



Introduction

Hot dip galvanizing is one of the most widely used methods of protecting steel from corrosion.

As a final step in the process, the hot dip galvanized coating is inspected for compliance with specifications. Interpretation of inspection results should be made with a clear understanding of the causes of the various conditions which may be encountered and their effects on the ultimate objective of providing corrosion protection.

This manual has been designed to assist in testing, inspection, and the interpretation of test results. It deals with numerous surface conditions, their origins, and their effects on protection from corrosion. This manual also considers undesirable design and fabricating features as well as unacceptable hot dip galvanizing practice. Although it is difficult to cover every condition, the manual covers many of the conditions frequently encountered in practice.

To effectively use this manual, inspectors should remember that the main **purpose of hot dip galvanizing is to protect steel from corrosion**. The length of time this protection can reasonably be expected to last is called its "service life or time to first maintenance". This is defined as the time taken for the appearance on an article of 5% surface rust. **The service life of a hot dip galvanized coating is directly pro-**

portional to the thickness of the coating. Corrosion protection is greater when the coating is thicker. Thus coating thickness is the single most important inspection check to determine the quality of a hot dip galvanized coating.

Coating thickness, however, is only one inspection aspect. Other features include the uniformity of the coating, coating adhesion and appearance. Possible brittleness and defects, which arise from incorrect design and fabrication, also need to be assessed by the inspectorate.

While minimum specified standards must be satisfied, their relative importance varies according to the end use of the product. For example, the aesthetic appearance of hot dip galvanized structural steel in an obscured application is different from that where a product is used as an architectural feature. An awareness of the end use of the product and the capability of the hot dip galvanizing process is essential for good inspection.

Inspection of hot dip galvanized products, as the final step in the process, can be most effectively and efficiently conducted at the galvanizer's plant. Here, questions can be raised and answered quickly, inspection speeded up and, the time saved is beneficial.

Occasionally, due to rough handling and possible site modifica-

tions, which include cutting and welding, coating repairs become necessary. Repair procedures and the recommended repair materials are covered in this manual.

The quality standards to which reference is made in the following sections are in accordance with International and South African National Standards' specifications.

Test Sample Selection

To effectively evaluate hot dip galvanized coatings, it is essential that randomly selected specimens be representative of an inspection lot. An inspection lot is a single order or batch awaiting despatch. For products required to comply with **SANS 121 / ISO 1461** the minimum number of articles from each inspection lot that forms the control sample shall be in accordance with **table 1 of the specification**.

Typically, the test unit for compliance with **SANS 32 / EN 10240** shall be, for each size, one tube per first 500 tubes and subsequently one per 1000 tubes for outside diameters greater than 21.3mm and one per 2000 tubes for smaller diameters.

Unless otherwise specified by the purchaser, an acceptance inspection should be arranged and undertaken before the products leave the premises of the galvanizer.

Coating Thickness and Uniformity

The thickness of the hot dip galvanized coating is the primary factor in determining its life under given service conditions. The thicker the coating, the better corrosion protection it offers. For most atmospheric conditions,

TABLE 1

Number of articles in the lot	Minimum number of articles in the control sample
1 to 3	All
4 to 500	3
501 to 1200	5
1201 to 3200	8
3201 to 10 000	13
> 10 000	20



the relationship between corrosion protection and coating thickness is approximately linear, i.e., the service life is doubled if the coating thickness is doubled. There is however a limit to the maximum coating thickness that can be obtained.

The factors which influence overall coating thickness are a combination of several variables. The galvanizer can alter zinc temperature, time of immersion and rate of withdrawal from the molten zinc. These factors can be used to marginally alter coating thickness, particularly with reactive steels. The formation of the protective iron/zinc alloy layer is a diffusion process. As with all diffusion processes, the reaction proceeds rapidly at first and slows down as the layer becomes thicker. Higher bath temperatures and longer immersion times will generally produce thicker alloy layers.

The thickness of the outer zinc layer of the coating is independent of immersion time. Thickness of this layer is determined by the rate of withdrawal from the zinc bath and the degree of drain-off of molten zinc. A fast rate of withdrawal causes an article to “drag out” more zinc. This results in a heavier coating, although the distribution of the zinc layer may be uneven. Wiping of the coating during withdrawal materially reduces its thickness and thus its protective value. It is discouraged except where necessary for the smoothness demanded by conditions of service such as for small bore pipe and conduit.

Tubes hot dip galvanized in accordance with **SANS 32 / EN 10240** utilise steam blowing internally and an air ring externally, to remove excess zinc. Some variation in internal coating thickness is acceptable within

50mm of tube ends. With fabricated articles, local differences in the drain-off, because of the shape of the article and the angle at which different surfaces leave the bath, may also result in some variation in coating thickness.

Other factors influencing the coating thickness may be beyond the control of the galvanizer.

The chemical composition of the steel plays a major role in determining the thickness and appearance of the final coating. Certain steel compositions tend to accelerate the growth of the iron/zinc alloy layer so that the hot dip galvanized coating may have a matte finish with little or no outer zinc layer. This coating also tends to be thicker than the typical bright hot dip galvanized coating. The galvanizer’s control over this condition is limited. *Steels containing the elements, phosphorus in excess of 0.03%, or silicon from 0.05% to 0.12% and above 0.3% or combinations of both elements, are particularly prone to heavier coatings consisting mainly of iron/zinc alloys.* Due to the iron/zinc alloy growth in these coatings, extending to the outer surface, the final appearance of the coating can be dark grey in colour distributed evenly or unevenly over the surface.

The surface condition of the steel before hot dip galvanizing also affects the thickness and smoothness of the final coating. Steels which have been abrasive blast cleaned, or left to weather and rust for some time prior to hot dip galvanizing, can produce substantially thicker coatings than those normally produced on chemically cleaned steel.

The mass, shape and degree of cold working of components to be hot dip galvanized also influences coating thickness and uniformity. When a fabricated article consists of both heavy and light sections, a

TABLE 2

MINIMUM COATING THICKNESS ON ARTICLES THAT ARE NOT CENTRIFUGED					
		SANS 121 / ISO 1461		SABS 763	
Category and thickness (t) mm		Local coating thickness μm^*	Mean coating thickness μm^*	Article Type	Thickness, μm . General Application
PROFILES	$t \geq 6$	70	85	A1, B1, D1, E1, F1	85
	$3 \leq t < 6$	55	70	A2, B2, F2	65
	$1.5 \leq t < 3$	45	55		
	$t < 1.5$	35	45	A3, B3, F3	45
CASTINGS	$t \geq 6$	70	80	D1	85
	$t < 6$	60	70		

* Local coating thickness is defined as the mean of the measurements taken within a specified reference area. Mean coating thickness is the control sample number average of the local coating thickness values from each reference area.

- Thickness legend - $3 \leq t < 6$ = thickness less than 6mm but greater and equal to 3mm.
- Where only one reference area is required according to size of the article, the mean coating thickness within that reference area shall be equal to the mean coating thickness given in the above table.



variation in coating thickness between the sections may result. Immersion time will vary according to the relationship of the surface area of an item to its mass. The galvanizer has little control over this situation.

Combining heavy and light sections in a single component may also result in unacceptable distortion (refer to HDGASA wall chart, "Design for Hot Dip Galvanizing").

Since the time to the appearance of first rusting of the base steel is usually determined by the thinnest portion of the coating, an evaluation of galvanizing quality must take into account both the minimum thickness of the coating and its distribution. Specifications for hot dip galvanizing recognise that variations in coating thickness are inherent in the process. The minimum thickness is generally defined as an average or mean thickness of the coating on specimens tested and/or a minimum thickness for any individual specimen.

When measurements are taken to determine the uniformity and thickness of a hot dip galvanized coating, 5 or more coating thickness readings should be taken in each reference area. Reference areas should be taken approximately 100mm from the ends of the article to avoid end effects. Usually the end of an article which leaves the bath last will carry a thicker coating. This is particularly so towards the edge, where, at the time of drainage, the last few drops of zinc tend to agglomerate as a result of surface tension.

The minimum coating requirements specified in **SANS 121 / ISO 1461** for different material thicknesses and classes of work are summarized in **table 2** and **table 3**. For comparative purposes, these tables compare thickness equivalents to the old **SABS 763** specification. **Table 4** indicates the minimum coating requirements specified in **SANS 32 / EN 10240** for different classes of coating.

Specifications do not stipulate maximum upper coating thickness limits, but **excessively thick coatings on threaded articles are undesirable. In order to ensure effective tensioning, the coating thickness on fasteners should not exceed a maximum of 65µm, this applies particularly, to high strength bolts and nuts.**

Variance in coating thickness.

A requirement for a thicker coating (25% greater than the standard in **table 2**) can be requested for components not centrifuged, without affecting specification conformity.

***NOTE:** Where steel composition does not induce moderate to high reactivity, thicker coatings are not always easily achieved. Thicker coatings are more resistant to severe environmental conditions, but can be more brittle and may require special handling. The efficacy of corrosion protection of a hot dip galvanized coating (whether light or dull grey) is approximately proportional to coating thickness.*

TABLE 3					
MINIMUM COATING THICKNESS ON ARTICLES THAT ARE CENTRIFUGED					
		SANS 121 / ISO 1461		SABS 763	
Category and thickness/diameter (t) or (ø) mm		Local coating thickness µm*	Mean coating thickness µm*	Article Type	Thickness, µm. General Application
FASTENERS	ø ≥ 20	45	55	C1	55
	6 ≤ ø < 20	35	45	C2	45
	ø < 6	20	25		
OTHER ARTICLES (INCLUDING CASTINGS)	t ≥ 3	45	55	C1 Washers	55
				D2	45
	t < 3	35	45	C2 Washers	45
<p>* Local coating thickness is defined as the mean of the measurements taken within a specified reference area. Mean coating thickness is the control sample number average of the local coating thickness values from each reference area.</p> <p>■ Thickness/diameter legend - 6 ≤ ø < 20 = diameter less than 20mm but greater and equal to 6mm.</p> <p>■ Where only one reference area is required according to size of the article, the mean coating thickness within that reference area shall be equal to the mean coating thickness given in the above table.</p>					

Thickness Testing

There are several methods to determine the thickness of the zinc coating on a hot dip galvanized article. The size, shape and number of pieces to be tested, will most likely dictate the methods of testing. The specified test methods are either destructive or non-destructive and are detailed in **SANS 121 / ISO 1461**. Identical methods are detailed in **SANS 32 / EN 10240**. The most practical tests are the non-destructive type, such as gauges utilising the electromagnetic principle.

1. Electromagnetic Testing Method.

Instruments, which rely on electromagnetic principles are probably the most widely