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Practical Guidelines for the Inspection and Repair of Hot Dip Galvanized Coatings

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1 INTRODUCTION

Hot dip galvanizing is used as a very effective steel corrosion protection method, providing a long service-life. The corrosion protection is dependent on the coating thickness and environmental conditions (ASM Handbook, 1994). Zinc coated components are also used to give a good appearance to the constructions. In recent years the interest in hot dip galvanizing for decorative and constructional applications has increased. The difference in the field of use determines the requirements to the coating appearance.

Duller coating finish is desired in buildings, because shiny coatings with high reflectivity may cause problems with passing traffic. At the same time most customers prize the bright spangled look for decorative applications. As a result of customer demands the requirements to the coatings and especially to the appearance have increased. Coating appearance is affected by processing properties, steel chemistry, and substrate surface condition.

Traditionally, hot-dip galvanized steel is specified for its superior corrosion protection, especially in harsh environment. Though corrosion resistance is inherent any time galvanizing is utilized, more and more specifiers select hot-dip galvanized steel for other reasons, including lowest initial cost, durability, longevity, availability, versatility, aesthetics and sustainability.

This **"Case Study paper"** is prepared is based on Practical Experiences during my factory Inspection services for Hot-Dip Galvanizing products for Swicthyards, Solar Mounting structures, Transmission Line Towers, Pipe racks System in Oil and Gas Refineries, Petrochemical Complex, Light Gauge framing Structures (LGFS), Structural Components for PEB Buildings during 14 years of Experience for various industry like Oil and Gas Projects, Power Projects, and Renewal Energy sectors.

I have all Official ASTM Standards for available References along with American galvinizers Association Guides. These defects are very common during manufacturing and improper loading and unloading of Hot-Dip Galvanizing structural membrers during supplying the customers via closed shipping containers.

2 PURPOSE OF INSPECTION

Hot- Dip galvanizing is one of the most economical maintenance free – corrosion protection systems available. Like any others manufacturing process, hot-dip galvanized steel requires an inspection of the finished product to ensure compliance with applicable standards and specifications. The inspection process requires a clear understanding of specifications requirements and compliance measurement techniques to make an accurate assessment.

A key feature of hot-dip galvanized (HDG) product is durability, which yields decades of maintenance-free performance. For any environment, the time to first maintenance of HDG steel is directly proportional to the thickness of the zinc coating.

Coating thickness is an important requirement in the specification and effectiveness of hot-dip galvanizing as a corrosion protection system. However, measuring coating thickness is only one of the many specification requirements in the inspection process. The inspection of hot-dip galvanized steel is simple and quick. The two properties of the hot-dip galvanized coating closely scrutinized are coating thickness and coating appearance. A variety of simple physical and laboratory tests may be performed to determine thickness, uniformity, adherence, and appearance.

Products are galvanized according to long established, accepted, and approved standards of ASTM, the International Standards Organization (ISO), the Canadian Standards Association (CSA), and the American Association of State Highway and Transportation Officials (AASHTO). These standards cover everything from the minimum coating thicknesses required for various categories of galvanized items to the composition of the zinc metal used in the process.

Testing methods and interpretation of results are covered in the publication, The Inspection of Products Hot-Dip Galvanized after Fabrication, published by the American Galvanizers Association (AGA).

International Journal of Engineering Research & Technology (IJERT)
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Vol. 8 Issue 03, March-2019

3 MEASUREMENT OF COATINGS

The specification give requirements concerning the amount of coating applied to the steel part during the hot-dip galvanizing process. The amount of coating can be specified by thickness or weight per surface areas. The specifications include tables providing specific requirements for thickness or weight per surface area based upon the steel part type and the measured steel thickness.

The minimum coating thickness requirements specified by ASTM for different classes of works are summarized in following tables

Table 1: Minimum Coating Thickness from ASTM A123/A123M

MINIMUM AVERAGE COATING THICKNESS GRADE BY MATERIAL CATEGORY - ASTM A123/A123M (ROLLED, PRESSED AND FORGED SHAPES, CASTINGS, PLATES, BARS AND STRIPS)					
• MATERIAL CATEGORY	• ALL SPECIMENS TESTED (STEEL THICKNESS RANGE (MEASURED), IN (MM))				
	• < 1/16 (<1.6)	• 1/16 to < 1/8 (1.6 to < 3.2)	1/8 to 3/16 (3.2 to 4.8)	> 3/16 to < 1/4 (> 4.8 to < 6.4)	> 1/4 (> 6.4)
Structural Shapes	• 45	• 65	• 75	• 85	• 100
• Strips and Bars	• 45	• 65	• 75	• 85	• 100
• Pipe and Tubing	• 45	• 45	• 75	• 75	• 75
• Wire	• 35	• 50	• 60	• 65	• 80
• Reinforcing Bars	•	•	•	•	• 100

Table 2: Chart for Coating thickness Grade

Coating Thickness Grade				
Coating Grade	• **Mils**	**OZ/FT2**	**µm**	**G/M2**
35	• 1.4	• 0.8	• 35	• 245
• 45	• 1.8	• 1	• 45	• 320
• 55	• 2.2	• 1.3	• 55	• 390
• 65	• 2.6	• 1.5	• 65	• 460
• 75	• 3	• 1.7	• 75	• 530
• 85	• 3.3	• 2	• 85	• 600
• 100	• 3.9	• 2.3	• 100	• 705

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

Table 3: Minimum Coating Thickness from ASTM A153 / A153M

MINIMUM AVERAGE COATING THICKNESS BY MATERIAL CLASS - ASTM A153/A153M (IRON AND STEEL HARDWARE)					
Class of Materials	• **Descriptions of Class of Materials**	**Minimum weight of zinc coating, OZ/FT2 (G/M2) of Surface**		**Minimum Thickness Mils (Microns)**	
		• **Average of Specimens Tested**	• **Any Individual Specimens**	• **Average of Specimens Tested**	**Any Individual Specimens**
Class - A	• Castings, Malleable Iron and Steel	• 2.00 (610)	• 1.8 (550)	• 3.4 (86)	• 3.1 (79)
• **Class - B**	• Rolled, Pressed and forged articles (Except those which would be included under class C or D)	•	•	•	•
• **B - 1**	• 3/16 in (476mm) and over in thickness and over 15 in (381mm) in length	• 2.00 (610)	• 1.8 (550)	• 3.4 (86)	• 3.1 (79)
• **B - 2**	• Under 3/16 in (476mm) in thickness and over 15 in (381mm) in length	• 1.5 (458)	• 1.25 (381)	• 2.6 (56)	• 2.1 (53)
• **B - 3**	• Any thick and 15 in (476mm) and under in length	• 1.3 (397)	• 1.1 (336)	• 2.2 (56)	• 1.9 (48)
• **Class - C**	• Fastners over 3/8 in (9.52mm) in diameter and similar articles, washers 3/16 in and 1/4 in (4.76 and 6.35 mm) in thickness	• 1.25 (381)	• 1.00 (305)	• 2.1 (53)	• 1.7 (43)
• **Class - D**	• Fastners over 3/8 in (9.52mm) in diameter and similar articles, washers 3/16 in and 1/4 in (4.76 and 6.35 mm) in thickness	• 1.0 (305)	• 0.85 (259)	• 1.7 (43)	• 1.4 (36)
• **Note:** In this case of long pieces, such as anchor rods and similar articles over 5ft. (1.52mm) in length. The weight of coating shall be determine at each and the middle of the article. In no case shall individual measurement be below the minimum shown in the "Any Individual specimen" of column.					

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

Table 4: Minimum Coating Thickness from ASTM A767 / A767M

Minimum Coating Thickness by Class ASTM A767 / A767M (Reinforcing Bars)			
Coating Class	• **Descriptions**	**Mass of Zinc Coating Min. G/M2 of surface**	**Weight of Zinc Coating Min. OZ/FT2 of surafce**
Class 1	• Bar Designation size no. 10 (3)	• 915	• 3
	• Bar Designation size no. 13 (4) and Larger	• 1070	• Nil
	• Bar Designation size no. 13 (14) and Larger	• Nil	• 3.5
Class 2	• Bar Designation size no. 10 (3) and Larger	• 610	• 2

4 Coating Thickness Measurement

Coating thickness refers to the thickness of the final Hot-dip galvanized coating. Two different methods are used to measure the coating thickness of hot-dip galvanized steel; a magnetic thickness gauge and optical microscopy. Utilizing a magnetic thickness gauge is a non-destructive, simply way to measure coating thickness. There are three different types of magnetic thickness gauges as below:

4.1 Pencil - style Gauge is pocket-size and employs a spring-loaded magnet encased in a pencil-like container (Figure no.1). Its accuracy depends on the skill of the inspectors, thus the measurement should be made multiple times.

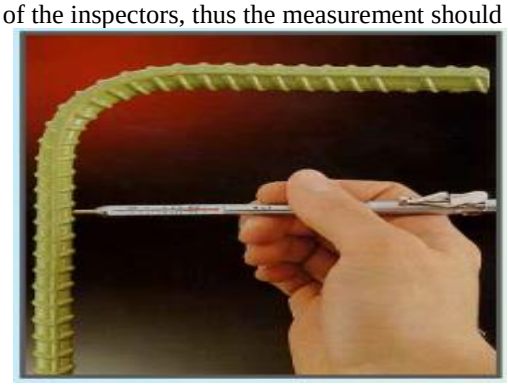

Figure 1: Pencil – Style gauge

4.2 Banana Gauge, (Figure no.2) can measure coating thickness in any position, without recalibration or interference from gravity.

Figure 2 : Banana Gauge

International Journal of Engineering Research & Technology (IJERT)
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Vol. 8 Issue 03, March-2019

The Electronic or Digital Thickness Gauge is the most accurate and easiest to use (Figure no.3). Electronic gagues can also store data and perform averaging calculations.

Figure 3: Digital Thickness Gauge (Shoe or Gun type)

The specification ASTM E376 Practice for measuring coating thickness by magnetic-Field or Eddy current (Electromagnetic) Examination Methods contains information on measuring coating thickness as accurately as possible.
The other method to measure coating thickness, Optical microscopy, is a destructive technique that expose the edge of coating under an optical microscope (Figure no.4). The sample must be sectioned then mounted and polished to show the exposed edge of the hot-dip galvanized coating. The calibrated eyepiece of an optical microscope can then determine the thickness of the coating. Since this technique destroys the part being measured, it is only used as a reference method for resolving measurement disputes.

5 Coating Weight

Coating weight refers to the mass of hot-dip galvanized coating applied to a product for a given surface area. Two different methods can be used to measure the coating weight of hot-dip galvanized steel. The first method uses a process called weight-galvanize-weigh, and is only appropriate for single specimen samples. Weigh-galvanize-weigh measures the weight of a steel part after it has been cleaned, and again after it has been galvanized. This technique only measures the zinc metal added to the steel and will underestimate the total coating weight by up to 10 percent.
The second method is a destructive technique called weigh-strip-weigh, and again is only appropriate for single specimen samples. Weigh-strip-weigh measures the weight immediately after a galvanized part is cooled, and again after the coating has been stripped off the part using an acid solution. The weigh-strip-weigh renders the part unusable as the coating is removed. The weights must then be divided by the surface areas of the steel part to determine a value that can be compared to the specification requirements.

Figure 4: Optical Microscpe

International Journal of Engineering Research & Technology (IJERT)
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Vol. 8 Issue 03, March-2019

6 FINISH AND APPEARANCE:

Several factors can affects the finish and appearance of hot-dip galvanized coatings. Some of these factors can be controlled by the galvanizers while others cannot. The inspection of finish and appearance is done with an unmagnified visual inspection, which is performed by fully observing all parts and pieces of a hot-dip galvanized product to ensure all specifications have been met. Visual inspection is done in order to observe surface conditions (both inside and cut) and to check all contact points, welds, junctions, and bend areas. The visual inspection should be completed at the galvanizing facility before the part is shipped.

10.1Different Appearance:

The appearance of the hot-dip galvanized coating can vary from piece to piece, and even section to section of the same piece. Common appearances for hot-dip galvanized steel immediately after galvanizing include bright and shiny, spangled, matte gray, and / or a combination of these. There are a number of reasons for the non-uniform appearance;however it is important to note appearance has no bearing on the corrosion protection of the piece. Furthermore, in time, after exposure to the environment, all galvanized coatings will take on a uniform matte gray appearance.

7 ADDITIONAL INSPECTION TEST

7.1 Adherence Test

Testing zinc coating adherence is achieved using a stout knife and smoothly running it along the surface of the steel without whittling and gouging, as detailed in the ASTM specification ASTM A123 / A123M and ASTM A153 / A153M.

7.2 Embrittlement Test

When there is suspicion of potential embrittlement of a products, it may be necessary to test a small group of the products to measure the ductility according to the protocol in specification ASTM A143 / A143M practice for safeguarding against Embrittlement of Galvanized structural steel products and procedure for detecting Embrittlement.

7.3 Bending Test for Reinforcing Steel

The hot-dip galvanized coating on a steel reinforcing bar must withstand bending without flaking or peeling when the bending test is performed in accordance with the procedure in ASTM A143 / A143M. Repairs is commonly bent cold prior to the hot-dip galvanizing process. When bending prior to galvanizing the fabricated bend diameter should be equal to or greater than the specified value in ASTM A767 / A767M.

7.4 Passivation Testing

The specification to determine the presence of chromate on zinc surfaces is ASTM B201. This test involves placing drops of a lead acetate solution on the surface of the product, waiting 5 seconds, and then blotting it gently. If this solution creates a dark deposit or black stain, there is passivated zinc present. A clear result indicates the presence of a passivation coating.

8 SAMPLING METHODS

A sampling protocol has been adopted by ASTM to ensure high quality products because the inspection of the coating thickness for every piece of materials galvanized in a project would not be practical. To properly evaluate hot-dip galvanized coatings, randomly chosen specimens are selected to represent the lot. The inspections quantities are determined by a lot sizes and are detailed in the ASTM specifications A123/A123M, A153/A153M and A767/A767M.

For products whose surface area is equal to or less than 160 in^2 (1032 cm^2), The entire suface of the tested product constitutes a single specimen. Products containing multiple materials categories or steel thickness ranges and products with surface areas greater than 160 in^2 (1032 cm^2) are sampling is based on the total lot size (Number of pieces) and is defined in the ASTM specifications.

For single specimen articles, specimens are randomly selected and a minimum of five widely dispersed measurement are taken over the surface area of each specimen to represent the average thickness. The average value of the five coating thickness measurement must be greater than or equal to one grade below the minimum average coating thickness for the material category. The average coating thickness of the lot (All specimens tested) must meet the minimum coating thickness for the material category.

For multi-specimen products, the product's surface area is subdivided. For Parts greater than 160 in2 (1032 cm2), three continuous local sections with equivalent surface areas constitutes a specimen. Each specimen (sub-section) must have five widely dispersed readings just as for single specimen articles. For fabrications with more than one material category or steel thickness, the fabrication will contain more than one specimen. Each specimen's (sub-section) average thickness measurement values must be greayer than equal to one grade below the minimum average coating thickness for the material category, and the overall sample (Three susb-section averages) must meet the minimum average coating thickness for the material category.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

9 FIELD INSPECTION

Inspection of hot-dip galvanized steel products does not end once they are accepted at the galvanizer's facility or job site. Once erected, any good corrosion protection strategy includes periodic inspection and maintenance to ensure the protective coating is performing as expected. When inspecting hot-dip galvanized steel in the field, the inspector should be aware of potential ace;erated corrosion areas and aesthetic surface defects.

When inspecting a galvanized coating in the field, the number one concern is the number of years remaining before the coating will need to be touched-up or replaced. Fortunately, estimating the remaining time to first maintenance for hot-dip galvanized coatings in atmospheric exposures is relatively simple. For a ballpark estimation, use a magnetic thickness gauge to take a coating thickness measurement.

10.2Visual Observations

In addition to talking coating thickness measurements, the galvanized coating can be visually inspected for signs of accelerated corrosion in specific areas. Thickness measurement should be taken in these areas to ensure adequate zinc coating remains or if touch up should be performed. Corrosion prone areas to inspect further include the following effects as:

9.1.1 Crevices

When corrosive elements such as water penetrates crevices, the limited air flow can create differences in potential creating anodic and cathodic areas which canlead to corrosion. Some common areas include: overlapped areas, mated sections between fastners, and areas where the galvanized coating is butted up against another surface such a wood, concrete or asphalt. When possible, crevices should be avoided during the design process.

9.1.2 Dissimilar Metals in Contact

When dissimilar metals are in contact, galvanic corronsion can occurs, zinc, which comprises the galvanized coating, is high on the galvanic series of metals; and therefore, will preferentially corrode to almost any other metal with which it is in contact. When Possible, preventing dissimilar metals from being in contact should be addressed during the design process. Electrically dissimilar metals from one another stops galvanic corrosion and can be accomplished by using plastic or rubber grommets between the dissimilar metals or by painting the cathode. When the surface area of the cathode is much larger than the anode, galvanic corrosion can quickly consume the anodic materials.

9.1.3 Areas Where Water pools

Flat areas can collect water and other corrosive elements and can have higher corrosion rates than vertical surfaces. Visually observing galvanized steel's flat areas and taking coating thickness measurements will ensure adequate corrosion protection remains. When possible, areas that collect water can be addressed by providing drain holes to prevent moisture from pooling on the surface for long period. If drain holes do exist, inspect the drain holes of the galvanized steel corrosion and touch – up when necessary.

9.1.4 Previously Touched-Up Areas

Areas of hot-dip galvanized steel previously touched-up either the initial coating or erection often corrode more quickly than the surrounding zinc coating and should be inspected visually and tested with a magnetic thickness gauge. These areas may be touched-up when necessary using the instructions listed in the touch-up and repairs section of this publication to extend the service life of the part.

When inspecting galvanized steel in the field, there are a few common appearance issues you may observe. Most are surface or aesthetic conditions an dnot cause for concern;however; others may require attention and or maintenance. The most common appearance issues on galvanized steel after being in service for a number of years include.

9.1.4.1 Brown Staining

Often mistaken for corrosion, brown staining is a surface defect created when iron in the zinc-iron alloy layers oxidizes. As previously noted in this publication, sometimes hot-dip galvanized coatings from without a free zinc layer, leaving intermetallic layers on the surface. Also, as galvanized steel weathers, the eta layer will be consumed and can lead to this phenomenon. Brown staining forms when free iron in the intermetallic layers reacts with moisture in the environment and oxidizes, discoloring the surrounding zinc coating. To distinguish betwwen red rust and brown staining, simply test the area with a magnetic thickness gauge. If the gauge reading shows a coating thickness, it is brown staining is simply an aesthetic concern, touch-up is not necessary in the stained area, and it may be removed by brushing with a nylon bristle brush.

9.1.4.2 Wet Storage Stains

As addressed earlier in this specification, improper storage and tight stacking of galvanized products can lead to the development of wet storage stain or zinc oxide and hydroxide build-up on the surface (Figure below). If aglvanzied products are going to be stored before erection, it is important to properly vent the bundle to avoid the development of wet storage stain. For more information, see the below section for wet storage stain. Similar to the development of wet storage stain when storing materials, galvanized products in place that have moisture on the surface without the movement of free flowing air can develop oxides and hydroxides that look like wet storage stain. A common area for this to occur is on surfaces where snow is piled on the surface and left to melt or in areas where water pools for extended periods without drying. Wet storage stain occurs most often during the first month after galvanizing.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

9.1.4.3 Weeping Welds

Weeping welds (See below figure) were discussed in this specification below, and tough they can seen immediately after galvanizing, often they occurs after the steel is in service. As reviewed earlier, weeping welds are mostly a cosmetic concern;however, corrosion can be accelerated in the area where the liquids and rust bleeding are leaking. To clean and seal weeping welds, you can wash away the oxides on the outer area and apply epoxy or caulk to the area to prevent water from penetrating the crevices in the future.

9.1.4.4 Bare Spots

The galvanized coating can be compromised during delivery, handling, erection, and while in use. Some cathodic protection is offered to bare areas of the steel by the surrounding galvanized coating, but these areas can still rust if the area is too wide or corrosive elements frequently attack the steel. Research has shown the galvanized coating offers cathodic protection to bare areas between 1mm to 5mm wide depending on the electrolyte that electrically connects the galvanized coating to the bare area. Bare areas should be touched-up in accordance with the procedures outlined in this specifications to ensure longevity of the surrounding coating.

10 TOUCH – UP AND REPAIRS METHODS

The touch-up and repair of hot-dip galvanized steel coatings is important to maintain uniform barrier and cathodic protection as well as ensure longevity. Although the hot-dip galvanized coating is very resistant to damage, small voids or defects in the coating can occur during the galvanizing process or due to improper handling of the steel after galvanizing. Touch-up and repair of galvanized steel is simple whether newly galvanized or in service for years. The practice is the same, but there are more restrictions to the allowable repairs on a new product than one that has been in service.

The main restriction in the specification for repairing newly galvanized materials is the size of the area which is outlined in the product galvanizing specifications (ASTM A123/A123M, A153/A153M and A767/A767M0. According to those specifications, the allowable surface area for repairs is no more than ½ of 1% of the accessible surface area to be coated on that article, or 36 in^2 (2250 mm^2) per ton of piece-weight, whichever is less. ASTM A780 practice for repairs of damaged and Uncoated areas of Hot-dip Galvanized coatings details how to repairs the damaged coating

Another tenet of the specification for touch-up and repairs is the coating thickness of the repair area. Touch-up materials are required to meet a coating thickness of at least 2.0 mils (50.8 µm) for one application, and the final coating thickness of the repairs area is dictated by the material used to do the repair, outlined below.

10.1Zinc-Based Solders

Soldering with zinc-based alloy is achieved by applying zinc alloy in either a stick or powder form. The area being repaired needs to be preheated to approximately 600 F (315° C). The acceptable material compositions of solders used for repair are included in the specification.

Figure 5: Zinc-Based Solder Technique

The final coating thickness for this repair shall meet the specification requirement for the material category for the steel part being repaired with a maximum thickness of 4 mils (100µm). The thickness shall be measured by any of the methods in A123/A123M that are non-destructive. Zinc-based solder products closely match the surrounding zinc and blend in well with the existing coating appearance.

10.2Zinc – Rich Paints

Zinc-rich paint is applied to a clean, dry steel surface by either a brush or spray. Zinc-rich paints must contain either between 65% to 69% metallic zinc by weight or greater than 92% metallic zinc by weight in dry film. Paints containing zinc dust are classified as organic or inorganic, depending on the binder they contain. Inorganic binders are particularly suitable for paints applied in touch – up applications of undamaged hot-dip galvanized areas.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

Figure 6: Zinc – Rich Paints

The coating thickness for the paint must be 50% more than the surrounding coating thickness, but not greater than 4.0 mils (100 µm), and measurements should be taken with either a magnetic, electromagnetic, or eddy current gauge to ensure compliance.

10.3Zinc – Spray (Metallizing)

Zinc – spray, or metallizing, is done by melting zinc powder or zinc wire in a flame or electric arc and projecting the molten zinc droplets by air or gas onto the surface to be coated. The zinc used is normally 99.5% pure or better.


Figure 7: Zinc – Spray (Metallizing)

The renovated area shall have a zinc coating thickness at least as thick as that required in ASTM A123/A123M for the material category. For best results, thickness measurements for the metallized coating should be taken with either a magnetic or an electromagnetic gauge.

10.4Site Repairs

The preferred method of repair is by zinc metal thermal spraying. Due to the remoteness of most sites, however, and the unavailability of metal spraying equipment, repairs by zinc rich epoxy or zinc rich paint have to date generally been more popular.

Site repairs should be limited to small coating defects and areas that have been cut or welded on site.

Should excessive amounts of grease or oil be present at the affected area, it should be removed by means of an approved solvent. All residues are to be thoroughly removed by washing with clean water.

The affected area should then be abraded with abrasive paper (roughness 80 grit) or alternatively thoroughly cleaned using, preferably a stainless steel brush. All dust and debris should be completely removed.

Repair can now be carried out using an approved product.

Single pack zinc rich paints are good materials and can easily be applied. They, however, require several coats to achieve a reasonable repair. Multiple coats will also necessitate longer drying times between coats.

Until recently, the approved products for repair were only available in large containers. Due to the large quantities involved and short pot life when mixed, the products proved to be expensive and wasteful.

Products are now available in two component form, packed for convenience in handy, easy to use squish packs. Two of these products are approved and available from the Hot Dip Galvanizers Association of America and all of its members.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

11 DIFFERENT TYPES OF GALVANIZING DEFECTS AND THEIR REMEDIES & REPAIR METHODS

The galvanized coating applied to steel is generally continuous, tough and of a thickness that will provide years of maintenance-free or low maintenance service.

However, there are a number of common defects that arise in the galvanizing process. These are readily visible and have a variety of causes - many of which can be avoided through good communication and disciplined operations.

The Australian Standard AS 4680:2006 - Hot Dipped Galvanized Coatings on Ferrous Articles, provides guidance regarding defects. It states that, galvanized coatings shall be:-

- Continuous, and as smooth and evenly distributed as possible;
- Free from defects that may affect the stated use of the article.
- Free from blisters, roughness, sharp edges and flux residues.

Lumps and zinc ash are not permitted where they may affect the intended end use of the galvanized product.

Visual inspection is the simplest and most important method to assess the quality of galvanized coatings.

A useful characteristic of the galvanizing process is that if the coating is continuous and has a satisfactory appearance; it will be sound and adherent.

The following Legends Indicates the category of Galvanzing Defects whether the HDG materials is accepeted or rejected as:

A – Accept / R – Rejected / N – Negotiate / C – Clean / REP – Repairs

Responsibility Index: G – Galvanized / D – Designer / B – Builder / Fabricator / S – Steel Type / Surface

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

Technical Guidelines for the Inspection and Repair of Hot Dip Galvanized Coatings as per ASTM / AS / NZS / ISO / AWS / AC					
SC	**Description**	**Cause**	**Effect / Remedy / Responsibility**	**A/R/N/C/REP**	**Example**
1	**APPEARANCE OF SODIUM DICHROMATE:** A small amount of sodium dichromate is generally added to the quench water bath for passivation.	Although the recommended quantity of sodium dichromate is about 0, 15 to 0,3%, occasionally when topping up, more is added. This often results in a dark yellow to brown colour on the galvanized surface. The darker colour will provide enhanced initial corrosion protection.	Maintain concentration of sodium dichromate at about 0,15 to 0,3%. **G**	**A**	
2	**ASH DEPOSITS:** Ash deposits are grey, no-metallic deposits consisting of zinc oxide that have been deposited no the hot dip galvanizing coating.	Zinc oxide deposits coo take place when the component is dipped or when it is removed from the both.	The coating is normally intact underneath the ash deposits. Ash must be removed and the coating thickness verified for conformance to the specification requirements. Remove ash from all liquid conveyance pipes. **G**	**A / N** **REP If Necessary**	
3	**BARE SPOTS:** Although excluded from ISO 1461, bare spots of about 5mm (2,2 x 2,2mm), due to small localised flows, ore adequately protected by the sacrificial properties of zinc and will have very little effect on the service life of the coaling. Where necessary, such spots may be repaired using one of the specified repair methods. Gross uncoated areas ore a cause for rejection. See Coating Repair Procedures.	There are several causes of bare spats. These include: **Over -drying:** If the time between fluxing and hut dip galvanizing is prolonged or the drying temperature is too high, the barrier protection provided by the flux may be lost. This is indicated by a rusty appearance on the un-galvanized article, which can result in coating discontinuities after hot dip galvanizing. G **Excess - aluminum:** A condition sometimes referred to as black. Spats may occur if the aluminum content of a bath becomes too high. No trouble should be experienced if flux concentration is correct and the aluminum content of the both is maintained below approximately 0,007%. G **Further causes are:** Blowouts; flux deposits; stains and inclusions; Mechanical damage; touch marks; uncoated surfaces caused by - surface contaminants, scale or sand; welds and weld spatter. See SC No's 6, 16, 19, 30, 33, 34, 35 and 37	**A / R** **REP If Necessary**	 

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

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SN	**Description**	**Cause**	**Effect / Remedy / Responsibility**	**A/R/N/C/REP**	**Example**
4	**BLACK STEEL INSPECTION:** Inspection prior to hot dip galvanizing is extremely important.	Components should be checked for distortion caused during rolling or fabrication. Check for appropriate vent, fill and drainage holes: removal of weld slag and spatter; venting of overlapping surfaces; unsuitable joining materials; temporary identification markings; clearance for moving ports and potential distortion due to the process.	Insufficient inspection prior to hot dip galvanizing can be the cause of dispute. **G**	**A / R**	
5	**BLASTING DAMAGE:** Sweep blasting, dune correctly, substantially increases paint adhesion and final coating appearance hut done incorrectly can result in coating damage.	Incurred nozzle pressure; nozzle angle; sweeping distance; size of abrasive and recycling of grit.	A hot dip galvanized coating wi8 be partially or fully destroyed by excessive blasting. Refer to the HDGASA Cede of Practice. **D / B**	**R**	
6	**BLOW OUTS:** Staining and coating defects around unsealed weld areas and vent holes. Similar to stains ceased by weeping. See SC 28.	Pre-treatment chemicals penetrating sealed overlap areas through the required vent holes and escaping during immersion in the molten zinc. This effect tends to damage the flux coating, causing localized uncoated areas.	Pre-heat item prior to immersion in zinc both to dry out overlap area as much as possible. **D / G**	**A** **C / REP If Necessary**	
7	**CLOGGED HOLES:** Zinc film clogging or partly bridging holes.	Molten zinc has a high surface tension and will not easily drain from holes under 8mm in diameter.	Makes holes as large as possible. Removal of molten zinc over the bath and utilization of vibrators will reduce the likelihood of clogging	**A** **C If required**	

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

Technical Guidelines for the Inspection and Repair of Hot Dip Galvanized Coatings as per ASTM / AS / NZS / ISO / AWS / AC					
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8	**CLOGGED THREADS:** Threaded components or attachments have threads dogged with zinc.	Insufficient centrifuging or poor drainage of threaded attachments on withdrawal from the galvanizing bath.	The correct centrifuging equipment or post galvanizing thread cleaning by heating, wire brushing or oversize tapping of nuts, will generally remove clogging. If necessary specify delivery of bolts end nuts in nutted up farm. **G**	**R** **C / REP**	
9	**DESIGN STRUCTURES IN MODULAR LENGTHS AND OPTIMUM WIDTHS TO SUIT AVAILABLE BATH SIZES.**	Double dipping can sometimes be used to hot dip galvanize fabrications that are too long or wide far single immersion. If the fabrication exceeds the bath size, members in the fabrication may require touching up.	Touch up and repair can be avoided, the cost of hut dip galvanizing reduced and the overall quality improved, if the design of the component is restricted to the length, width and depth 0f the galvanizing bath. **D / B**	**A** **C / REP**	
10	**DESIGN STRUCTURES IN MODULAR LENGTHS AND OPTIMUM WIDTHS TO SUIT AVAILABLE BATH SIZES.**	Double dipping can sometimes be used to hot dip galvanize fabrications that are too long or wide far single immersion. If the fabrication exceeds the bath size, members in the fabrication may require touching up.	Touch up and repair can be avoided, the cost of hut dip galvanizing reduced and the overall quality improved, if the design of the component is restricted to the length, width and depth 0f the galvanizing bath. **D / B**	**A** **C if Possible**	
11	**DISTORTION:** Distortion is the unwanted warping that occasionally becomes evidents after hot dip galvanizing. The hot dip galvanizing process occurs ala molten zinc temperature of 450° C. This is at the lower end of stress relieving temperature for treating steel	Thus, any inherent rolling or welding stresses in the fabrication, are likely to be released. This may result in a dimensional change, i.e. distortion.	Use symmetrical designs; Use sections of similar thickness; Stiffen unsupported thin wall sections; Use preformed members with the correct minimum bend radii; Use balanced or staggered welding techniques; Make use of temporary braces on thin walled sections such as troughs, cylinders and angle frames. Avoid quenching after galvanizing. Components can be straightened after hot dip galvanizing. **D / G**	**A / N** **REP If Possible**	

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

Technical Guidelines for the Inspection and Repair of Hot Dip Galvanized Coatings as per ASTM / AS / NZS / ISO / AWS / AC					
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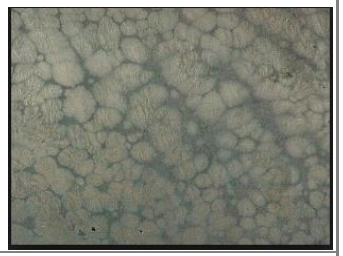
12	**DRAINAGE SPIKES.** Spikes and teardrops of zinc often appear along the edge of a component after hot dip galvanizing.	The edge mast likely to have these spikes is the last to leave the bath on withdrawal. This applies particularly to complex fabrications.	Drainage spikes are easily removed at the bath while still molten but with complex fabrications, the solidified spikes will be removed by fettling by the galvanizer prior to inspection. **G**	**A /N** **C / REP If Possible**	
13	**DROSS.** Dross particles are iron/zinc alloy crystals produced when hot dip galvanizing steel. These precipitate to the bottom of the bath and are removed by the galvanizer.	Gross dross deposit from the bottom of the zinc both, trapped in the corner of a fabrication. The dross incorporated in the coating prevents drainage of the zinc in the intermediate area and a buildup occurs.	Dross consists of the same iron/zinc alloy as the coating, it will provide the same corrosion protection as a normal hot dip galvanized coating. **G**	**A /N** **C / REP If Possible**	
14	**DULL GREY OR MOTTLED COATING APPEARANCE:** Dull grey or mottled coatings can appear as a dark grey circular pattern, a localized dull patch or, may extend over the entire surface of the component.	This appearance indicates the presence of extensive iron/zinc allay phase growth, mused by steels with high reactive levels of Silicon and Phosphorous in steels.	Although not as aesthetically pleasing as a coating with free zinc on the surface, a dull grey coating provides similar or hotter corrosion protection. **D / S**	**A**	
15	**FLAKING OR DELAMINATION OF COATING.** No adhesion of zinc to steel surface. Thick, rough coating.	High phosphorous content (greater) than 0, 03% causes entire coating to delaminate from the steel.	Use a steel that has a phosphorous content of lower than 0, 03%. **D / S**	**R /N**	

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

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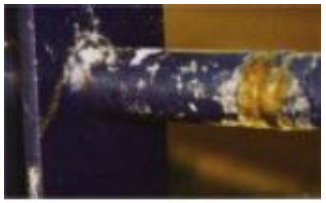
16	**FLUX DEPOSITS, STAINS AND INCLUSIONS:** Flux deposit or stains from the galvanizing process may adhere to the steel or become included in the coating. Flux residues are black, brown, grey or yellowish non-metallic deposits consisting mainly of ammonium chloride.	Flux deposits or stains may occur as a result of excessive "dusting" with ammonium chloride on withdrawal from the molten zinc. Flux inclusions can occur when a surface flux blanket is applied to the zinc surface (wet galvanizing). Flux blankets are normally only used for specialized processes, e.g. galvanizing of tubes and fasteners.	Flux deposits or stains should be removed and the underl~4ng coaling measured to determine whether it conforms to the minimum requirements of the specification. **G**	**A / N** **C / REP If Possible**	
17	**DISCOLOURATION OF THE PAINT COATING OVER HOT DIP GALVANIZING AFTER EXPOSURE TO THE ENVIRONMENT.**	Inadequate repair of a damaged surface on the hot dip galvanized coating prior to the application of a paint coating.	Make use of the correct repair materials and application procedures when touching up cut or welded hot dip galvanized components. See Coating Repair Procedures. **B**	**R** **REP**	
18	**COATING THICKNESS PROVIDED ON FASTENERS USE TO ASSEMBLE HOT DIP GALVANIZED STRUCTURES.**	No matter how the zinc coating is applied, the coating life is proportional to its thickness in a given environment. Often electroplated fasteners with insufficient coating thickness are incorrectly used in external environments.	Specify hot dip galvanized fasteners to ISO 1461, where required. Alternatively overcoat fastener with an approved zinc rich point or epoxy. See Coating Repair Procedures. **D / B**	**R** **REP If Acceptable**	
19	**MECHANICAL DAMAGE:** Mechanical handling or transports damage may occurs, particularly with extremely thick coatings, which is tend to be brittle in nature.	The use of chains, wire ropes, dragging or dropping of the component onto a hard surface, can cause mechanical damage. This is particularly relevant with thick brittle coatings.	Warning labels, highlighting a thick coating and possible damage if manhandled, should be attached by the galvanizer, before the component is transported. The use of nylon lifting slings is recommended. **G / B**	**A** **REP If Necessary**	

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

Technical Guidelines for the Inspection and Repair of Hot Dip Galvanized Coatings as per ASTM / AS / NZS / ISO / AWS / AC					
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20	**OXIDE LINES.** Light aluminium oxide film lines on hot dip galvanized surface.	Due to the shape and/ or drainage conditions of some components, the hoist crane has stopped and started upon withdrawal of the items from the molten zinc.	No effect on corrosion resistance. The overall appearance becomes uniform in time. **G**	**A**	
21	**PIMPLES OR BLISTERS:** Pimples or Blistering formed during Hot-dip galvanizing are usually associated with surface imperfections such as dross inclusions.	Dross pimples result from agitation of the dross layer at the bottom of the bath or from dragging material through the dross layer. They appear as small, hard lumps on an otherwise normal galvanized surface. Blisters may be formed by hydrogen, which is absorbed daring pickling and diffused at galvanizing temperatures.	The galvanizer should avoid disturbing the dross layer at the bottom of the bath by controlling immersion depths and dressing regularly. Since dross pimples represent minor disturbances in coating uniformity, they do not affect corrosion resistance. **G**	**A** **C If Necessary**	
22	**REACTIVE AND NON - REACTIVE STEELS, WELDED TOGETHERS:** Variations in coating thicknesses can arise when reactive and non - reactive steel welded togethers. Efforts to increase to coating thickness on the less reactive steel may result in an undesirably thick and brittle coating on the most reactive steel.	This difference in coating thickness, is brought about by a combination of a more reactive silicon killed steel, and/or high phosphorous resulting in a thicker coating and a less reactive aluminium killed steel, resulting in a coating thickness sometimes below that required in the specifications. Should the galvanizer be asked to re-galvanize in accordance with the specification, the resultant coating thickness on the reactive steel will be excessively thick, resulting in a brittle coating more susceptible to damage.	Select the same steel for fabricating a component. If need be, accept a concession request by the galvanizer when the thinner coating is possibly below specification. **D / B**	**A / N**	
23	**REMOVAL OF ZINC COATING BY EXCESSIVE CLEANING:** Unless otherwise agreed, the galvanizer will limit cleaning of the final coating by mechanical means to that required in the specifications.	Excessive cleaning of the coating, particularly the edges, by mechanical methods, can result in uncoated areas.	The affected areas usually only appear after the component is installed. Care should be exercised by the galvanizer to avoid over cleaning. **G / B**	**R / REP at the galvanizer or alternatively at site**	

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

Technical Guidelines for the Inspection and Repair of Hot Dip Galvanized Coatings as per ASTM / AS / NZS / ISO / AWS / AC					
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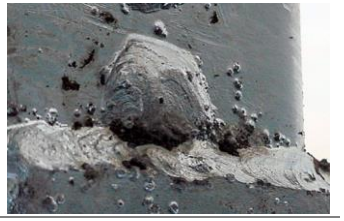
24	**ROLLING DEFECTS IN STEELS:** Thses defects may be broadly classified as surface discontinuities in the steel that have been elongated dring rolling.	Steel may occasionally include laminations, laps, folds and nonmetallic impurities, which result in slivers rolled into the metal surface. Defects of this type are sometimes detected before or after pickling, but may only become apparent after hot dip galvanizing.	Surface flaws in the base material may be removed by local grinding after hot dip galvanizing followed by repair of the affected surface. Minor surface defects will not adversely influence coating life. **S**	**A** **REP If Necessary**	
25	**ROUGH COATINGS, CAUSED BY STEEL SURFACE CONDITIONS.**	Rough surfaces, typical of coatings on corroded steel surfaces, can be hot dip galvanized satisfactorily. The coating will, however, reflect the texture of the substrate. Other causes of rough surfaces include uneven cold working, over pickling, a high galvanizing temperature and/ or extended immersion in the molten zinc.	The rougher surface will produce a thicker coating and result in a longer service life. **S**	**A**	
26	**ROUGH HEAVY COATINGS, CAUSED BY A ROUGH SURFACE AND/OR THE CHEMICAL COMPOSITION OF THE STEEL "TREE BARK EFFECT"**	Rough, heavy coatings refer to hot dip galvanized components showing markedly rough surfaces. This can include coatings that have a generally rough surface and, in some cases, groove type surface configurations, "tree bark effect" caused by variations in surface steel analysis.	The thicker coating produced will provide greater corrosion protection. Except when the coating tends to flake off or delaminate see SC 15. **S**	**A / R**	
27	**ROUGH HEAVY COATINGS CAUSED BY INSUFFICIENT CENTRIFUGING.**	Efficient centrifuging, will generally remove excess zinc and provide a smooth and attractive exterior.	Provided the steal/casting surface is reasonably smooth, correctly centrifuged articles will provide an acceptable finish. **G**	**R** **C / REP If Acceptable**	
28	**STAINS CAUSED BY WEEPING.**	The salts from acid or flex that have penetrated porous welding or between contact surfaces during pickling can weep after hot dip galvanizing and water quenching, producing a stained area.	The stains can be easily removed by means of bristle brushing. Should the component be destined for a corrosive area, the crevice should be sealed with a sealant after cleaning. **D / B**	**A / C / REP If Necessary**	

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

Technical Guidelines for the Inspection and Repair of Hot Dip Galvanized Coatings as per ASTM / AS / NZS / ISO / AWS / AC					
SN	**Description**	**Cause**	**Effect / Remedy / Responsibility**	**A/R/N/C/REP**	**Example**
29	**TIGHTLY ADHERENT LUMPS OF ZINC ON THE INSIDE OF HEAVY WALLED STEEL PIPING.**	Heavy walls and thick flanges used in the manufacture of piping can act as a heat sink when immersed in molten zinc. This effect considerably lengthens the immersion time. Occasionally the galvanizer will remove the pipes before all the zinc has melted from the inside of the pipe.	The galvanizer should ensure all zinc hen been removed from the side of the pipe by longer immersion times. **G**	**R** **C / REP If Acceptable**	
30	**TOUCH MARKS:** The zinc in the galvanizing bath should have free access to all component surfaces or small unmated or damaged areas can results.	Articles entering the galvanizing baths should not be in tight contact with each other. Jigging wire should also be loosely attached to eliminate wire marks. Where a component has been resting on jigging or dipping equipment, an uncoated area an touch mark could appear.	Minimize contact between components and jig connections. (Loosen jigging wire). Small components can be centrifuged. **G**	**R** **REP If Necessary and Acceptable**	
31	**TYPICAL SPANGLED HOT DIP GALVANIZING COATING:** A typical hot dip galvanized surface is shown in the example. The surface is silver grey in color and not necessary but often as a spangled effects (Zinc Crystal) in a range of sizes.	Surface appearances may vary according to the chemical composition of the steel. Cooling rate has a direct effect on the surface brightness and spangle size. Easter cooling usually results in a brighter coating with a smaller spangle size.	Small additions of aluminium to the molten zinc, brightens the coating. **S / G**	**A**	
32	**UNEVEN DRAINAGE.** Uneven drainage results in an uneven or lumpy area on which zinc build op has occurred.	This condition can occur over the entire surface Grin isolated areas. Uneven drainage also includes drips en the ends of ports, runs near halos. The cause is withdrawal speed too high or low galvanizing temperature.	Although not particularly attractive, this condition dons not adversely affect coating performance. Protuberances and lumps, which interfere with mating surfaces are unacceptable. **G**	**A / C If Necessary**	

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

Technical Guidelines for the Inspection and Repair of Hot Dip Galvanized Coatings as per ASTM / AS / NZS / ISO / AWS / AC					
SN	**Description**	**Cause**	**Effect / Remedy / Responsibility**	**A/R/N/C/REP**	**Example**
33	**UNCOATED SURFACES CAUSED BY STEEL SURFACE CONTAMINANTS OR ENTRAPPED AIR.**	Residues, such as oil based paint, grease, oil or labels on the steel surface or incorrectly positioned vent holes, can result in localized un-galvanized areas in an otherwise continuous galvanized coating. Defects after galvanizing can vary in color from grey black to brown while no galvanized coating has been formed.	Ensure all paint or grease is removed prior to hot dip galvanizing. Make usual suitable marking pens for temporary identification. Correctly position adequately sized vent hubs. **B**	**A / N / R** **REP If Necessary**	
34	**UNGALVANIZED SURFACES CAUSED BY SCALE OR SAND.**	Sand on cast iron or scale on the steel surface is generally caused by the process used to form or roll the product. A localized un-galvanized area in an otherwise continuous coating can occur if scale or sand from the moulding or rolling is not removed by acid pickling or abrasive blasting.	These ungalvanized areas may occur in a linear pattern on angles, channels or other rolled products. They can also appear on cast iron products. **S / G**	**R / N** **REP If Acceptable**	
35	**UNGALVANIZED AREA IN THE VICINITY OF A WELD.**	A localized un-galvanized area near a weld can be caused by weld slug deposit, weld porosity or weld undercut. Oxide deposits and residues from welding are resistant to normal pickling adds and mint be removed before the work is pickled and hot dip galvanized.	Weld slag deposits should be removed by fabricators by means of abrasive blast cleaning. The deposit can also be removed by proper chipping or wire brushing. Shielded arc welding as opposed to slick welding is preferred for components which are to hot dip galvanized. **B**	**R / N** **REP If Necessary**	
36	**USE CONVENTIONAL FIXING METHODS SUCH AS BOLTS AND NUTS, OR REPAIR DAMAGED COATINGS CAUSED BY WELDING OR NON0-CONVENTIONAL FIXING METHODS.**	Conventional drilling and bolting after hot dip galvanizing is preferred. Should welding or noon-conventional method of fixing be used, resulting in damage to the coating, an approved repair method is necessary.	Coating repair can be done by zinc motel spraying urn zinc rich painter epoxy, providing the product conforms to the requirements of the specification. (See Coating Repair Procedures). **D / B**	**A** **REP**	

International Journal of Engineering Research & Technology (IJERT)
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Vol. 8 Issue 03, March-2019

Technical Guidelines for the Inspection and Repair of Hot Dip Galvanized Coatings as per ASTM / AS / NZS / ISO / AWS / AC					
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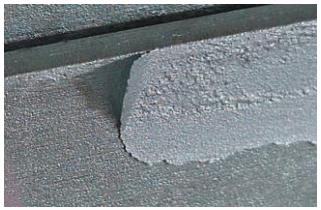
37	**WELD SPATTER.** Weld spatter is oxidized, normally spherical expelled weld metal, that is fused or not onto the surrounding material during welding.	Weld spatter is caused by weld pool explosions when improper welding parameters are used, or if the material is dirty or contaminated.	Loosely adherent weld spatter should be removed prior to hot dip galvanizing. Although not acceptable in terms of the specification the presence of tightly adherent weld spotter after hot dip galvanizing will not affect the corrosion resistant properties of the coating. **B**	**A / N**	
38	**WET STORAGE STAINS AND WHITE RUST:** Wet storage stains and white rust as it is commonly called, is a white voluminous deposit that is occasionally found on the surface of freshly galvanized coating.	Wet storage stain (zinc hydroxide) is formed on freshly galvanized surfaces whirls are in close contact in presence of moisture. Freshly galvanized coatings react with the environment until such time as a stable zinc carbonate film is formed on the cooling surface.	Wet storage stain ceases when the cause is eliminated. If the coating thickness at the affected area is equal to, or greater than the minimum required in the specification, it is not a cause for rejection, other than for aesthetic reasons. The latter is subject to discussion with the end user. Customer is to exercise caution during transport and storage. **G / B**	**A** **C If Necessary**	
39	**ZINC METAL SPRAYED REPAIR APPLIED TO INADEQUATELY BLASTED SURFACES OR NOT WIRE BRUSHED AFTER APPLICATION.**	In order for zinc metal spraying to adhere on application, the damaged galvanized surface mast be adequately blasted. As it is difficult not to over spray, excess zinc metal spray loosely adheres to the surrounding coating.	Prepare surface for repair by adequate blasting. Loosely applied zinc metal sprayed coating at the perimeter of the repair should ho removed by wire brushing If net removed, there is no compromise in the corrosion resistance. **G / B**	**A** **C**	
40	**ZINC SPLATTER:** Splashes or flakes of loosely adherent zinc, caused by moisture on the steel surface when hot dip galvanizing.	When hot dip galvanizing an unusually deep fabrication by double dipping, moisture and the surface of the steel contacts with the molten zinc causing splashes of zinc to loosely adhere to the already hot dip galvanized surface.	The loosely adherent zinc splashes are easily removed. An experienced galvanizer can ensure the coating overlap on double end dipped surface, is not visible. **G**	**A / C**	
Technical Guidelines for the Inspection and Repair of Hot Dip Galvanized Coatings as per ASTM / AS / NZS / ISO / AWS / AC					

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

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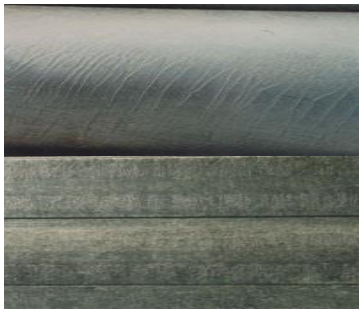
41	**Excess Aluinium in Galvanizing Bath:** These are the black spots occurs on the steel surface.	When the excess aluminium is in the galvanizing bath, it creates black marks or bare spots on the steel surface.	These effects can be repaired only if small areas are evident. If this condition occurs over the entire part then it must be rejected.	**R (Rejected) / G (Galvanizers) / REP If Necessary**	
42	**Runs:** These are the localized thick areas of zinc that occurs on the surface of galvanized elements.	These effects causes when zinc freezes on the surface of the galvanized elements during the removal from the zinc bath.	Unless they affect the intended use of steel part, not necessary to remove. If runs are unavoidable due to the design of the product, but will interfere with the intended application, they can be buffed.	**A / REP If Necessary**	
43	**Rust Bleeding:** These appears as a brown or red stain that leaks from unsealed joints aftet hot dip galvanization.	This effect caused by pre-treatment chemicals that penetrate through unsealed joint.	It can be cleaned up by washing the joint after the crystals are hydrolysed.	**A / REP If Necessary**	
44	**Striations/ Fish Boning:** These are the parallel ridges in the galvanized coaings.	Striations are characterized by raised parallel ridges in the galvanized coating, which can be caused by the chemical composition of the steel. Striations are related to the type of steel that was galvanized, and while the appearance is affected, the performance of the corrosion protection is not striations are acceptable.	Fish-boning, similar to striations, is an irregular pattern over the entire surface of the steel part, which is caused by differences in the surface chemistry of a large diameter steel piece and variations in the reaction rate between the steel and molten zinc. These surface conditions do not affect the corrosion performance and are acceptable.	**A**	

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

Technical Guidelines for the Inspection and Repair of Hot Dip Galvanized Coatings as per ASTM / AS / NZS / ISO / AWS / AC					
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45	**PUDDLING:**	These are caused by poor drainage also the Design issues are the main cause of puddling and can only be eliminated by good design. With the exception of blowouts and bleeding, and where the galvanizedcoating is missing, most galvanizing defects have no effect on the coatings' durability.	These defects are unavoidable in the hot-dip galvanising of general items and are acceptable as long as they do not interfere with the assembly of the function of the item or present a safety hazard in handling service.	**REP If Necessary**	

REFERENCES:

Codes And Standards

1) **ASTM A123 / A123M – 2002: -** Zinc (Hot-Dip galvanized) Coatings on iron and steel products.
2) **ASTM A143 – 2014: -** Practice for safeguarding against embrittlement of Hot-Dip Galvanized Structural Steel Products and procedure for Detecting Embrittlement.
3) **ASTM A153 / A153M – 2009: -** Zinc Coating (Hot-Dip) on iron and steel Hardware.
4) **ASTM A 36 / A36M – 2008 –** Standards specification for Carbon Structural Steel.
5) **ASTM A 384 – 2007:-** Practice for safeguarding against warpage and Distortion during Hot-Dip Galvanizing Of steel Assemblies.
6) **ASTM A 385 – 2011:-** Practice for providing High Quality Zinc Coatings (Hot-Dip).
7) **ASTM A 780 –** Repairs of Damaged Hot – Dip Galvanizing Coatings
8) **ASTM B6 – 2012 –** Standards Specification For Zinc.
9) **ASTM E376 –** Practice for measuring coating thickness by Magnetic – field or Eddy Current (Electromagnetic) examination Contains.
10) **ASTM B201 –** Testing Chromate coatings on Zinc and cadmium surfaces.
11) **ASTM A767 / A767M –** Zinc coated Galvanized steel bars for concrete Reinforcements.
12) **AS/NZS – 4680- 2006: -** Hot Dipped Galvanized Coatings on fabricated ferrous Articles.

Guides

13) American Galvanizers Asscoaitions Guides.
14) Practical experience during Factory inspection Services for Hot-Dip Galvanizing structural members.
15) Hot – Dip Galvanizing for corrosion preventions (A specifiers guide).

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