating specification depends on a number of factors, the most important of which is the type of coating system selected.

Prior to blasting, steelwork should be degreased and all weld spatter removed. If grease or oil is present on the surface it will appear to be removed by the blasting process, but this is not the case.

Although not visible, the contamination will still be present as a thin layer, and will affect the adhesion of subsequent coatings. The presence of residual chlorides on the surface of rusted steel will create a problem with subsequent coating operations, as the blasting will not remove these chlorides from the surface. Test procedures for chloride detection have been established and high-pressure water blasting after dry blasting may be required to reduce chlorides to acceptable levels. Weld seams and sharp edges should be ground down. This is because paint coatings tend to run away from sharp edges, resulting in thin coatings and reduced protection. Weld spatter is almost impossible to coat evenly, in addition to often being loosely adherent, and it not removed is a common cause of premature coating failure.

The profile or roughness obtained during blasting is important, and will depend on the abrasive used, the air pressure and the technique of blasting. Too low a profile may not provide a sufficient key for a coating, while too high a profile may result in uneven coverage of high, sharp peaks which will protrude through the applied paint film, possibly leading to premature coating failure, particularly for thin coatings such as blast primers. The following table gives a brief guide to typical roughness profiles obtained using various types of abrasive.

Type or Abrasive	**Mesh Size**	**Max Height of Profile**
Very fine sand	80	37 micrometers
Coarse sand	12	70 micrometers
Iron shot	14	90 micrometers
Typical non-metallic “copper slag”	75	100 micrometers
Iron grit No. G16	12	200 micrometers

Wet abrasive blasting

Wet abrasive blasting uses a slurry of water and abrasive rather than dry abrasive alone. This has the advantage that the hazards of dust and associated health problems are largely overcome. A further important advantage is that when wet blasting old, well rusted surfaces, many of the soluble corrosion products in the pits of the steel will be washed out, which will greatly improve the performance of the following paint system. However, a disadvantage of this technique is that the cleaned steel begins to rust rapidly after blasting.

It is therefore common practice to include proprietary inhibitors in the blast water that will prevent this rusting for a sufficient time to allow painting to be carried out. In general, the use of very low levels of such inhibitors does not affect the performance of subsequent paint coatings for non-immersed steel work. The use of a moisture tolerant primer, which can be applied to wet blasted steel while it is still damp, can make the use of inhibitors unnecessary.

Where wet blasted surfaces have been allowed to corrode, they should be mechanically cleaned or preferably sweep blasted, to remove the corrosion prior to painting unless a surface tolerant paint has been specified.

High Pressure Fresh Water Cleaning

A number of factors influence the results obtained by high-pressure water washing. There are no recognised standards of surface cleaning - as exist for grit blasting - and it is difficult to predict the outcome of a cleaning procedure.

Pressures used range from 70kg/cm2 to 2800kg/cm2 (1000 psi to 40000 psi) and volumes of throughput also vary considerably

High-pressure washing can also he used to clean corroded areas and has been used as an alternative to grit blasting. The result depends to a very large extent on the condition of the surface. Compact corrosion scale cannot be completely removed at a reasonable rate until pressures exceed 2100 kg/cm^2 (30000 psi).

Vacuum Blasting
Vacuum blasting, which eliminates the dust hazard, has a relatively slow rate of cleaning, but is ideal for cleaning limited areas, such as welds and burn damage when open blasting may seriously damage the intact surrounding coating. The abrasive is driven by compressed air into a specially designed head held on the steel surface, where, as soon as it strikes the surface it is sucked back into the machine for separation of the dust and re-use of the abrasive.

Wet Blasting (Hydro blasting)
Water and abrasive are now more commonly used to clean surfaces. There are two main methods available:

(1) High pressure water + grit - this system is essentially a fan-jet washing type of equipment (approx.140kg/cm^2 with small amounts of abrasive present in the fan). It is useful for the controlled removal of particular coats of paint but a very slow method for total removal of paint to bare steel as the quantity of abrasive used is normally only 25% of that consumed by dry blasting.

(2) Abrasive blasting + water injection - the abrasive stream is shrouded in water by the injection of a small amount of water at the blasting nozzle. Production rates are similar to dry blasting.

The main advantages of these systems are that they cut down air pollution, compared to dry blasting and eliminate contamination of nearby machinery by abrasive dust. Wet blasting has also proved an excellent tool when preparing old steel that is heavily contaminated with soluble salts, particularly chlorides.

The main draw back of wet blasting is that the steel exposed flash rusts on drying. This can be prevented by the introduction of a rust inhibitor in the water; these inhibitors are usually water soluble inorganic materials.

3. ABRASIVE CHARACTERISTICS
The highest quality applied paint coatings require the highest quality surface preparation, and a Class 2½ blast is a minimum requirement for maximum coating performance. The characteristics of the abrasive will influence the nature of the blasted surface and thus the ultimate performance of the coating.

The abrasive blast cleaning industry borrows heavily from the terminology of the geological sciences. The concept of relative hardness adopted by the abrasive industry is taken from a term from mineralogy called the “Mohs number” developed by Friedreich Mohs, a nineteenth century German mineralogist. His scale of hardness for 10 common minerals (talc is the softest rated at 1 and diamond is the hardest rated at 10) is widely used to set minimum limits on this property.

Abrasives for blasting generally have a hardness greater than 6.0 on the Mohs scale. Silica sand has a hard¬ness of 7.0 and garnet has a Mohs number of 7.5. Diamond is arbitrarily set at 10.

Grain shape will influence the performance of the abrasive on the steel surface. Rounded or smooth grains have a peening effect on the steel. Angular or sharp edges grains will produce a sharper profile.

The shape of the abrasive grain affects the performance of the media. Very angular grains may tend to break down more readily than rounded grains, forming greater amounts of dust. More rounded grains may present a larger surface area for contact with the steel,
resulting in surface profiles that are deeper than expected. Like the size and hardness of an abrasive, grain shape can influence materials consumption, waste minimization, dust generation, environ¬mental compliance, and surface profile. All of these items significantly affect total project cost.

4. ABRASIVE BLASTING & OCCUPATIONAL HEALTH

The occupational health and safety risks associated with abrasive blasting are well established, although requirement may vary from state to state. Silica sand in not a permissible abrasive in many areas unless it is used under strict environmental control standards. The ethics of awarding contracts to low cost tenders who use cheap (silica sand) abrasives and do not comply with accepted OH&S industry standards are questionable.

Blast cleaning involves pro¬pelling abrasive media at speeds in excess of 175 km per hour and turn¬ing paint, rust, and substrate sur¬faces into a dust cloud consisting of many air-borne particles. In fact, if a particle size analysis of the air-borne particles generated from blast cleaning process is done, dust par¬ticles ranging in size from less than 1 micron to 1,000 microns could be found. One micron is 1/1000th of a millimetre.

The smallest size particle that the unaided eye can see is generally accepted to be around 50 microns.

However, dust particles 10 microns and smaller are the only dust particles small enough to reach the deep inner regions of the lung. As particle size in¬creases above 10 microns, particles are more likely to be arrested in the upper respiratory system and be either swallowed or expelled. (In the case of lead dust particles. This is one way for lead to be inadvertently ingested and be absorbed in the gastrointestinal system). Thus the dust particles that cannot be seen maybe the most dangerous, not the big particles that are visible in most dust clouds.

Whether or not any of the air-borne dust particles are a potential health hazard depends not only on the size of the dust particles but also on the toxicity of the materials in the dust cloud and the amount of dust breathed into the respiratory system. This depends on the size of the dust particles in the work area and the concentration (total amount) of dust present. The toxicity of the particles in the dust cloud depends upon several other factors.

Air-borne dust generated from a blasting process may consist of broken down abrasive, pulverized surface coating, and abraded material from the object being blasted. The potential toxicity of each component in the dust cloud can be determined by reviewing material safety data sheets (MSDS) for the abrasive in use, and reviewing specific information on the chemical content of any old coatings being removed, as well as identifying the chemical make-up of the substrate or object being cleaned.

Some dusts are termed “nuisance” dusts. They produce little adverse effect to the body unless the airborne concentration is so high that it defeats the normal clearance mechanisms of the lungs. Other dusts are highly toxic to the body, such as dust from silica sand.

5. CONCLUSION

Almost all steel that is coated required some type of surface preparation and the quality of surface preparation is the single most important factor in determining coating reliability. 95% of all paint failures are caused by inadequate or poor quality surface preparation. The environmental responsibilities associated with maintenance painting and the impact of environmental legislation on paint technology will make adequate surface preparation even more important in the understanding of coating performance and the management of corrosion.

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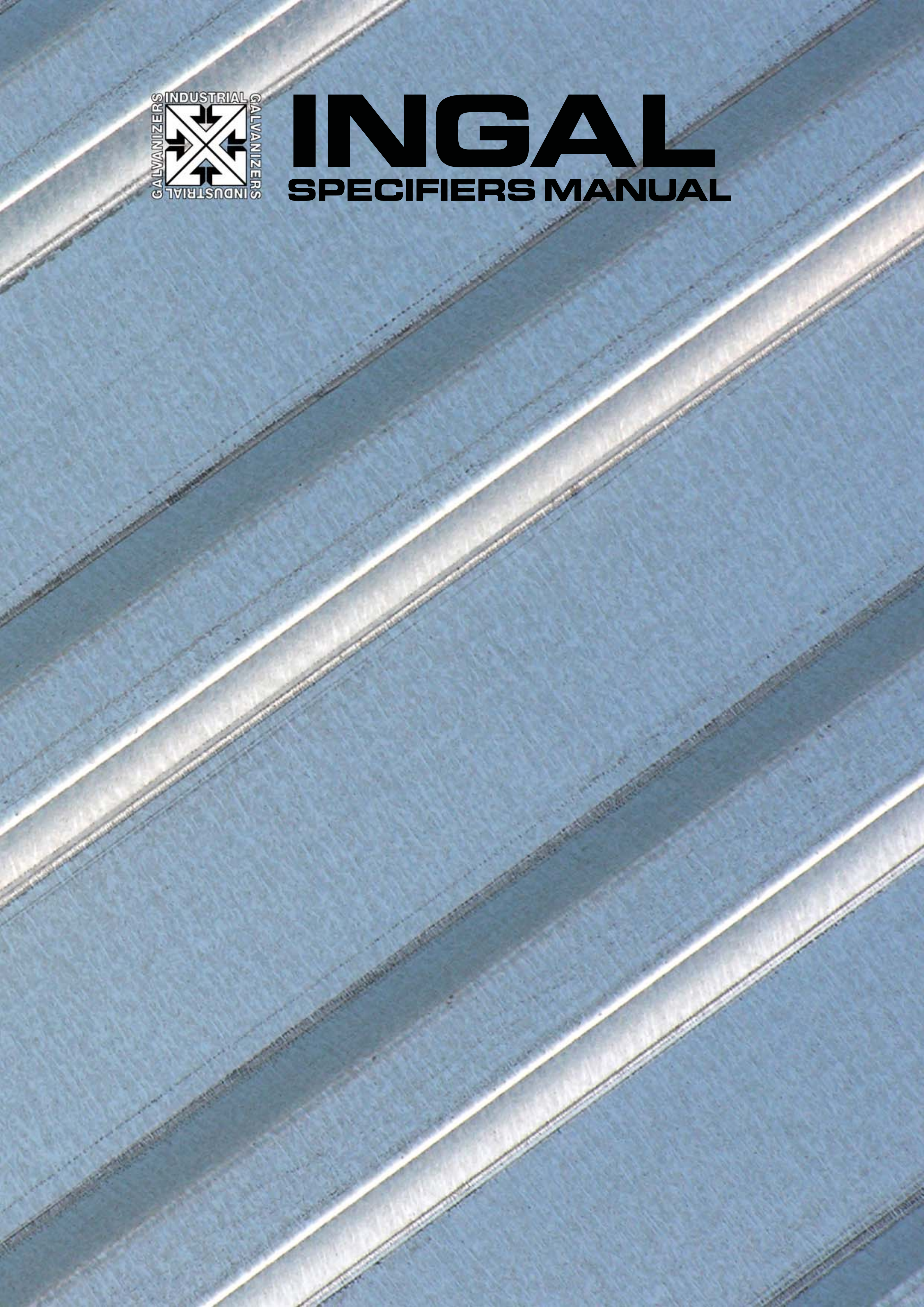

01 - SPECIFIERS MANUAL — THIRD EDITION

Industrial Galvanizers Australian Galvanizing Division (IGAG) operates nine galvanizing plants around Australia, ranging in size from large structural galvanizing facilities to specialised small plants designed to process small parts.

The Australian Galvanizing Division has galvanized in excess of 2 million tonnes of steel products in Australia since its first plant was commissioned in 1965 and is recognized for its ability to handle complex and difficult projects, as well as routine contracts.

This experience has been collated in the Specifiers Design Manual, to assist those involved in the design of steel products and projects to better understanding the galvanizing process and allow the most durable and cost-effective solutions to be delivered to these products and projects. All sections of this Third Edition have been completely updated and additional sections have been included to provide additional technical information related to the use of hot dip galvanized steel.

In addition to its Australian Galvanizing operations, Industrial Galvanizers Corporation has a network of manufacturing operations in Australia, as well as galvanizing and manufacturing businesses throughout Asia and in the USA.

The company's staff in all these locations will be pleased to assist with advice on design and performance of hot dip galvanized coatings and products. Contact details for each of these locations are located elsewhere in this manual.

This edition of the Industrial Galvanizers Specifiers Manual has been produced in both html and .pdf formats for ease of access and distribution and all documents in the Manual are in .pdf format and can be printed if paper documents are required.

The Specifiers Manual is also accessible in its entirety on the company's web site at www.ingal.com.au.

Additional copies of the Specifiers Manual are available on CD on request.

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