Guide to Inspection of Hot-Dip Galvanized Products (Guardrail Products)

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Guide to Inspection of
Hot Dip Galvanized Products
(Guardrail Products)

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Acknowledgment

This guide was developed by the North Carolina Department of Transportation to assist inspectors, suppliers, and fabricators of hot dipped galvanized guardrail materials. Although this guide specifically addresses guardrail materials, its theories and principles can be applied to all hot-dip galvanized materials. The information provided herein is for general information only and is not intended as a substitute for competent professional examination and verification as to accuracy, suitability, and applicability.

The information contained in this guide was compiled from literature research, and field and plant reviews of guardrail and guardrail producers, galvanizers, and fabricators. Since the majority of the information presented herein came from previously published articles, each individual piece of information reprinted will not be acknowledged.

Special thanks to the following organizations and companies for allowing the Department to incorporate some of their materials, guidelines, plant procedures, and other information into this guide.

American Galvanizers Association
Buffalo Specialty Products, Incorporated
Bryson Products
Galvan Industries, Incorporated
Gregory Galvanizing and Metal Processing
Moore Galvanizing
Southern States Galvanizing
Thomas and Betts Corporation
Trinity Industries, Incorporated
Young Galvanizing
Zinc Corporation of America

I. Introduction

Over the years, the North Carolina Department of Transportation has realized the need to ensure that all products incorporated into highway construction meet or exceed all material requirements as specified in NCDOT's Standard Specifications for Roads and Structures. Additionally, the Department has realized the need to ensure uniformity in conducting its inspections, testing, and acceptance of these materials.

The purpose of this guide is to provide the inspector, contractor, and producer with an established procedure and acceptance criteria for performing inspections and testing of hot-dipped galvanized guardrail. Although this guide specifically addresses galvanized guardrail materials, its principles and ideas can be utilized to cover a wide range of other hot-dip galvanized materials.

A. Background

One of the major concerns associated with the use of steel products in highway construction is the product's durability. Durability, as used in this guide, refers to the steel's ability to resist corrosion. There are several ways to enhance steel's durability. Some of these are:

- Epoxy coating or painting the steel after fabrication
- Altering the chemical composition of the steel (such as is the case with weathering steel)
- Hot dip galvanizing the product.

Hot-dipped galvanizing can be either continuous or batch dipped. In continuous hot-dip galvanizing, the steel sheets or coils are continuously hot-dipped galvanized prior to the material being fabricated such as the galvanized coils used in the fabrication of galvanized corrugated metal pipe. In a batch process, the material is fabricated before it is hot-dipped galvanized. Hot-dip galvanizing is the most widely used method of enhancing the durability of steel products. Although this manual is intended to be used as a guide in inspecting, testing, and accepting hot-dipped galvanized guardrail materials, it is important to recognize that every condition that may arise cannot be covered here, and this manual is not intended to remove sound engineering judgment.

B. The Hot-Dip Galvanizing Process - Batch Dipped

Hot-dip galvanizing is a process in which a product is immersed in molten zinc in order to coat the product with a protective layer of zinc. The zinc coating provides a barrier of protection for the steel, and the chemical properties of zinc provide what is known as cathodic protection. Barrier protection of the steel is achieved by providing a barrier between the base metal and the electrolytes in the environment.

Cathodic protection is achieved through a process called the sacrificial anode method. In this method a metal or alloy that is anodic is placed in contact with the metal to be protected. This allows the protected metal to become the cathode in the circuit inhibiting corrosion. The anodic metal, commonly zinc, corrodes providing the sacrificial protection.

There must be two other conditions present for the sacrificial anode method to work. First there must be a return current path for the electrons to flow from the anode to the material being protected

(physical contact) and second the presence of an electrolyte to convey the electrons (water/humidity). The hot-dip galvanizing process ensures these conditions as it forms a metallurgical bond which acts as the physical contact needed between the coating and the underlying steel or iron. The metallurgic bond is formed when the molten zinc reacts with the steel surface to form various zinc-iron alloy layers. These various layers of zinc alloys can be seen by taking a cross section photograph of the galvanized material through a microscope. This process results in a photomicrograph similar to the one shown in Figure 1.

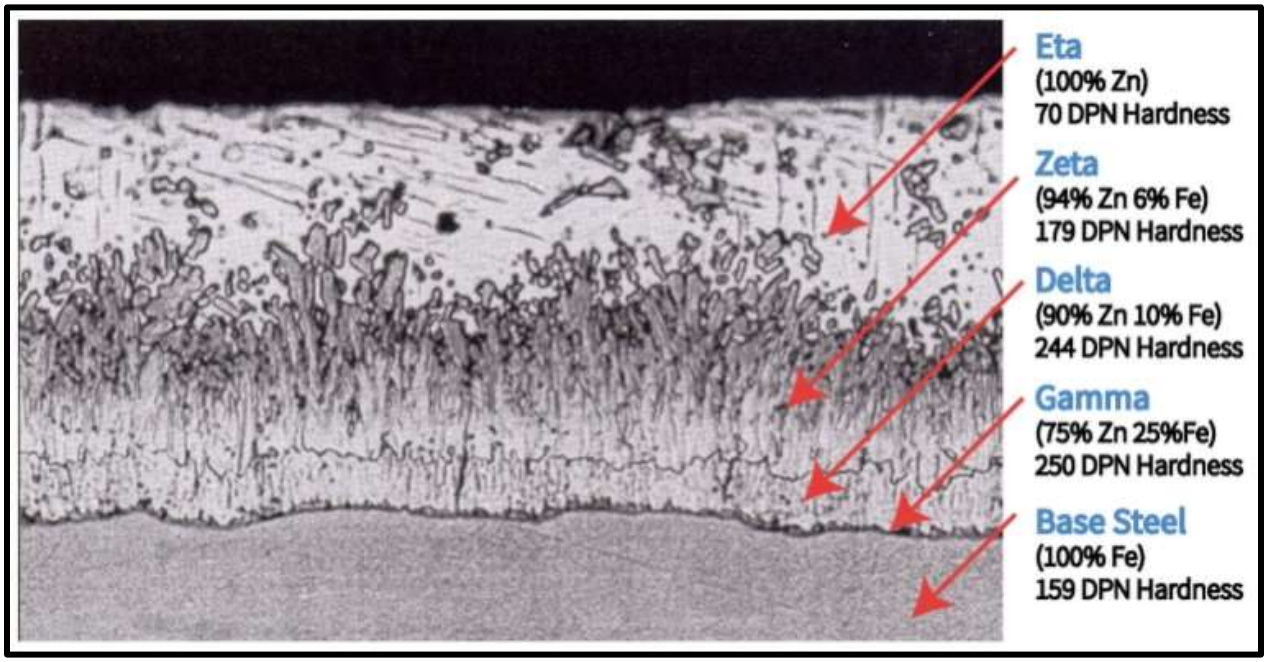


Figure 1 - Photomicrograph of zinc alloy layers

Figure 1 shows a cross section of a typical galvanized steel coating. These layers, from the outside in, are the Eta layer, Zeta layer, Delta layer, and the Gamma layer. Below the name of each layer in Figure 1 is the layer's hardness. The higher the number, the greater the hardness. As can be seen in this figure, the Gamma, Delta, and Zeta layers are typically harder than the underlying steel. These layers provide the galvanized material with protection against coating damage caused by abrasions or rough handling during shipping to, or at, the job site. Since barrier protection from corrosion is dependent upon the integrity of the coating, the toughness of galvanized materials makes for a reliable system for this purpose. Additionally, since zinc provides cathodic protection, it provides far better protection from physical damage to the coating. Unlike some other types of coatings, the zinc coating will sacrifice itself to protect the base metal. Figure 2 shows an example of what can happen when a paint coated material is damaged by a scratch along with what happens to a similar scratch on galvanized steel.

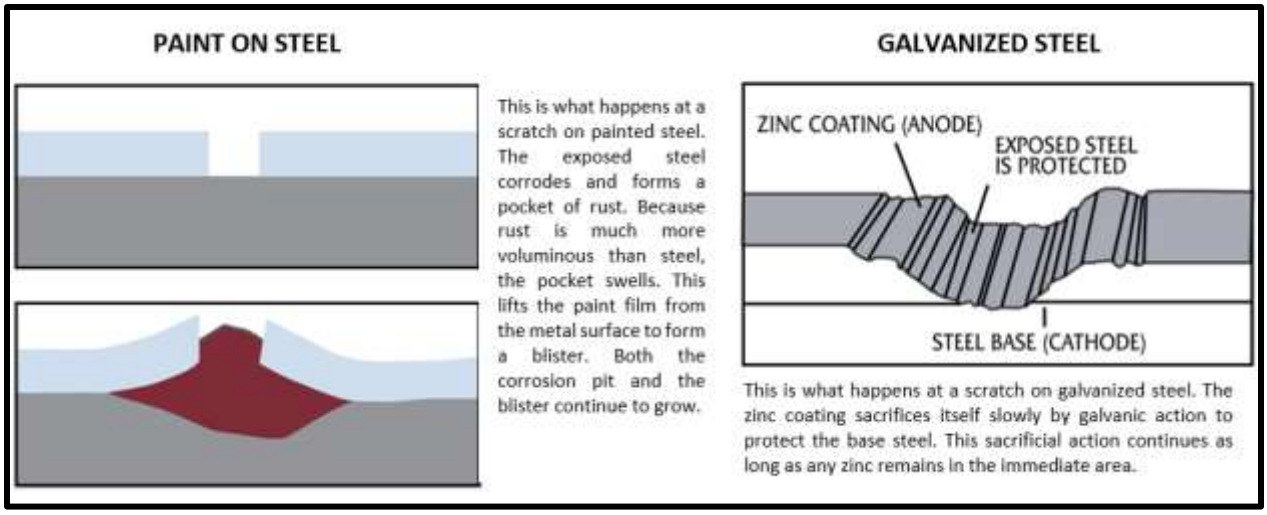


Figure 2 - Scratches on painted and galvanized steel

A good example of cathodic protection can be found in the shipping industry. Since nearly all ships are constructed of steel, the potential of the metal to rust in a wet and salty environment is great. The rusting process is inhibited by applying large zinc blocks along the hull of the ship. The zinc blocks become anodes and the majority of the rust occurs at these locations. The zinc sacrifices itself to protect the ship's hull.

The hot-dip galvanizing process consists of basically three steps. These are: surface preparation, galvanizing, and inspection. The first step, surface preparation, is the most important step and it generally consists of cleaning, acid pickling, and fluxing. In cleaning, a hot alkali or sulfuric acid solution is used to remove dirt, paint markings, grease, and oils from the metal surface. Acid pickling is used to remove scale and rust from the metal surface. It is usually accomplished by immersing the metal in a hot sulfuric acid bath, or a bath of hydrochloric acid at ambient temperature. Surface preparation can also include abrasive cleaning such as sand blasting. The last step in surface preparation is fluxing. Fluxing the metal prior to galvanizing removes oxides and prevents further oxides from forming on the metal surface. Fluxing can be applied to the base metal by two methods. The method used depends on whether the galvanizing plant uses a dry or wet galvanizing process. In the dry process, the metal is dipped in an aqueous solution of zinc ammonium chloride and allowed to dry thoroughly before proceeding into molten zinc bath. In the wet process, a layer of molten zinc ammonium chloride is used to coat the metal just before dipping the metal in the molten zinc bath. The layer floats on top of the molten zinc in the bath. Figure 3 shows a typical plant layout for the batch hot-dip galvanizing process.

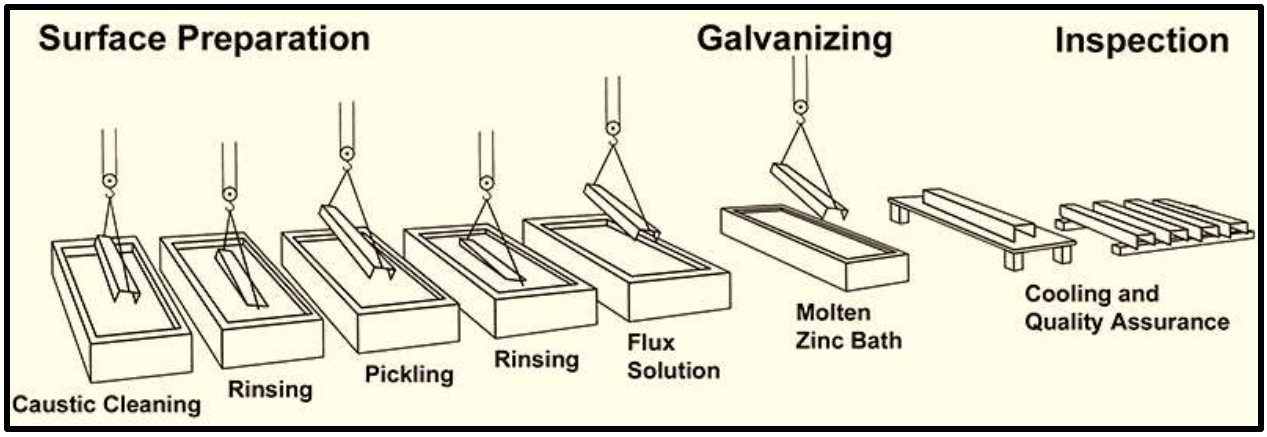


Figure 3 - Typical hot-dip galvanizing plant layout

The second step in the hot-dip galvanizing process is the galvanizing. In this step, the metal is immersed in a molten bath of zinc. The bath temperature is approximately 850 degrees Fahrenheit. For the zinc to properly bond to the metal, the item being galvanized needs to stay in the bath long enough for the metal to reach the same temperature as the molten zinc. After this has occurred, the item is removed very slowly from the bath, and the excess zinc is removed from the item by air blowing, draining, vibrating, or centrifuging. The galvanized item is then cooled in air or quenched in a water bath. Some producers or fabricators are also using a quenching bath of diluted sodium dichromate or chromic acid. The purpose of the coating of zinc chromate is to protect the material from, and/or inhibit the formation of, white rust and wet storage stains. These items will be discussed later in this guide.

The final step in the hot-dip galvanizing process is the inspection. In this process there are several items which will provide information on determining the acceptability of the finished product. The most important of these is the visual inspection. Visual inspections can identify problematic areas early, such as excessive ash inclusions, bare spots, flux inclusions, wet storage stains, blisters, and dross protrusions. Sampling, testing, and other inspection procedures will be discussed later in this guide. Hot-dip galvanizing is a factory-applied coating, and as such, the galvanizer has the primary responsibility of ensuring that an acceptable finished product is delivered to the job site.

C. The Hot-Dip Galvanizing Process - Continuous Dip

The continuous galvanizing process consists of the following phases: surface preparation, galvanizing, post treatment application, and inspection. During the surface preparation state, material passes through a leveling section to ensure all ASTM flatness tolerances are met. Material then enters an alkali cleaning section utilizing immersion and high-pressure sprays to remove any oils or greases. Material is then rinsed and enters a series of hydrochloric acid tanks designed to remove any scale or oxides present. Material then passes through a final rinse and drying section leaving a clean, dry surface suitable for galvanizing. During the galvanizing stage, the material passes through an induction heating section, then down into a kettle of molten zinc. As the strip exits the zinc bath, coating weights are controlled through the use of precision air knives to ensure a uniform coating, meeting all ASTM and AASHTO requirements.

Post treatments of chromate and oil are applied upon customer request. These post treatments aid in the deterrence of white rust. All material is then edge conditioned to ensure proper width tolerances are met and to eliminate any sharp edges.

The final stage of the continuous galvanizing process is inspection with all material being inspected for bare spots, zinc dross, and proper coating weights. Coating weight spot checks are made using a magnetic coating weight gauge and an ASTM weigh-strip-weigh coating weights test performed on each coil with samples retained. Figure 4 shows the continuous hot-dip galvanizing process.

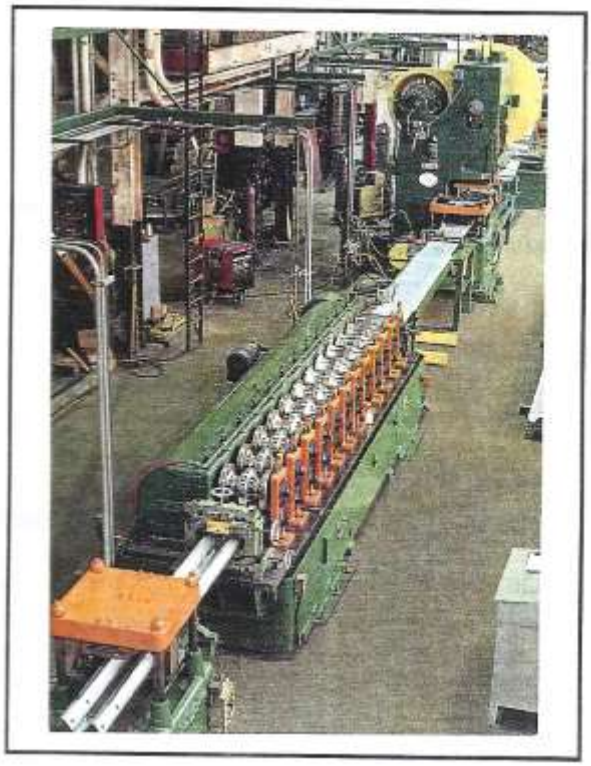


Figure 4 - Continuous Hot-Dip Galvanizing Process

II. NCDOT Brand Certification Program

In an effort to make the inspection, testing, and approval procedures more efficient, the Department decided to move to a Brand Certification Program. Brand Certification is a process by which the fabricators furnish the Department with a Registration and Guarantee that the material furnished under this Guarantee meets all applicable specifications, all quality control tests have been performed on the material as outlined in the program, the fabricator has on file all records and reports covering the material, the fabricator will replace any material that does not meet these specifications, and the fabricator understands that failure to comply to the program requirements may result in his company being removed from the list of prepared suppliers or that his company may not be allowed to furnish materials to the State. AASHTO M 180, Steel Components for Highway Guardrail, Section 5.3, allows for the use of a Brand Registration and Guarantee in accepting guardrail materials. Appendix A outlines the Department's Brand Certification Program for

Guardrail Materials. The goals of this program are to decrease the amount of submittals and certifications that are required to be furnished to the Department with each shipment of guardrail materials, to decrease the amount of time it takes for guardrail materials to be installed once the materials arrive on the project, and to give the fabricator more responsibility in furnishing the Department with materials conforming to the appropriate specifications.

The following guardrail materials and all associated accessories may be accepted under this program, provided the fabricator has supplied the Department with a Brand Registration and Guarantee in compliance with the Department's Brand Certification procedures outlined in Appendix A:

Rail Elements

Posts and Offset Blocks

Terminal Sections

Hardware

Anchor Units

Transition Sections

A. <u>Producer's Requirements</u>

Under the Brand Registration Program, the producer is required to submit a Brand Registration and Guarantee Certificate as outlined in AASHTO M 180, Section 5.3 by December 31 of each year. This Guarantee shall show the brand name or designation, the manner in which it will appear on the fabricated beams, the typical mechanical properties, the chemical composition, the class and type of guardrail, and other specific properties as required by the Engineer. The fabricator shall also guarantee that as long as material is furnished under that brand and designation it will conform fully to the requirements of the specification and it shall be replaced without cost to the Department when it is found not to be in conformity with NCDOT Specifications.

In addition to the Brand Registration, each producer must also file with the Department a Certificate of Compliance. This Certificate of Compliance shall cover all manufacturers, suppliers, and/or galvanizers which will be furnishing material or performing work for the guardrail producer. This certificate of compliance shall be the producer's guarantee that all material suppliers shall abide by the requirements of AASHTO M 180 and that they will furnish the guardrail producer all necessary mill test reports and certifications as required by the Brand Registration program. <u>The format for both the Brand Registration and Guarantee Certificate, and the Certificate of Compliance can be found in Appendix B.</u>

The producer must also supply to the Department, attached to both the Brand Registration and the Certificate of Compliance, a description of their quality control program, and one for each of their manufacturers, suppliers, and or galvanizers. This document should include each state of production, and the names of the quality control personnel and their duties. If any changes occur to the Brand Registration, Certificate of Compliance, or the quality control program, the producer will be required to submit an updated Guarantee. If no changes occur, the producer shall submit a new Brand Registration, Certificate of Compliance, and quality control procedures on or before December 31, of each year.

B. NCDOT Requirements

Upon receipt of the Brand Registration and Guarantee, The Department will review the required documentation for compliance with the program and AASHTO M180 Section 5.3. If all submittals are found to be in order, the supplier will be added to the list of approved guardrail material producers. This list is maintained on the State's' mainframe network and is available to any DOT office. The Department will conduct random plant checks of each supplier to ensure conformance to the Brand Registration and Quality Control Program. Additionally, the Department will visually inspect each shipment of guardrail materials, either before or after installation, for workmanship, dimension tolerances, minimum coating requirements, and for damages that may have occurred in transit. The producer will not be required to submit certifications with each shipment of guardrail as long as that supplier is on the approved list. Guardrail materials furnished by an approved producer may be installed prior to visual inspections by the Department. Sampling material tests for compliance with the Brand Registration will be at the producer's facilities and/or job site. Since the Department will be conducting random checks of the producer's fabrication plant and visual inspection at the job site, raw materials and sample representing the finished product may be obtained for verification testing. The supplier will aid in this process and will furnish samples as requested by the Department. An inspection lot shall consist of materials of the same kind which were galvanized at approximately the same time, in the same manner, and in the same galvanizing kettle. In the case of small objects such as nuts, bolts, and washers, an entire article or group of articles will be taken as verification samples.

For fabricated products such as plates, bars, angle sections, posts, and beam sections, test specimens of smaller sizes than those being galvanized may be submitted as test specimens as long as they are made of the same material as the full-length pieces, made in the same shape, and galvanized at the same time of the full length pieces. These test specimens shall be marked and identified in a manner approved by the Department and included with the guardrail shipment. In the case of sections, the specimen size shall be at least 3 feet (1m) in length. If test specimens are not furnished with each shipment, the Department retains the right to take a verification sample from the material actually shipped to the job site.

III. Inspection and Testing

As mentioned earlier, the most important step in the hot-dip galvanizing is visual inspection. This process can be done quickly with the aid of several simple physical and laboratory tests. These tests may include, but are not limited to, thickness, uniformity of coating, adherence of coating, and appearance testing. Specific requirements for each type of material will not be covered here since Highway agencies such as American Society for Testing and Materials (ASTM) and American Association of State Highway and Transportation Officials (AASHTO) cover everything required from the coating thickness to the composition of the zinc metal used in the hot-dip galvanizing process. (Appendix A, Section III shows the material requirements for the North Carolina Department of Transportation Brand Certification Program. Appendix C shows some of the standards relating to hot-dip galvanized materials.) Additionally, the American Galvanizers Association provides several publications to aid in the design and inspection of hot-dip galvanized materials. Appendix E contains actual photographs of guardrail materials shipped to North Carolina for incorporation into its highway system. On each page is a brief description of the condition shown, the primary causes of the condition, and the effect the condition has on the finished product.

A. <u>Coating Thickness</u>

As stated earlier, ASTM and AASHTO specifications establish the minimum standards for the thickness of galvanized coatings for various items. Factors that may influence the thickness and appearance of the galvanized coating include the chemical composition and surface condition of the steel, the bath immersion time, temperature, withdrawal rate, and the cooling rate of the steel.

The chemical composition of the steel may affect the rate at which the zinc-alloy layers form. Silicon and phosphorous levels in the steel will strongly influence the thickness of the coating. Other chemical properties such as carbon and sulfur may produce a minor effect on the coating thickness. Certain steel compositions accelerate the formation of the zinc-alloy layer. This may result in the coating having a dark grey, matte finish. This galvanized coating will provide the same corrosion protection as the common spangle finish.

There are several methods to determine the weight or thickness of the zinc coating on a galvanized article. The methods of testing chosen will most likely be dictated by the size, shape, and number of pieces to be tested. Test methods may be non-destructive or destructive. Non-destructive methods do not require the removal of zinc coating or sectioning of the substrate material.

The average weight of the zinc coating may be determined by weighing the articles before and after galvanizing, subtracting the first weight from the second, and dividing the result by the surface area. The first weight shall be determined after pickling and drying, the second after cooling to ambient temperature. *NOTE: This method does not consider the weight of iron reacted from the article that is incorporated into the coating. It may thus underestimate coating weight by as much as approximately 10%. Base metal reactivity will affect the extent of underestimation.*

The destructive test methods require the removal of the zinc coating or sectioning of the substrate material. The average weight of zinc coating may be determined by stripping an entire piece in accordance with ASTM Test Method A 90, or alternatively, the average weight of coating may be determined by stripping test pieces from the sample specimen, each with a measurable area of coated surface of at least 10 in. (2) (64.5 cm (2)). Cut one specimen approximately 4 in. (100 mm) from each end of the member and a third specimen from the approximate center of the member. The weight of coating obtained at each location shall not be less than the value listed the value listed in Table 1 under the heading “Any Individual Specimen or Computed Value.” The average weight of coating for the item shall not be less than the value listed in Table 1 under the heading “Average of Specimens Tested.” If these coating weight measurements are made on an article with different thicknesses of steel, then the values in Table 1 shall apply to each thickness of steel on the article.

The thickness of the coating may be determined by magnetic thickness gauge measurements in accordance with ASTM Practice E 376. A minimum of five readings shall be taken (in each location) peripherally about 4 in. (100 mm) from each end and in the approximate center of the member. The average thickness values taken at each location shall not be less than the value listed in Table 1 of ASTM A 123, under the heading “Any Individual Specimen or Computed Value.” The average coating thickness for the item shall be the average of the values obtained in the three locations and shall not be less than the value

listed in Table 1 of the ASTM A 123 under the heading "Average of Specimens Tested." If these coating thickness measurements are made on an article with different thicknesses of steel, then the values in Table 1 shall apply to each thickness of steel on the article. An example of how to average the readings and where they should be taken is shown in Figure 5.

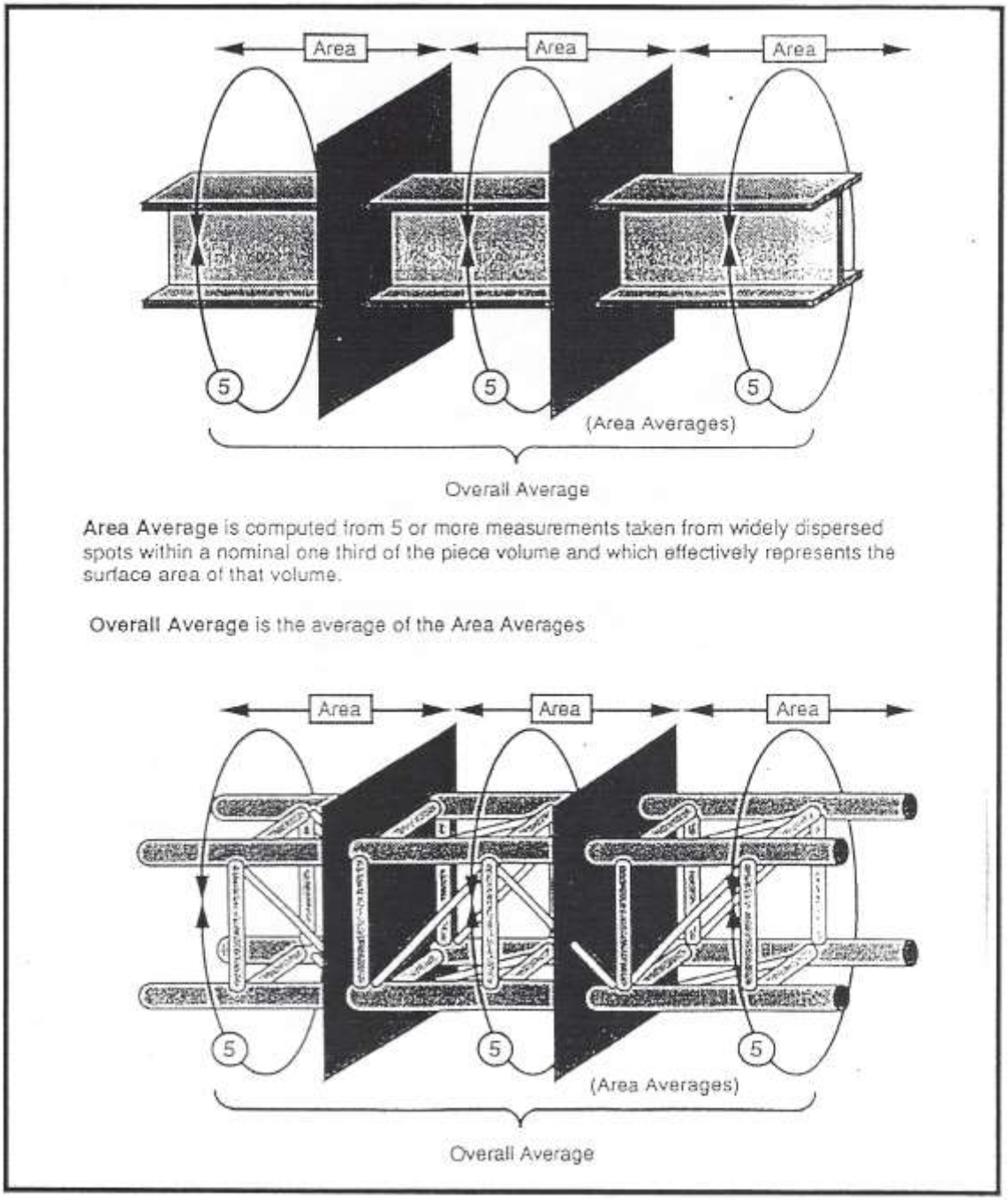


Figure 5 – Location of readings and their averaging methodology

Figure 6 - Magnetic balance coating thickness gauge

Magnetic type gauges measure the magnetic attraction between a magnet and a coating or its substrate or the reluctance of magnetic flux passing through the coating and substrate. These gauges are designed to measure thickness of a nonmagnetic coating on a magnetic substrate. Other types of gauges are also used to measure the thickness of coatings, but magnetic types are the most widely used.

Magnetic thickness gauges are affected by variations in the magnetic properties of the basis metal. To avoid the influence of severe localized heat treatments and cold working, the instrument used should be standardized using a reference standard having a base metal with equal magnetic properties to the test specimen.

The most commonly used tool in determining the coating thickness is the "Magna Gauge." The Magna Gauge is a magnetic balance gauge that is based on the theory that the attraction of two ferromagnetic bodies is dependent on the distance between them. In the case of galvanized materials, this distance is caused by the coating thickness of the zinc. Figure 6 shows a typical Magna Gauge. Coating thickness measurements are taken by placing the rubber magnet housing on the surface of the item being tested. The scale ring is turned forward to the maximum reading. Next the release trigger is pulled upward, releasing the magnetic tip perpendicular to the coating surface. With the magnetic tip in contact with the surface, the scale ring begins to turn slowly until the spring tension on the magnet just overcomes the attractive force between the magnet and the substrate of the galvanized item. At this point, the magnet breaks away from the surface and the scale ring stops rotating. Now a coating thickness reading is made from the scale ring. This break in contact is shown by an indicator on the top of the Magna Gauge and can be heard and felt.

There are other instruments and devices used to determine the coating thickness of Galvanized materials. Although their use will not be discussed here, it is advantageous to identify them. They are the coating pull-off gauges, which are based on the magnetic attraction to the underlying steel, and the electromagnetic thickness instruments, which are based on the magnetic reluctance of the coating. As with all testing and inspecting instruments, certain precautions should be taken to avoid possible errors in the readings. Below is a sample of some of the precautions.

- Follow the manufacturer's instructions on the use of the instrument.
- The instrument should be recalibrated frequently.
- The test surface should be free from dirt, grease, oxide and corrosion products.
- Test spots should be representative of the whole piece, avoid obvious peaks and irregularities.
- A sufficient number of readings should be taken to obtain a true average.

An approved method such as described in ASTM E 376 should be followed in determining coating thickness on galvanized material. The procedures used by NCDOT are described in Appendix D.

B. <u>Uniformity Testing</u>

The uniformity of coating thickness on a galvanized material is usually not a concern with materials which are galvanized after fabrication, as long as the minimum coating requirements are met. Due to the galvanizing process itself, variations in the coating thickness will occur. These variations may be due to several factors such as the angle of withdrawal of the material from the molten zinc bath, the rate of withdrawal, the number of items hung on top of each other during the dipping process (this may cause the lower items to have excessive coatings due to drippings from the items hung above the lower bars) and the shape of the item being galvanized. Where the coating thickness is not uniform, the service life of the galvanized coating will generally be governed by the amount of zinc available at the place where the coating is thinnest rather than by the overall or average thickness of the coating. By taking a number of readings at several different locations on a particular galvanized item, the coating thickness as well as the uniformity of the coating can be determined.

C. <u>Adherence of Coating</u>

Adherence of galvanized coatings is important because most hot-dipped galvanized materials must be transported, handled, and erected after galvanization has occurred. The coating must be sufficiently adherent to withstand handling consistent with the nature and the thickness of the coating in normal use of the article, without peeling or flaking. Heavier coatings, usually greater than ten mils thick, may be more brittle than the typical coating and thus may be subject to more damage during handling, transportation, and erection of the galvanized member.

Testing for adherence can be accomplished by a paring test. This test, which is often called the Stout Knife Test or the Cutting and Whittling Test, is detailed in ASTM A 123 and A 153. This test is performed by cutting or prying on the galvanized coating with a sharp knife. For the adherence to be considered acceptable, it should be possible to only remove a small portion of the galvanized coating. It should not be possible to peel any portion of the coating in the form of a layer so as to expose the underlying iron or steel in front of the knife point.

IV. Storage and Handling

Up to this point, we have concentrated our review on material preparation and the hot-dip galvanizing process. But this is only part of the finished product. Several other factors such as storage and handling of the galvanized material may affect the finished product and service life of the member.

One such problem that is familiar to producers, purchasers, and governmental agencies, is wet storage stains or “white rust." This section defines what white rust is, why it occurs, and ways to prevent it.

Wet storage stains or "white rust" are the white or grayish deposits formed on closely packed, newly galvanized items stored or shipped under damped or poorly ventilated conditions. This deposit is actually caused by the accelerated corrosion of the zinc coating and is a result of the items exposure to certain conditions. *It is not indicative of inferior galvanizing quality*. These deposits are normally found on stacked or bundled items. While "white rust" is a white or grayish color, it should not be confused with the normal oxidation of galvanized products which occur due to atmospheric exposure.

Wet storage stains in general are usually not detrimental to the protective coating because they can be removed and even prevented. However, when the galvanized materials are improperly transported, stored, or handled, it becomes a serious problem. Not only does the galvanizer have complete responsibility for the quality control of the items being galvanized, but he also has partial responsibility for protecting the items from wet storage stains, in that he is responsible for the initial storage and sometimes transportation of the items. While the producers and galvanizers have the responsibility to produce a good quality product in conformance with the governing specifications, he cannot control the proper handling and storage of the materials when they leave his plant. It is also the purchaser's responsibility to ensure the proper handling and storage of the material at the construction site to protect the materials from the formation of wet storage stains.

When galvanized articles are closely packed, deprived of freely moving air, and exposed to moisture, a set of conditions arise which tend to accelerate the corrosion of zinc surfaces. This is due largely to the retention of water which would normally be evaporated by freely moving air in adequately ventilated stockpiles. Since it is unrealistic to assume that the purchasers will restack the galvanized items bundled at the galvanizing facility, the galvanizer should assure that each stockpile or bundle of guardrail is provided adequate ventilation during the initial storage and bundling of the rail.

The moisture that causes wet storage stains to form originates in several ways. It may be present on the galvanized parts at the time of stacking or bundling due to incomplete drying after quenching, or it can be a result of direct exposure to rain or seawater, or from condensation due to atmospheric changes. If closely packed galvanized items become wet, the moisture tends to stay on the items due to capillary action and the lack of free-flowing air around the members. This moisture, in effect, forms a barrier between the stacked items. This water barrier provides the zinc surfaces with a different supply of oxygen causing a change in the electrolytic potential of the zinc where the moisture is concentrated. In effect the center of the moisture area becomes anodic and the edges of the moisture surface becomes cathodic. The corrosion of the zinc in these areas is accelerated because the zinc ions are constantly leaving the coating to bond with the anodic area which is the water.

This corroding of the zinc coating can further be accelerated when the moisture contains chlorides found in seawater, sulfur compounds from heavy industrial environments, and flux residues from the galvanizing process. These contaminants increase the concentration of oxygen cells by increasing the water's electrical conductivity. The important thing to remember is that severe damage can be done in a relatively short time by water alone, without any other contributing factors.

Since the extent of the "white rust" is dependent on the exposure time to the retained moisture, the fabricator and purchaser must take appropriate actions to protect the galvanized items from free moisture. White rust can be minimized by maintaining a low humidity environment around the material and by providing adequate ventilation between the stacked pieces. Some other points to observe, as recommended by the American Galvanizers Association, are:

1. The galvanized steel, as produced, should be clean and free from flux residues.
2. The material should be stored under cover, in dry and well-ventilated conditions, preferably with heating facilities. It is important to store the materials away from open doorways.
3. Small items that are quenched and stored in containers should be thoroughly dried before packing. Where the containers are sealed, the inclusion of a desiccant is recommended.
4. If outdoor stacking is unavoidable, the articles should be raised from the ground and separated with strip spacers, to provide free access of air to all parts of the surface (see Figure 7). They also should be inclined in a manner which will give maximum drainage (see Figure 8). Under no circumstances should galvanized steel be allowed to rest on cinders or clinkers, neither should it be stored on wet soil or decaying vegetation. The use of spacers is also recommended during any shipment if there is likelihood of condensation. For example, where material is chilled while traveling over mountains and then exposed to warmer and more humid air at a lower level, spacers are mandated. It is important that resinous woods are not used for spacers or packing since this in itself can start corrosion. Woods recommended for use in transporting and storing galvanized products should be dry and untreated without preservatives or fire-retardant chemicals. Poplar, ash, and spruce have been used quite satisfactorily in contact with galvanized steel in storage and transport.
5. Uncovered material should not be left standing at in-transit loading points where it may be exposed to rain, mist, condensation, or snow.
6. In shipment overseas, galvanized steel should not be consigned as deck cargo or stowed in parts of the ship's hull where contact with bilge water is likely. As noted, seawater is especially corrosive under conditions conductive to wet storage stain. The high humidity at sea, particularly in the tropics, makes the provision of dry and well-ventilated facilities particularly important.

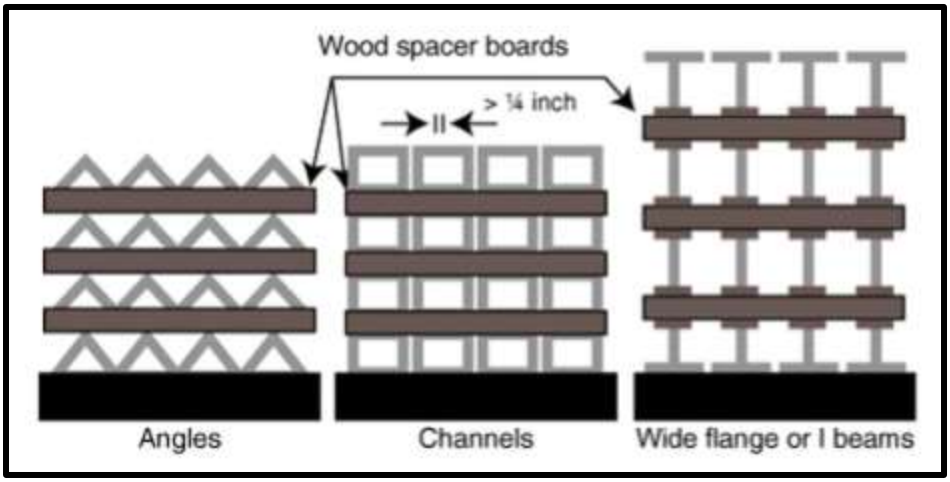


Figure 7 – Proper spacing between items

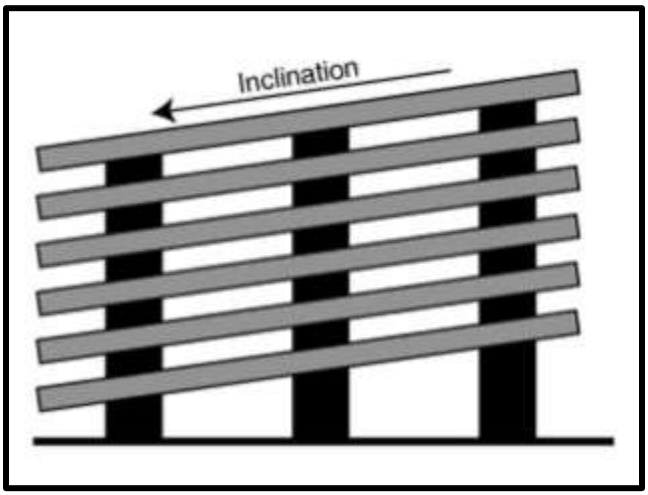


Figure 8 – Proper drainage of items

Another way for the galvanizer to help prevent the formation of wet storage stains on galvanized guardrail items is to provide a surface treatment to protect the zinc coating from the water. The most common treatment method used by guardrail producers is to dip the finished guardrail in a chromate bath. Like the zinc bath, the chromate bath immersion time has a direct effect on the coating. The maximum protection provided by the chromate is directly related to the film thickness. The thick chromate films appear on the guardrail as golden brown or khaki color. However, due to aesthetic reasons these thick films are not considered desirable. For temporary protection during storage and transportation a thinner film may be used.

Because chromate dip treatments usually provide several months of protection from wet storage stains, tight stacking conditions may be acceptable, but the guardrail material is often shipped at the beginning of a project, and it may be six months to a year before it is actually installed. Keep in mind, however, that due to the ever-changing construction practices, and the type of construction phasing, the

guardrail material may be stockpiled on a project for extended periods of time, in these cases, the guardrail material should be protected from the formation of wet storage stains. Figure 8 shows the effects of wet storage stains on a guardrail section.

Figure 8 – Section of guardrail on the left shows the effects of wet storage stain, while the right side is unaffected.

When wet storage stains occur in small quantities, they will generally not affect the service life of the guardrail. The extent of wet storage stains can be determined by lightly rubbing the surface of the material with the fingertips. If the surface is light in color and smooth, the stain will gradually disappear resulting in a normal service life for the guardrail.

When the wet storage stain is white in color and is determined to be rough by rubbing the surface with the fingertips, the buildup is considered to be medium to heavy and must be removed. If the stains are not removed, the protective film of zinc carbonate, which is essential for the protection of the underlying steel, cannot form in the affected area. Light buildups of the stains can be removed by brushing the area with a stiff bristle brush. Do not use a wire brush since this will remove part of the underlying zinc coating. Heavy deposits can be removed by brushing the affected area with a 5% solution of sodium or potassium dichromate with the addition of 0.1% by volume concentrated sulfuric acid. This solution is applied to the affected area with a stiff brush, left on the piece for approximately thirty seconds, then it is thoroughly rinsed off, and the area is dried. After performing any type of corrective actions on wet storage stains, the coating thickness in the affected areas should be checked to ensure that sufficient zinc coating remains on the guardrail to provide for normal corrosion resistance.

In the advanced stages of wet storage staining, the white or grayish corrosion product may become darker in color. When this occurs, a significant amount of the coating has been lost and the service life of the guardrail is decreased. In severe cases where heavy deposits or red rust have formed due to prolonged storage in poor condition, the corrosion products must be removed, and the area repaired with two coats of zinc-rich paint (three dry mils thick) as detailed in ASTM A 780. In extreme cases, the guardrail may need to be re-galvanized.

APPENDICES

Appendix A

North Carolina Department of Transportation Guardrail Material Brand Certification Program

Effective since January 1, 1995, all guardrail materials delivered to and incorporated in any NCDOT project must be furnished by a pre-approved supplier. This includes all rail elements, posts and offset blocks, terminal sections, anchor units, transition sections, and all associated hardware. For a company to be approved as a supplier of guardrail materials, a Brand Registration and Guarantee Certificate meeting the requirements as set forth below, must be filed with the State Materials Engineer. This certification will be valid for one year and a new certification is due on or before December 31st of the subsequent years if no major changes have taken place in the manufacturing process. If changes have occurred, a new Brand Certification will be required before the material can be accepted.

I. Guardrail Materials Brand Registration Program Procedures

A. Each manufacturer must be actively enrolled in the AASHTO Product Evaluation & Audit Solutions Guardrail/Guiderail Program (formerly National Transportation Product Evaluation Program (NTPEP)).

B. Each guardrail manufacturer will submit a Brand Registration and Guarantee Certificate on or before December 31st of each year. A suggested Registration Certificate is attached in Appendix B-I.

C. Each guardrail manufacturer will submit with the Brand Registration and Guarantee, a Marking Scheme Document which indicates how guardrail materials will be marked. Any deviations from the requirements of AASHTO M 180 shall be detailed in this document and submitted to the Department. A suggested Document is attached in Appendix B-II.

D. Each guardrail manufacturer will submit with the Brand Registration and Guarantee, a Certificate of Compliance which lists all manufacturers, suppliers, and/or galvanizers which will be furnishing material or performing work for the company. (This list shall include plant name and address; type of work being performed for the manufacturer). An example Certificate of Compliance is attached in Appendix B-III.

E. Each guardrail manufacturer will submit with the Brand Registration and Guarantee a description of their quality control program if any inspecting or testing procedures are different from the Department's minimum quality control requirements listed in Part II of these procedures (see below).

II. Guardrail Manufacturer Quality Control Procedures

The manufacturer will perform the following minimum quality control procedures, and the statement "*We certify that these materials have been inspected and tested and conform to the NCDOT Brand Certification Program for Guardrail Materials*" shall be on each shipping document, and signed by a responsible company representative who has legal authority to bind the company. In addition to the above statement, a listing of the heat numbers for the material being shipped will appear on each shipping document. One additional copy of the shipping documents shall be submitted to the Materials and Tests

Unit. Records of the following tests and inspection procedures will be accessible to NCDOT and retained for a minimum of three years.

Tests and Inspections Procedures:

Item	**Frequency**
(1) Maintain File of Metal sheet manufacturer's certified mill analysis	Each Heat
(2) Steel sheet or coil thickness measurements	Two per heat
(3) Coating thickness measurements on galvanized product	10% random check per dip
(4) Product dimension a. Rail-measurement b. Backup plates c. Flared Ends d. Posts e. Blocks f. Buffer Ends g. Anchor Boxes h. Plates i. Soil Plates j. Soil Tubes k. Bridge Shoes l. Hardware m. Miscellaneous Pieces	One per production shift per day per product
(5) Hole Placement	10% production
(6) Welds	10% production
(7) Surface Finish – visual	100% production
(8) Repair of damaged metallic coating, surface cleaning, thickness	100% production

III. Materials

All base metal used in the beam, transition, and buffer sections shall consist of a sheet made of open hearth, electric furnace or basic oxygen steel and shall meet the mechanical properties as specified in AASHTO M 180, Section 8. The zinc used for coating the Type II sections shall be as prescribed by AASHTO M 120 and shall be at least equal to Prime Western grade. Nuts and bolts used for Type II beams shall conform to or exceed the requirements of ASTM A307. Back-up plates shall consist of one-foot sections of beams and shall be the same Class and Type specified for the full-length beams. End or buffer sections shall be of the same or greater thickness of metal and the same type as the beam to which it is attached unless specified differently by the Engineer.

IV. Coating Requirements

The weight of the galvanized coating will be determined by the means of a magnetic thickness gauge. The weight of the galvanized coating for the double exposed surface should be a minimum of 4.0

oz. per square foot and no less than 40% of the coating thickness can occur on one side (1.0 oz/ft2 = 1.7 mils of coating thickness). The sheets or beams shall be of a prime finish, free from defects such as blisters, flux and uncoated spots. The coating shall be smooth, free of beading or sharp projections along the edges and shall adhere tenaciously to the surface of the metal. All holes shall be clean and reasonably free of excess zinc. Uncoated edges resulting from shearing or piercing will not be considered objectionable.

V. Verification samples

Verification samples may be requested by NCDOT for testing. These samples will be taken in the presence of the department's inspector and shall be the size and shape specified by the inspector at the time of sampling.

VI. Monitoring Procedures (QA)

NCDOT representatives will randomly conduct a minimum of one plant inspection per year per manufacturer with the cooperation and assistance of the manufacturer to ensure that the Brand Registration and quality control requirements are met. Additionally, Materials and Tests representatives will visually inspect all guardrail when received on the project or at any maintenance facilities.

VII. Compliance

Failure to comply with Brand Registration and Guarantee requirements may result in the manufacturer being removed from the Department's Approved Supplier list of guardrail. If a manufacturer is removed from the Approved List, they will not be approved to supply guardrail to the Department until such time as they can prove that they can conform to the Brand Registration and Guarantee Program.

Appendix B - Templates

I. Brand Registration and Guarantee for Guardrail Materials

(COMPANY NAME)
(COMPANY ADDRESS)
(COMPANY TELEPHONE NUMBER)

BRAND REGISTRATION AND GUARANTEE

FOR GUARDRAIL MATERIALS

This guarantee verifies that all guardrail materials including rail elements, posts, offset blocks, hardware, anchors, anchor assemblies, terminal sections and accessories furnished by (company name) conform to the requirements of AASHTO Specification M-180, ASTM A-36, and AASHTO M-111 as applicable. Any material found not in conformance will be replaced at no cost to the NCDOT. Bolts and nuts will meet ASTM A-307 and be galvanized to meet AASHTO M-232. Washers will be galvanized to meet AASHTO M-232.

(Company name) also guarantees that all materials furnished are of domestic origin and are melted, manufactured and galvanized in the U.S.A.

DATE _____BY_____

NOTARY:

II. Brand Registration and Guarantee - Marking Scheme Document

(COMPANY NAME)

(COMPANY ADDRESS)

BRAND REGISTRATION AND GUARANTEE

MARKING SCHEME DOCUMENT

The guardrail materials furnished under this Brand Registration will be marked in the following way:

A. Marking specifics for guardrail beam elements.
   (1) Brand: Company brand or mark
   (2) M-180: AASHTO Specification
   (3) Heat number: 6-10 digits, alpha-numeric
   (4) Coating lot: Week [one or two digits [(e.g., 1 through 52)]
       Year [two digits, (e.g., 94)]
   (5) Class-Type
      (a) Class: A - Base metal nominal thickness 0.10511--12 ga.
      (b) Type: 2 - Zinc coated, 3.60 ounces per sq. ft.

B. Markings specifics for buffer, posts, offset blocks, hardware, anchors, anchor assemblies, terminal sections and accessories:

   (1) Markings for these items will be on durable tags attached to each bundle, or at the option of the supplier, can be embossed in the metal during fabrication.

(Company name) guarantees that all guardrail material identified and marked as stated above conforms to the requirements of AASHTO Specifications M-180.

DATE_____BY_____

III. Certificate of Compliance

(COMPANY NAME)

(COMPANY ADDRESS)

"CERTIFICATE OF COMPLIANCE"

We (company name), certify that all our material suppliers, manufacturers, and galvanizers are required to furnish us mill test reports and certifications for each shipment of material ordered. These documents will be on file and will be available to the North Carolina Department of Transportation upon request.

The following is a list of manufacturers and suppliers who will be furnishing material to our company for guardrail materials and associated hardware:

(1) (Name of supplier and address)
(2)
(3)
(4)
(5)

The following is a list of galvanizers who will be performing work for our company:

(1) (Name of galvanizer and address)
(2)
(3)
(4)
(5)

I understand that any additions to the above lists will require the submittal of an updated Certificate of Compliance. I further understand that if no changes occur, I will be required to submit a new Certificate of Compliance to the State Materials Engineer on an annual basis, December 31, of each year.

IV. Facility Ownership Update Form

Name of Company:
NCDOT Facility Number GR-_____

Corporate Address and Contact Information:

Street: _____
Street: _____
City: _____ State: _____ ZIP _____
Telephone: _____ FAX: _____
Email: _____
Name and Title of Contact: _____

Facility Mailing Address and Contact Information:

Street: _____
Street: _____
City: _____ State: _____ ZIP _____
Telephone: _____ FAX _____
Telephone: _____
Email: _____
Name and Title of Contact: _____

Facility Physical Address:

Street: _____
Street: _____
City: _____ State: _____ ZIP _____
Comments: _____
_____
_____

Plant Personnel Responsible for Quality:

	Name	Title	Cert. Number
1)			
2)			
3)			
4)			
5)			

The Quality Control Plan for this facility HAS been revised since it was NCDOT Approved? **YES / NO**

If YES, or a **NEW** facility, attach copy of current Quality Control Plan to this document and submit for review.

I certify that the foregoing entries are correct.

Signature _____
Title: _____
Date: _____

Appendix C - NCDOT Specifications for Guardrail Products

Table 1 - Standards Relating to Hot Dip Galvanized Guardrail Material

ASTM	American Society for Testing and Materials
A123	Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
A143	Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement
A153	Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A384	Standard Recommended Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies
A385	Standard Practice for Providing High Quality Zinc Coatings (Hot-Dip)
A767	Standard Specifications for Zinc Coated (Galvanized) Steel Bars for Concrete Reinforcements
A663	Standard Specification for Steel Bars, Carbon, Merchant Quality, Mechanical Properties
A36	Standard Specification for Carbon Structural Steel
A568	Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-rolled and Cold-Rolled, General Requirements
A780	Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
A924	Specification for General Requirements for Steel Sheets, Metallic-Coated by the Hot-Dip Process
E376	Standard Practice for Measuring Coating Thickness by Magnetic-Field or Eddy Current (Electromagnetic) Testing Methods
AASHTO	American Association of State Highway and Transportation Officials
M180	Corrugated Sheet Steel Beams for Highway Guardrail
M111	Standard Specification for Zinc (Hot Dip Galvanized) Coatings on Iron and Steel Products
M232	Standard Specification for Zinc Coating (Hot Dip) on Iron and Steel Hardware
CSA	Canadian Standards Association
G164-M	Hot Dip Galvanizing of Irregularly Shaped Articles

Appendix D - Guardrail Inspection

The following section contains a detailed description of the methods used for inspecting the thickness of zinc coatings. Examples are given for both the Metric and English system of measurements.

The procedure for testing the zinc coating on a galvanized product is essentially the same regardless of which system of measurements is used. In the Metric system, the coating thickness will be measured in micrometers (μm) and will be reported in grams per square meter (g/m). In the English system, the coating thickness will be measured in mils and will be reported in ounces per square foot (oz./ft^2).

A. <u>Testing Zinc Coating</u>

I. Guardrail:

There are two methods of determining the weight of zinc coating on a guardrail beam using the magnetic gauge as required in AASHTO M-180 sec. 9.1.2 and Table 2. They are the single-spot test and the triple-spot test methods. The single-spot test requires that a reading be taken at the same point on both the front and back sides on the beam. This point is chosen randomly. The weight required is 3.6 oz./ft^2. The triple-spot test is like the single spot test except that the beam is divided into thirds and readings are taken at a random point within these three divisions and then averaged. The weight required is 4.0 oz./ft^2. The guardrail beams also must have a minimum of 40% of the required zinc coating on a side or a minimum of 1.6 oz./ft^2 (2.7 mils thickness).

1. Take a minimum of three single-spot readings on the rail and record.
   Example:

<u>Front</u>	<u>Back</u>
3.6	3.6
3.4	3.2
<u>3.5</u>	<u>3.3</u>
10.5 =total	10.1 =total

2. Total the number of readings from both sides.
   Example: 10.5 + 10.1 = 20.6 mils

3. Divide this total by the number of single-spot readings to get the average.
   Example: 20.6 / 3 = 6.9 mils

4. Convert the average mils to oz./ft^2 by dividing by 1.7 mils/oz./ft^2
   Example: 6.9 mils / 1.7 mils/oz/ft^2 = 4.1 oz./ft^2

5. Determine if each side has a minimum of 40% of the required zinc coating by averaging the readings on each side and dividing by 1.7 mils/oz./ft^2 and then compare with the required minimum of 1.6 oz./ft^2.
   Example: Front (10.5 / 3) / 1.7 = 2.1 oz./ft^2

   Back: (10.1 / 1.7 = 2.0 oz./ft^2

Note: Technician will enter the average zinc coating thickness on the HiCams Guardrail FIR report for acceptance in mils not oz./ft^2.

II. Posts, Blocks and Buffers

The posts, blocks, buffers and most other guardrail items also require a minimum coating of 3.4 oz./ft^2 (3.3 mils) on each surface. Therefore, where possible, take 3 single-spot readings as described for rail above. On posts for instance, take a single spot reading on each flange and on the web. Calculations are done the same.

1. Take 3 single-spot readings and determine the average.
   Example: Web 3.6

   3.6

   Flange 3.4 Average = 20.4 / 6 = 3.4 mils

   3.3

   Web 3.2

   3.3

   20.4 = total
2. Divide the average by 1.7 mils/oz./ft^2 to convert to oz/ft^2.
   Example: 3.4 mils / 1.7 mils/oz./ft^2 = 2.0 oz./ft^2

If any item fails, test two other like guardrail items within the same lot. If any one of those also fails, then slug the item in question and submit the sample to the Chemical lab to be stripped and weighed.

If a discrepancy arises with zinc coating on a material that cannot be slugged or sampled. The SMS and/or AME will be contacted for an investigation of the material in question.

If zinc coating is damaged due to shipping or installation, repair damaged coating in accordance with Article 1076-7 of the NCDOT Standard Specifications.

Appendix E - Pictorial Inspection Guide

Appendix E contains visual inspection notes in reference to photographs of guardrail material shipped to North Carolina for incorporation into its highway system.

The guide notes pertain to the galvanization process, acceptable and non-acceptable (rejectable) guardrail conditions, storage, and examples of guardrail production processes. The notes are included in Tables 1 through 5.

The Master table below has been made for ease of navigation within this document.

Table 1 - Guardrail Material Galvanization Process

Photograph Number	Description
1	Steel products before being galvanized
2	Interior of galvanizing plant showing layout
3	Guardrail material in pickling bath
4	Acid bath at galvanizing plant
5	Zinc bath prior to dipping guardrail
6	Plant worker removing ash from top of zinc bath prior to material entering bath
7	Reinforcing steel being galvanized
8	Guardrail material in zinc bath
9	Guardrail leaving zinc bath
10, 11	Workers removing excess zinc from guardrail
12	Ash which has formed after removal of material from zinc bath
13	Plant inspector checking the coating thickness

Photographs Listed in Table 1 – Guardrail Material Galvanization Process

Photographs 1 – 13

Photo 1 Steel products before being galvanized.

Photo 2 Galvanizing Process, actual plant layout.

Photo 3 Guardrail material in pickling bath.

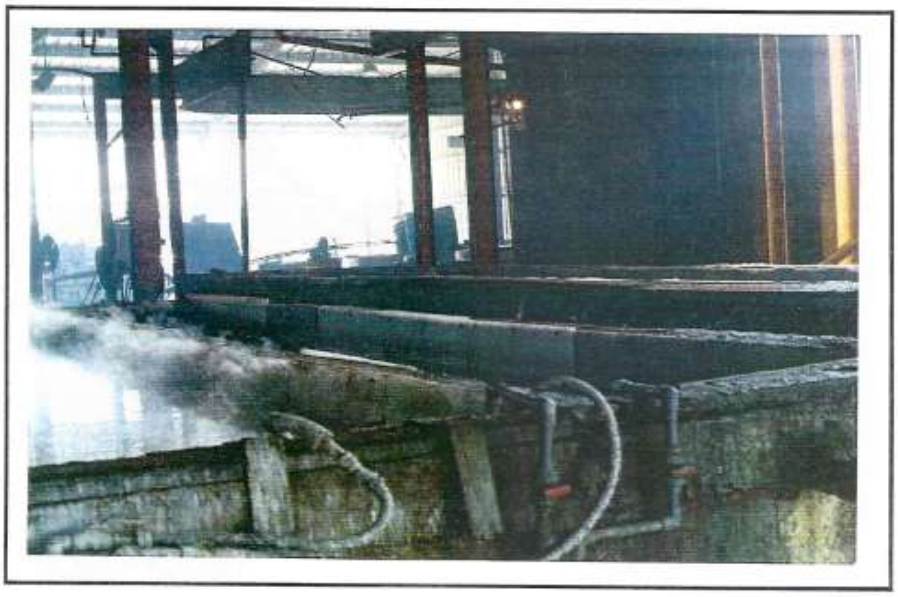


Photo 4 Acid bath at the galvanizing plan.

Photo 5 A zinc bath prior to dipping guardrail. Notice the buildup of ash in the bath. The ash must be pushed off the surface or it will stick to the guardrail.

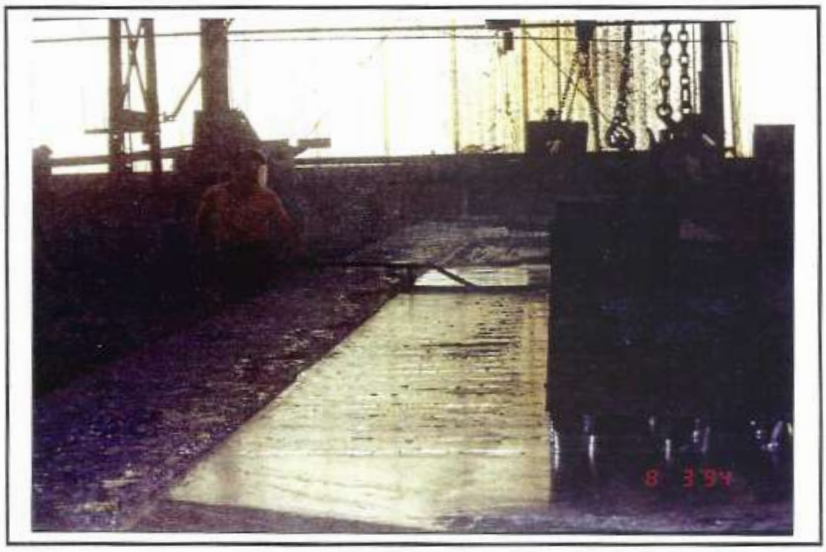


Photo 6 Plant worker removing ash from the top of the zinc bath prior to the material entering the bath.

Photo 7 Reinforcing steel being galvanized. Material longer than the zinc bath can be galvanized by dipping one half of the material, then dipping the other half.

Photo 8 Guardrail material in zinc bath. Notice the ash has already returned to the surface of zinc. This must be removed before the material is removed from bath or it will stick to the guardrail.

Photo 9 Guardrail leaving the zinc bath. The rail is withdrawn at an angle to help prevent spiked and excess zinc buildup.

Photo 10 Worker removing excess zinc from the guardrail. This will help prevent spikes and lumps on the rail.

Photo 11 Workers removing excess zinc from the guardrail. This will help prevent spikes and lumps on the rail.

Photo 12 Ash which has reformed after removal of material from the zinc bath. This must be removed before another item is dipped into the tank.

Photo 13 Plant inspector checking the coating thickness.

Table 2 – Acceptable Guardrail Conditions

Condition	Photograph Number	Comments/Notes	Repairable? Repair Method
Spikes, Icicles	14-20	The guardrail is acceptable unless sharp points provide a safety hazard during handling or roadside operations	Yes. Remove spikes with sander or file. If spikes break off leaving bare spots, repair following procedure for bare spots.
Excess Buildup of Material	21-22	The guardrail is acceptable unless sharp points provide a safety hazard during handling or roadside operations	Yes. Remove excess buildup with sander or file. If bare spots occur, repair by following procedure for bare spots.
Lumpiness and Runs	23-25	The guardrail is acceptable unless Lumpiness and Runs interfere with mating surfaces or by prior agreement.	None
Dull Gray Coating	26-29	-	-
General Roughness	30-34	The guardrail is acceptable unless General Roughness interferes with mating surfaces or by prior agreement.	None
Dross Protrusions	35	Acceptable unless the Dross Protrusions occur in heavy amount.	None
Rust Stains	36	Acceptable unless the Rust Stains exist in gross amounts.	Yes. Brush areas with stiff brush, apply two coats of zinc-rich paint (min. 3 dry mils thick)

Photographs Listed in Table 2 – Acceptable Guardrail Conditions

Photographs 14-36

Spikes and Icicles

Photographs 14-20

Photo 14 *Condition*: Spikes, Icicles

Causes: Uneven drainage of the steel when withdrawn from the zinc bath.

Effect: May break off resulting in Bare Spots (Exposed Steel). Sharp points may provide a safety hazard to pedestrians or during handling or roadside operations.

No effect to service life.

Acceptable Guardrail Conditions Continued

Spikes and Icicles Continued

Photo 15 *Condition*: Spikes, Icicles

Causes: Uneven drainage of the steel when withdrawn from the zinc bath.

Effect: May break off resulting in Bare Spots (Exposed Steel). Sharp points may provide a safety hazard to pedestrians or during handling or roadside operations.

No effect to service life.

Acceptable Guardrail Conditions Continued

Spikes and Icicles Continued

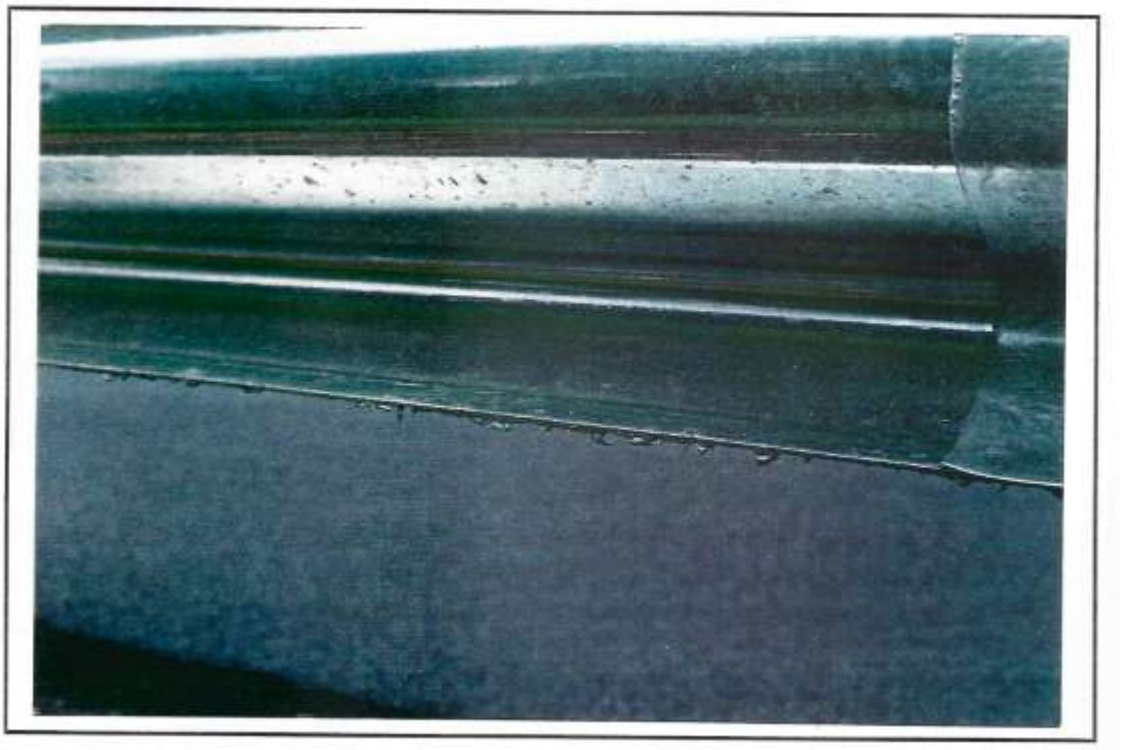


Photo 16 *Condition*: Spikes, Icicles

Causes: Uneven drainage of the steel when withdrawn from the zinc bath.

Effect: May break off resulting in Bare Spots (Exposed Steel). Sharp points may provide a safety hazard to pedestrians or during handling or roadside operations.

No effect to service life.

Acceptable Guardrail Conditions Continued

Spikes and Icicles Continued

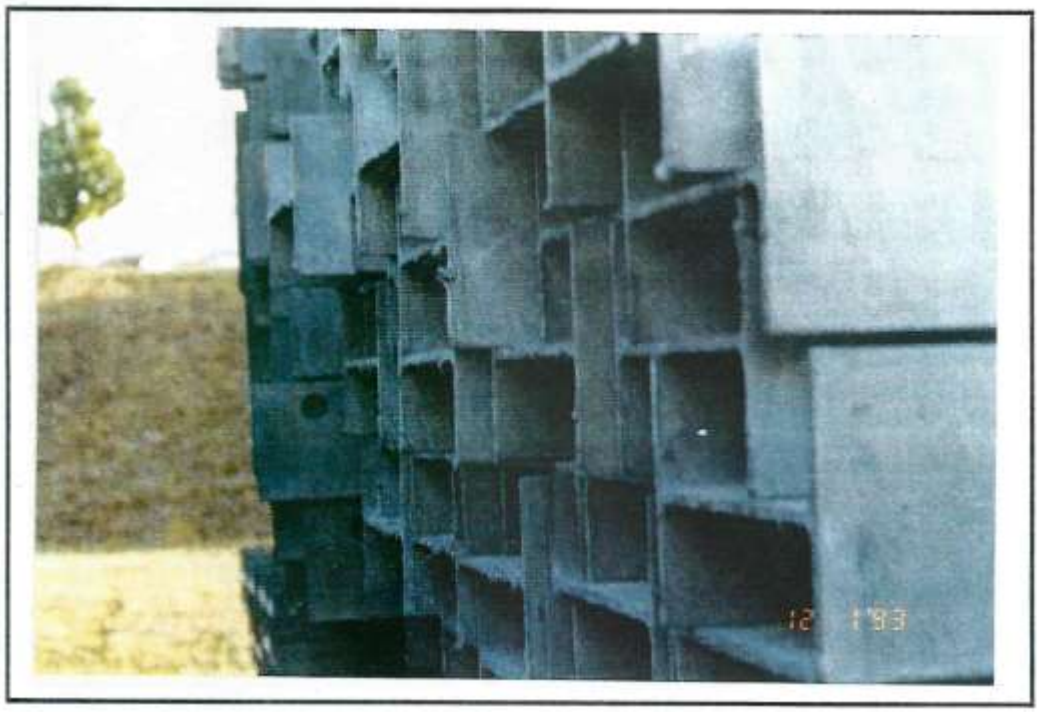


Photo 17 *Condition*: Spikes, Icicles

Causes: Uneven drainage of the steel when withdrawn from the zinc bath.

Effect: May break off resulting in Bare Spots (Exposed Steel). Sharp points may provide a safety hazard to pedestrians or during handling or roadside operations.

No effect to service life.

Acceptable Guardrail Conditions Continued

Spikes and Icicles Continued

Photo 18 Condition: Spikes, Icicles

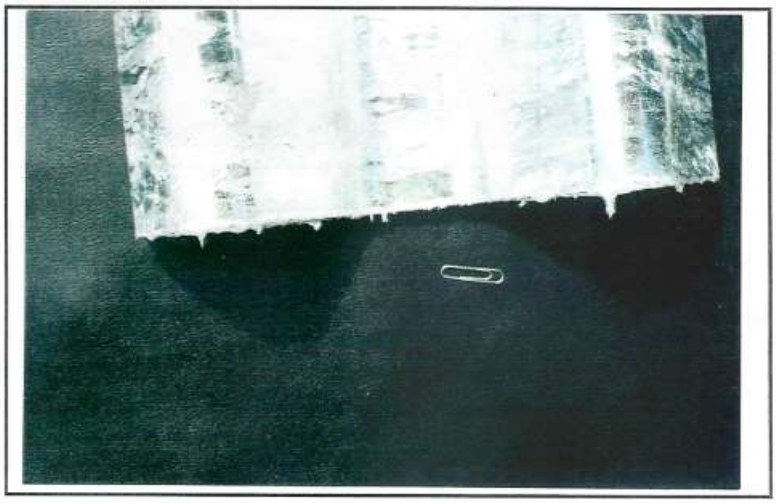


Photo 19 *Condition*: Spikes, Icicles

Causes: Uneven drainage of the steel when withdrawn from the zinc bath.

Effect: May break off resulting in Bare Spots (Exposed Steel). Sharp points may provide a safety hazard to pedestrians or during handling or roads operations.

No effect to service life.

Acceptable Guardrail Conditions Continued

Spikes and Icicles Continued

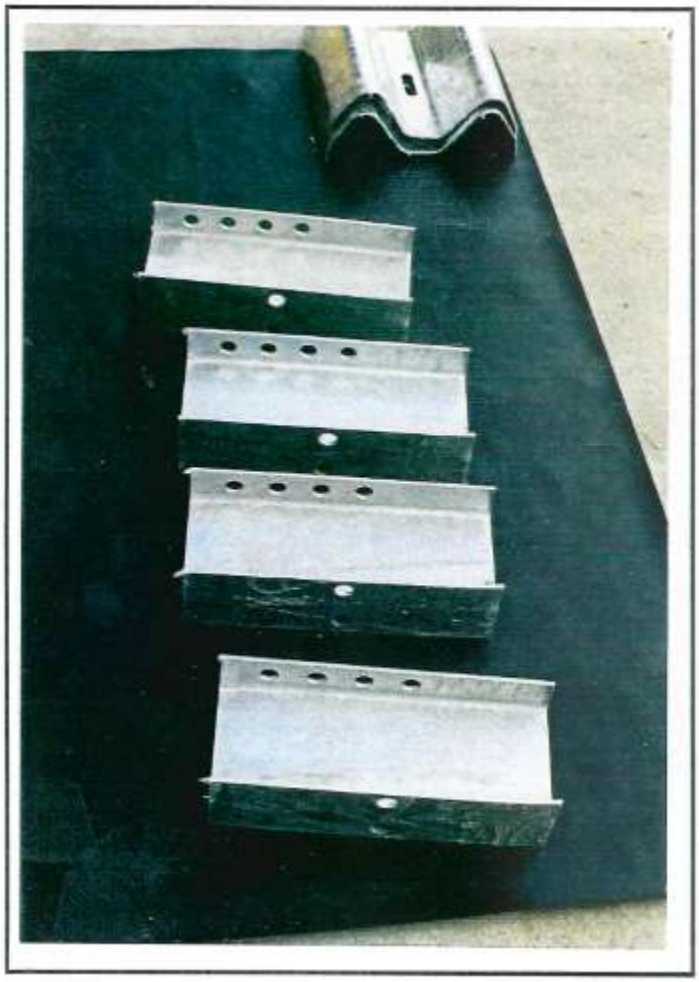


Photo 20 *Condition*: Spikes, Icicles

Causes: Uneven drainage of the steel when withdrawn from the zinc bath.

Effect: May break off resulting in Bare Spots (Exposed Steel). Sharp points may provide a safety hazard to pedestrians or during handling or roadside operations.

No effect to service life.

Photographs Listed in Table 2 – Acceptable Guardrail Conditions

Excess Buildup of Material

Photographs 21, 22

Photo 21 *Condition*: Excess Buildup of Material

Effect: May break off leaving bare spots or may pose a safety hazard to handlers and pedestrians. No effect on service of material.

Acceptable Guardrail Conditions Continued

Excess Buildup of Material

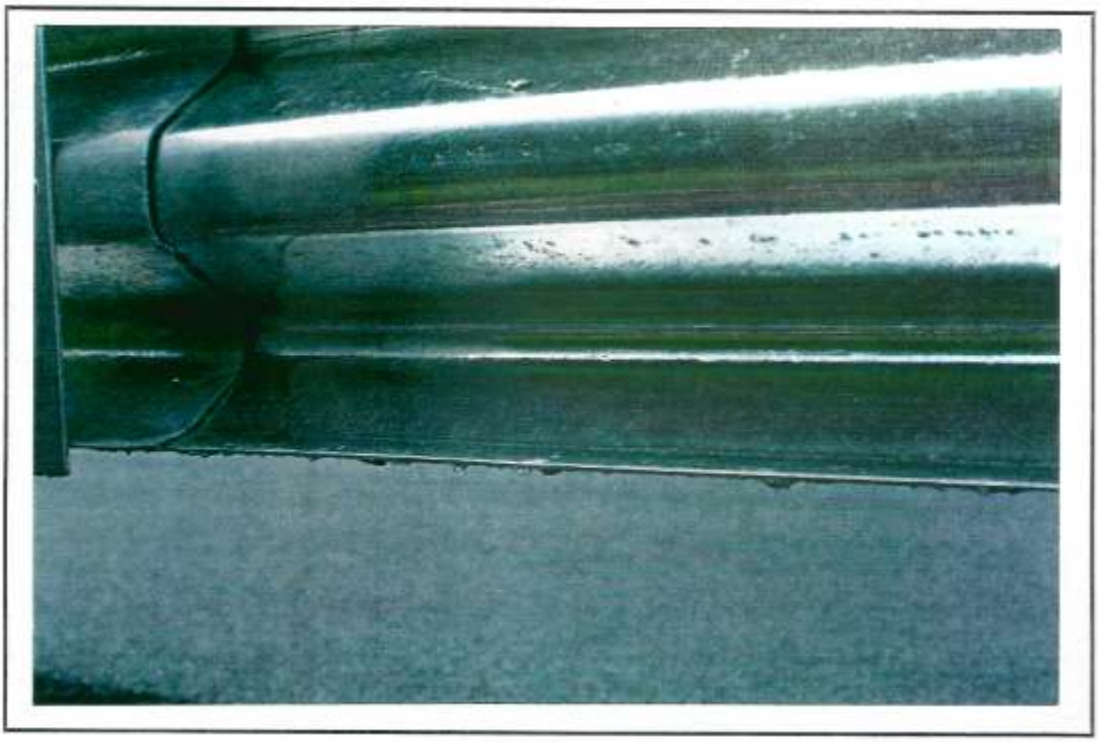


Photo 22 *Condition*: Excess Buildup of Material

Effect: May break off leaving bare spots or may pose a safety hazard to handlers and pedestrians. No effect on service of material.

Photographs Listed in Table 2 – Acceptable Guardrail Conditions

Lumpiness and Runs

Photographs 23 -25

Photo 23 *Condition*: Lumpiness and Runs

Causes: Withdrawal speed from dipping tank too high. Cold galvanizing bath. Delayed runoff from seams, joints, etc. Pieces in contact during withdrawal.

Effect: Not detrimental unless smooth surface for "mating" of pieces is required.

Acceptable Guardrail Conditions

Lumpiness and Runs

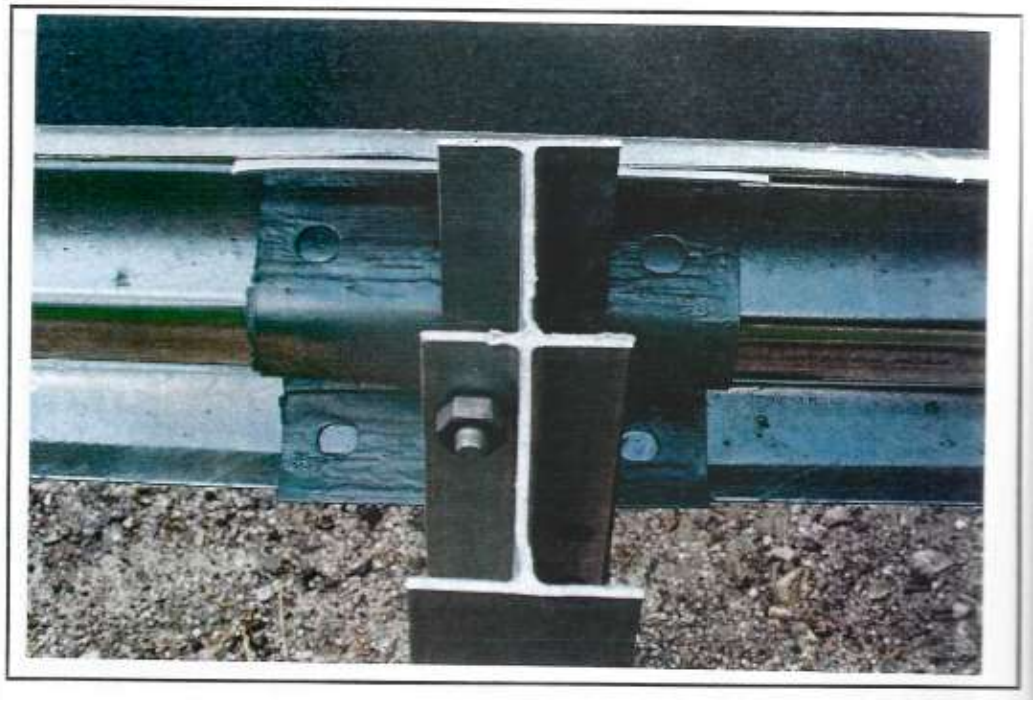


Photo 24 *Condition*: Lumpiness and Runs

Causes: Withdrawal speed from dipping tank too high. Cold galvanizing bath. Delayed runoff from seams, joints, etc. Pieces in contact during withdrawal.

Effect: Not detrimental unless smooth surface for "mating" of pieces is required.

Acceptable Guardrail Conditions Continued

Lumpiness and Runs Continued

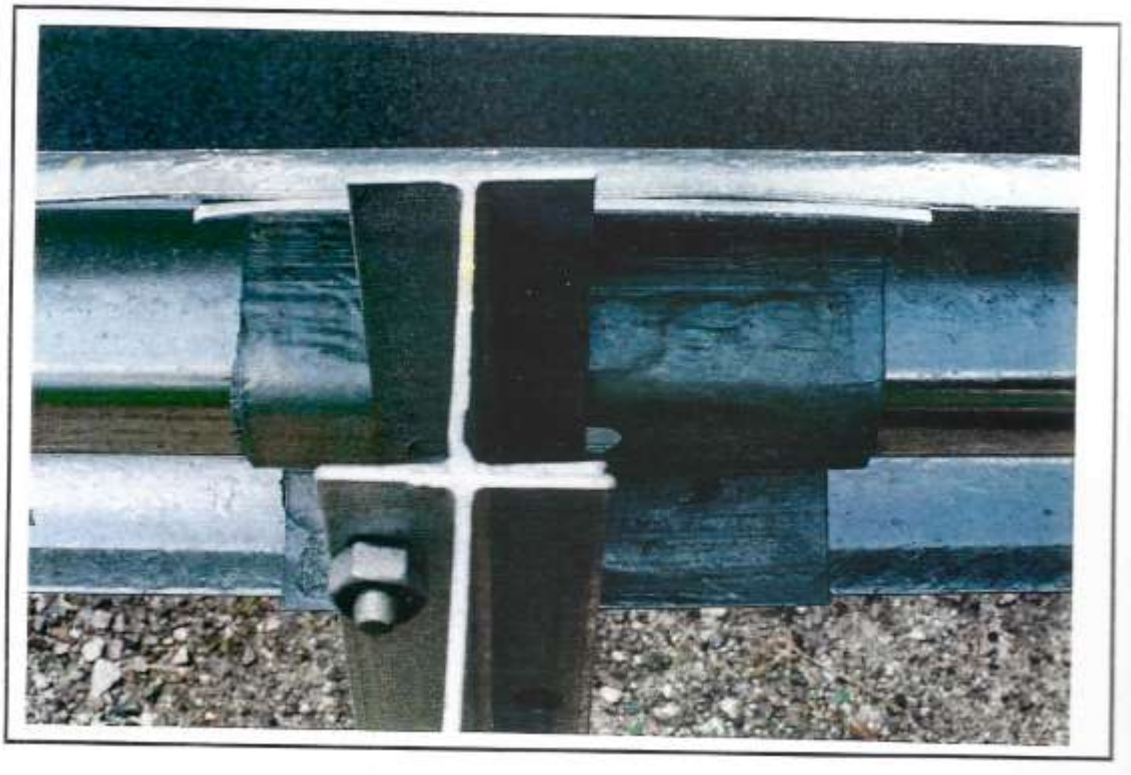


Photo 25 *Condition*: Lumpiness and Runs

Causes: Withdrawal speed from dipping tank too high. Cold galvanizing bath. Delayed runoff from seams, joints, etc. Pieces in contact during withdrawal.

Effect: Not detrimental unless smooth surface for "mating" of pieces is required.

Photographs Listed in Table 2 – Acceptable Guardrail Conditions

Dull Gray Coating or Mottled Appearance

Photographs 26-29

Photo 26 *Condition*: Dull Gray Coating or Mottled Appearance

Causes: Steel composition, cold working of the steel, or slow cooling after galvanizing.

Effect: Gray coating is often thicker than bright coating providing longer service life. May discolor over time.

Acceptable Guardrail Conditions Continued

Dull Gray Coating or Mottled Appearance Continued

Photo 27 *Condition*: Dull Gray Coating or Mottled Appearance

Causes: Steel composition, cold working of the steel, or slow cooling after galvanizing.

Effect: Gray coating is often thicker than bright coating providing longer service life. May discolor over time.

Acceptable Guardrail Conditions Continued

Dull Gray Coating or Mottled Appearance Continued

Photo 28 *Condition*: Dull Gray Coating or Mottled Appearance

Causes: Steel composition, cold working of the steel, or slow cooling after galvanizing.

Effect: Gray coating is often thicker than bright coating providing longer service life. May discolor over time.

Acceptable Guardrail Conditions Continued

Dull Gray Coating or Mottled Appearance Continued

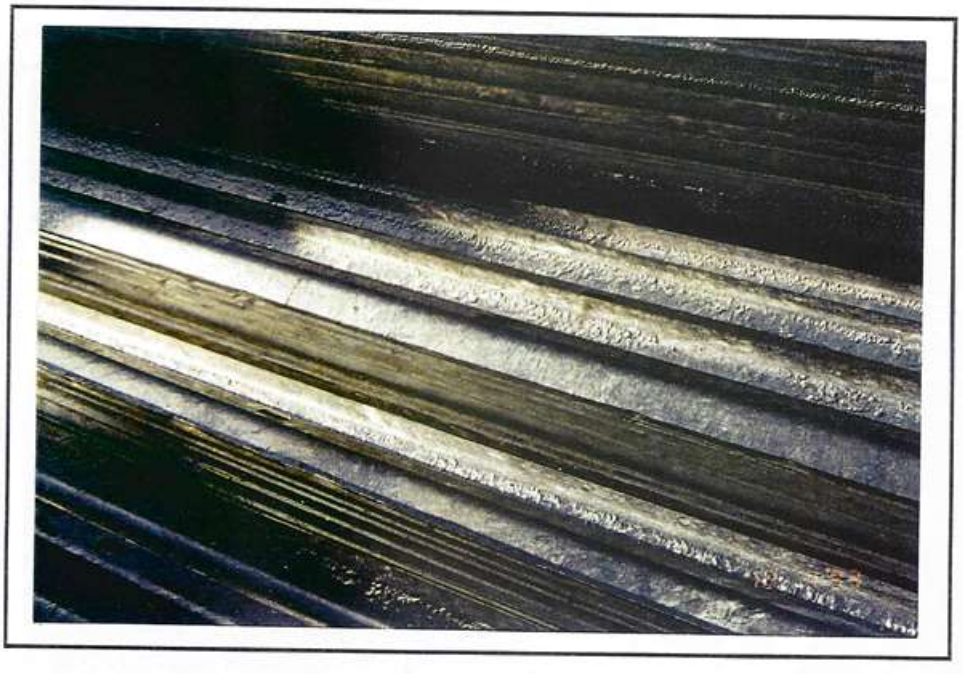


Photo 29 *Condition*: Dull Gray Coating and General Roughness

No adverse effect on the finished product.

Photographs Listed in Table 2 – Acceptable Guardrail Conditions

General Roughness

Photographs 30-34

Photo 30 *Condition*: General Roughness

Causes: Roughness of steel surface, over-pickling prior to plating, uneven cold working of steel, high temperature or long immersion time in bath.

Effect: Not detrimental unless smooth surface for "mating" of pieces is required.

Acceptable Guardrail Conditions Continued

General Roughness Continued

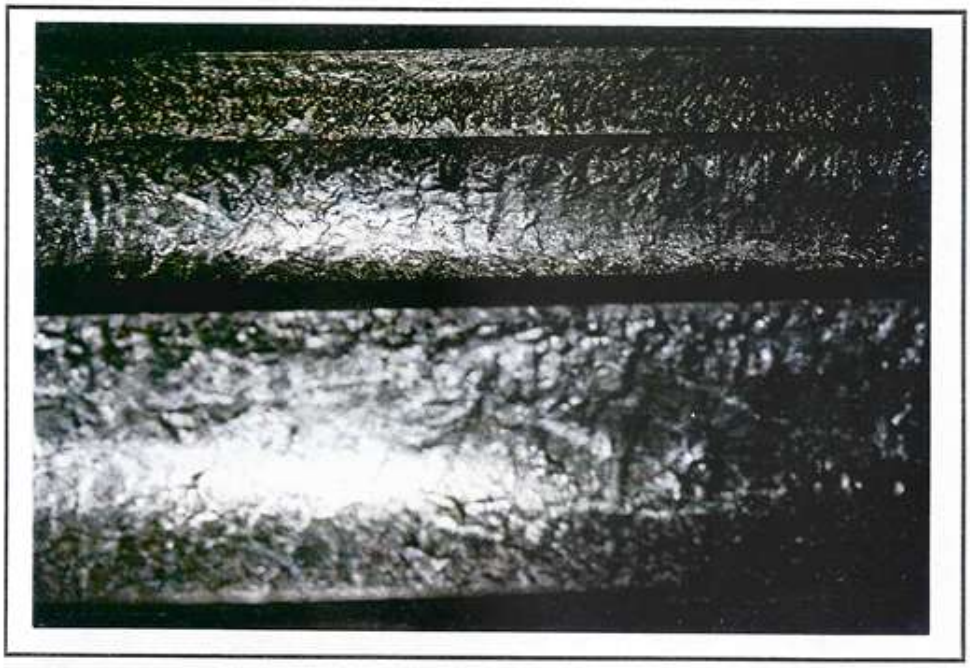


Photo 31 *Condition*: General Roughness

Causes: Roughness of steel surface, over-pickling prior to plating, uneven cold working of steel, high temperature or long immersion time in bath.

Effect: Not detrimental unless smooth surface for "mating" of pieces is required.

Acceptable Guardrail Conditions Continued

General Roughness Continued

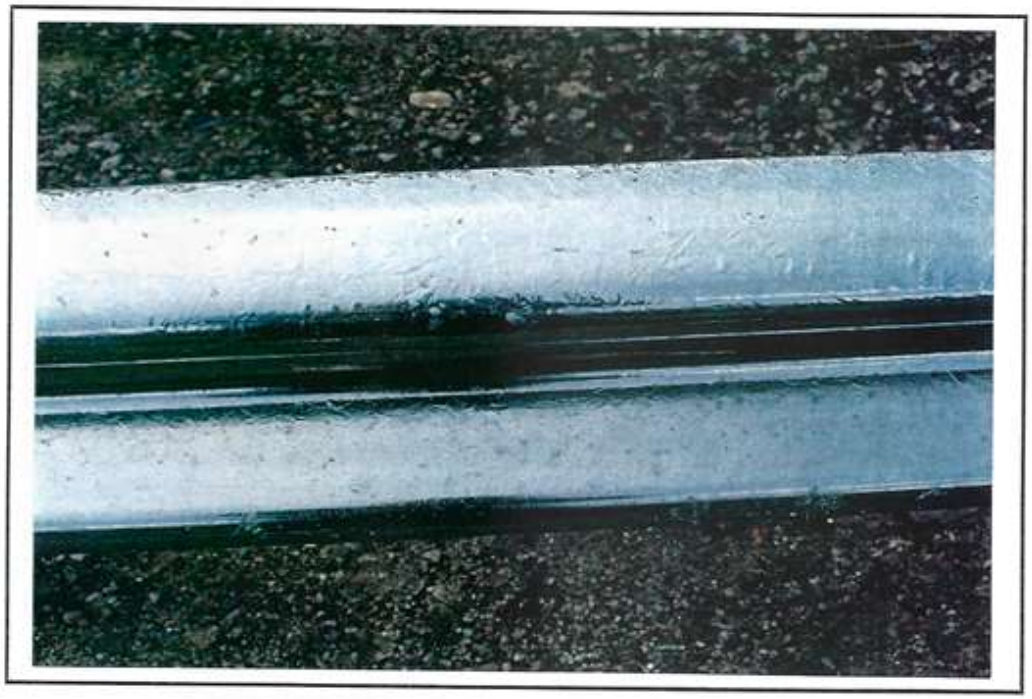


Photo 32 *Condition*: General Roughness

Causes: Roughness of steel surface, over-pickling prior to plating, uneven cold working of steel, high temperature or long immersion time in bath.

Effect: Not detrimental unless smooth surface for “mating” of pieces is required.

Acceptable Guardrail Conditions Continued

General Roughness Continued

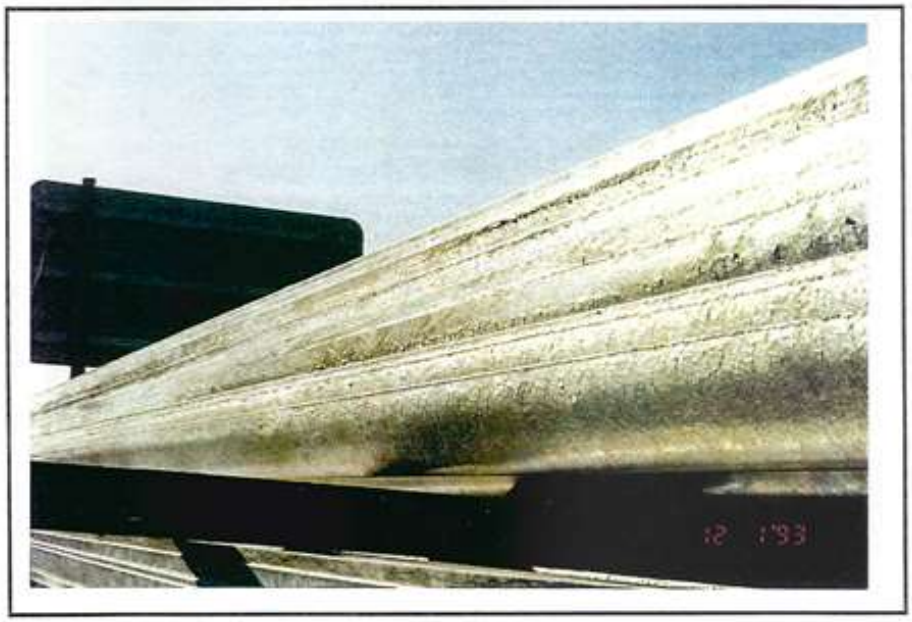


Photo 33 *Condition*: General Roughness

Causes: Roughness of steel surface, over-pickling prior to plating, uneven cold working of steel, high temperature or long immersion time in bath.

Effect: Not detrimental unless smooth surface for "mating" of pieces is required.

Acceptable Guardrail Conditions Continued

General Roughness Continued

Photo 34 *Condition*: General Roughness

Causes: Roughness of steel surface, over-pickling prior to plating, uneven cold working of steel, high temperature or long immersion time in bath.

Effect: Not detrimental unless smooth surface for "mating" of pieces is required.

Photographs Listed in Table 2 – Acceptable Guardrail Conditions

Dross Protrusions

Photograph 35

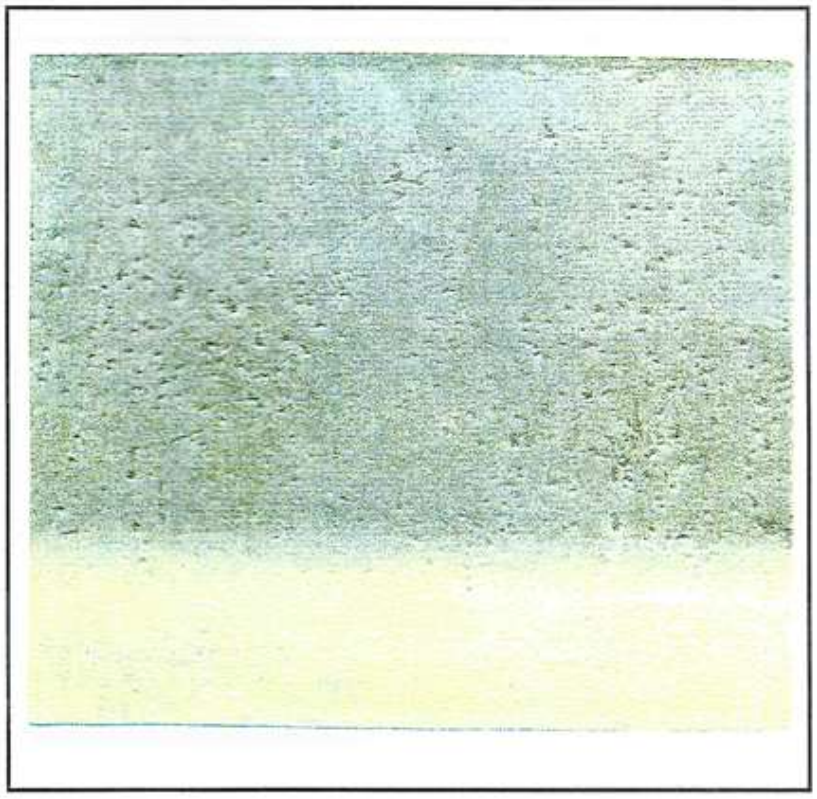


Photo 35 *Condition*: Dross Protrusions

Dross Protrusions appear as small, hard lumps on an otherwise normal galvanized surface. The protrusions result from agitation of the dross layer at the bottom of the bath or from dragging material through the dross layer. The dross incorporated in the coating prevents drainage of the bath zinc in the immediate area and a buildup occurs. Since the dross consists of the same iron-zinc as the coating, it will provide the same corrosion protection as a normal galvanized coating.

Photographs Listed in Table 2 – Acceptable Guardrail Conditions

Rust Stains

Photograph 36

Photo 36 *Condition*: Rust Stain Caused by Seepage

After galvanizing, the salts from the acid that have penetrated between contact surfaces during pickling can weep and react with the galvanized surface producing a rust stained area.

Appendix E – continued

Table 3 – Rejectable Guardrail Conditions

Condition	Photograph Number	Comments/Notes	Repairable? Repair Method
Bare Spots	37-46	Rejectable unless area is repaired.	Yes. Brush area with stiff a brush, apply two coats of zinc-rich paint (min. 3 dry mils thick.)
Ash Inclusions	47-57	The guardrail is rejectable if ash inclusions are existent in gross lumps or excessive small areas on individual pieces.	None
Bent Rail	58-62	The guardrail is rejectable if the bent area prevents mating of surfaces or if cracking of the coating has occurred.	Yes. Cracked areas should be cleaned with a stiff brush and painted according to the repair method for "Bare Spots"
Bent Plate	63	The guardrail is rejectable if the bent area prevents mating of surfaces or if cracking of the coating has occurred.	Yes. Cracked areas should be cleaned with a stiff brush and painted according to the repair method for "Bare Spots"
Field Bending	64	Rejectable	None
Flux Inclusions	65-66	Rejectable	None
Excess Holes	67-79	See Appendix E, FHWA Guidelines.	None
Wood Post without AWW Stamp	70	Wood posts without the AWW stamp on both ends of the post should be rejected. AWW stamps on both ends indicate that the post has been inspected and accepted by NCDOT contract inspectors.	None
Laminations	71	The guardrail is rejectable if the minimum coating thickness is not present or if the laminations can be peeled off by prying on the area with a stout knife.	Yes. Can be painted with zinc-rich paint if lamination area is less than ½ of 1% of the total surface areas (see note).
Wet Storage Stains (White Rust)	72-74	The guardrail is rejectable if the Wet Storage Stains are present in medium to heavy ranges as discussed in Section IV, Storage and Handling.	Yes. Clean area with a stiff brush, apply acid solution for 30 seconds, thoroughly rinse and dry. Note, after repair coating should be checked to ensure minimum coating thickness.

Note: Laminations suggest that there is a problem within the steel composition. If the laminations are significant then the strength of the steel has been compromised.

Photographs Listed in Table 3 – Rejectable Guardrail Conditions

Photographs 37 – 74

Bare Spots (Exposed Steel)

Photographs 37 – 46

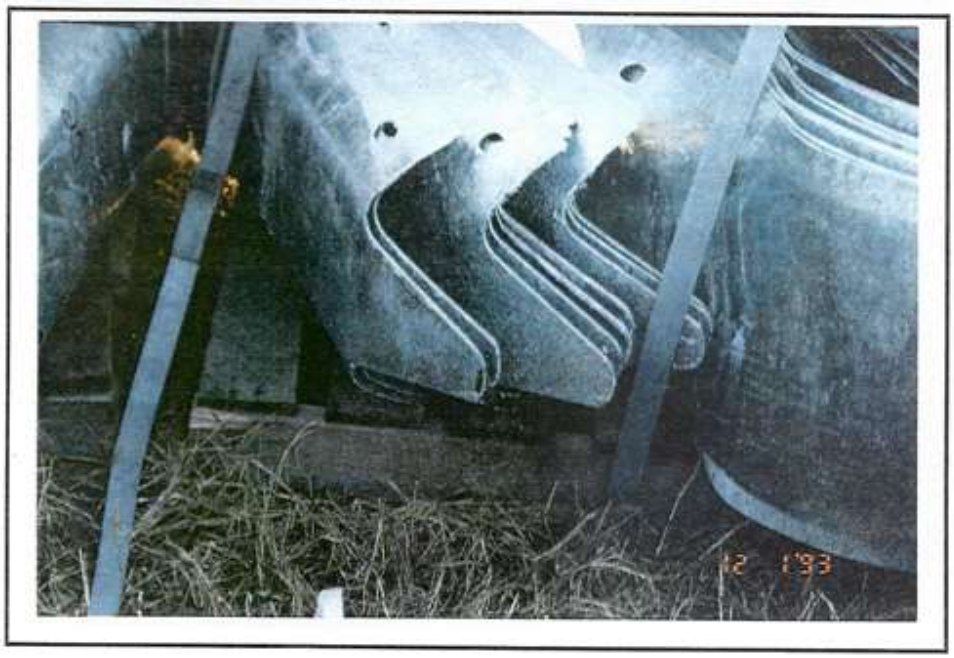


Photo 37 *Condition*: Bare Spots (Exposed Steel)

Cause: Excess material deposited during zinc plating has broken off.

Effect: Lack of protection for the steel resulting in rusting of the piece

Repair: Paint with two coats of zinc-rich paint (three dry mils.)

Rejectable Guardrail Conditions Continued

Bare Spots (Exposed Steel) Continued

Photo 38 *Condition*: Bare Spots (Exposed Steel)

Cause: Excess material deposited during zinc plating has broken off.

Effect: Lack of protection for the steel resulting in rusting of the piece.

Repair: Paint with two coats of zinc-rich paint (three dry mils.)

Rejectable Guardrail Conditions Continued

Bare Spots (Exposed Steel) Continued

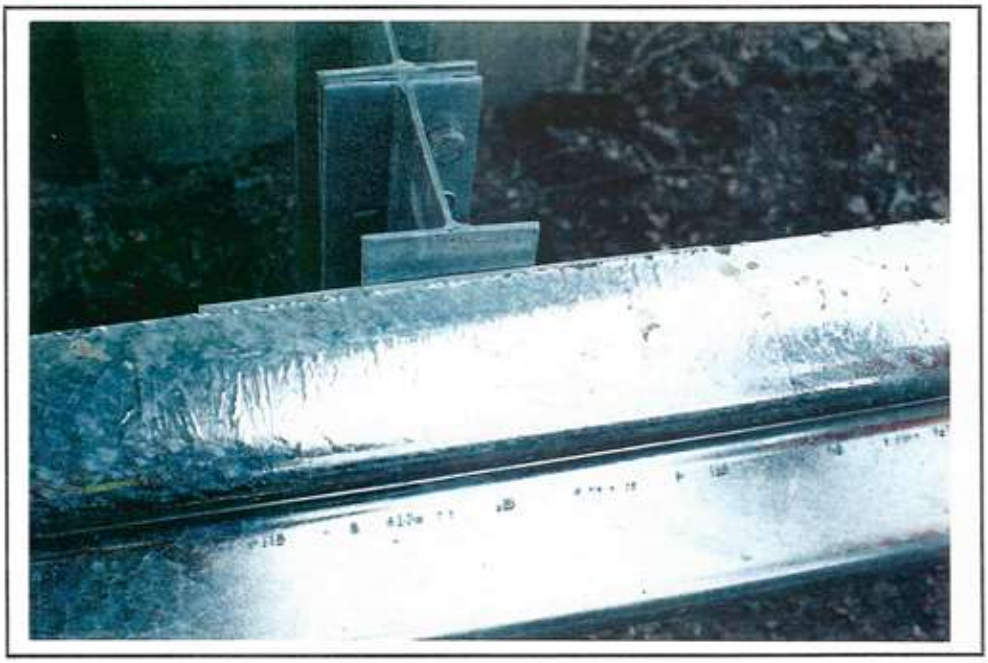


Photo 39 *Condition*: Bare Spots (Exposed Steel)

Cause: Excess material deposited during zinc plating has broken off.

Effect: Lack of protection for the steel resulting in rusting of the piece

Repair: Paint with two coats of zinc-rich paint (three dry mils.)

Rejectable Guardrail Conditions Continued

Bare Spots (Exposed Steel) Continued

Photo 40 *Condition*: Bare Spots (Ungalvanized Areas)

Cause: Residue on steel prevents plating of zinc on steel surface.

Effect: Lack of protection for the steel results in rusting of the piece.

Rejectable Guardrail Conditions Continued

Bare Spots (Exposed Steel) Continued

Photo 41 *Condition*: Bare Spots (Ungalvanized Areas)

Cause: Residue on steel prevents plating of zinc on steel surface.

Effect: Lack of protection for the steel results in rusting of the piece.

Rejectable Guardrail Conditions Continued

Bare Spots (Exposed Steel) Continued

Photo 42 *Condition*: Bare Spot

Cause: Residue on steel prevents the zinc from bonding with the steel surface.

Repair: Material should be re-galvanized

Rejectable Guardrail Conditions Continued

Bare Spots (Exposed Steel) Continued

Photo 43 *Condition*: Bare Spot

Cause: Residue on steel prevents the zinc from bonding with the steel surface.

Repair: Material should be re-galvanized

Photo 44 Bare spots on galvanized material being repaired at the producer's yard.

Rejectable Guardrail Conditions Continued

Bare Spots (Exposed Steel) Continued

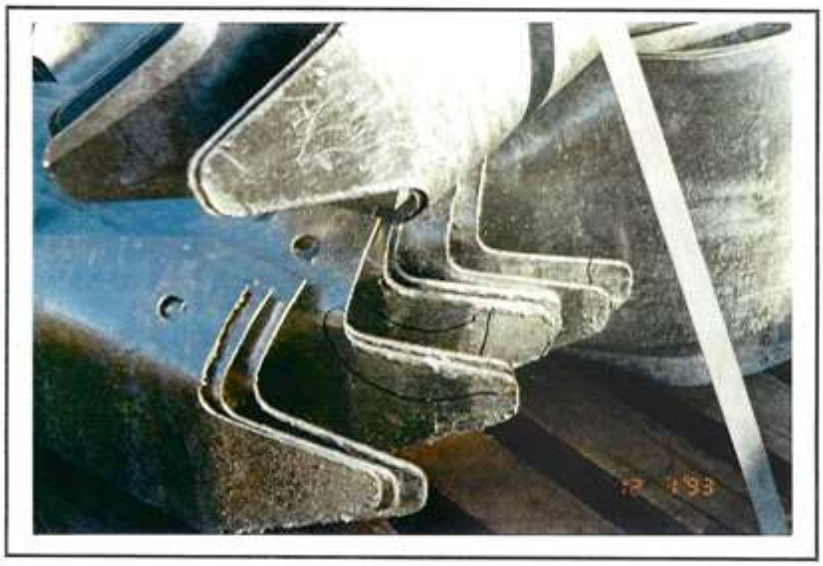


Photo 45 *Condition*: Bare spots on edge of guardrail

Photo 46 *Condition*: Bare spots on edge of guardrail.

Cause: Breaking off of excess material.

Photographs Listed in Table - Rejectable Guardrail Conditions

Ash Inclusions

Photographs 47-57

Photo 47 *Condition*: Ash Inclusions

Causes: Ash burnt on the steel during dipping, or ash pick up during removal from the bath.

Effect: No adverse effect on service life if coating is the required thickness.

Rejectable Guardrail Conditions Continued

Ash Inclusions Continued

Photo 48 *Condition*: Ash Inclusions

Causes: Ash burnt on the steel during dipping, or ash pick up during removal from the bath.

Effect: No adverse effect on service life if coating is the required thickness.

Rejectable Guardrail Conditions Continued

Ash Inclusions Continued

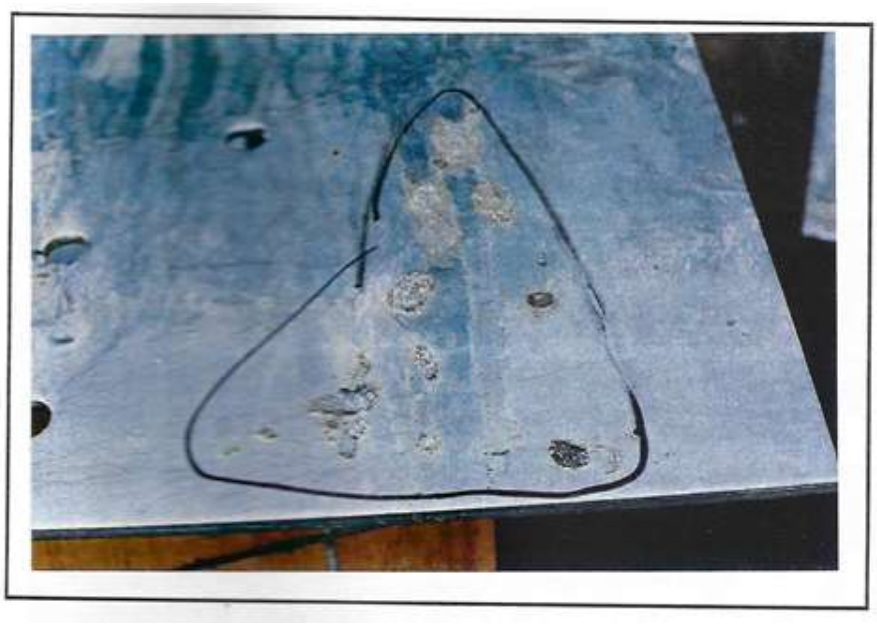


Photo 49 *Condition*: Ash and Flux Inclusions

Photo 50 *Condition*: Ash Inclusions

Rejectable Guardrail Conditions Continued

Ash Inclusions Continued

Photo 51 *Condition*: Ash Inclusions

Photo 52 *Conditions*: Excessive Ash Inclusions

Rejectable Guardrail Conditions Continued

Ash Inclusions Continued

Photo 53 *Condition*: Ash Inclusion

Rejectable Guardrail Conditions Continued

Ash Inclusions Continued

Photo 54 *Condition*: Ash Inclusion

Rejectable Guardrail Conditions Continued

Ash Inclusions Continued

Photo 55 *Condition*: Ash Inclusion

Photo 56 *Condition*: Ash Inclusion

Rejectable Guardrail Conditions Continued

Ash Inclusions Continued

Photo 57 *Condition*: Ash Inclusion

Photographs Listed in Table 3 – Rejectable Guardrail Conditions

Bent Rail

Photographs 58-62

Photo 58 *Condition*: Bent Rail (Cracked or Broken Galvanization)

Causes: Bending of steel after plating

Effect: Lack of protection for the steel resulting in the rusting of the piece.

Note: Front view of bent area does not reveal coating damage. Look at rear view of dent to ensure no coating damage to backside of piece.

Rejectable Guardrail Conditions Continued

Bent Rail Continued

Photo 59 *Condition*: Bent Rail (Cracked or Broken Galvanization)

Causes: Bending of steel after plating

Effect: Lack of protection for the steel resulting in the rusting of the piece.

Note: Front view of bent area does not reveal coating damage. Look at rear view of dent to ensure no coating damage to backside of piece.

Rejectable Guardrail Conditions Continued

Bent Rail Continued

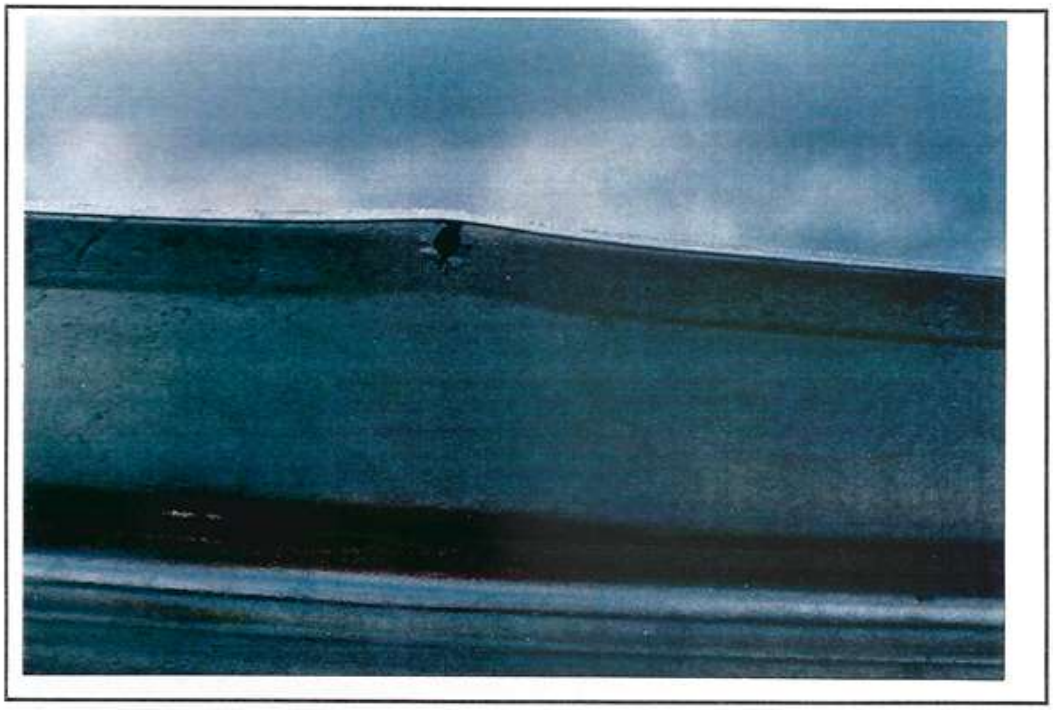


Photo 60 *Condition*: Bent Rail (Cracked or Broken Galvanization)

Causes: Bending of steel after plating

Effect: Lack of protection for the steel resulting in the rusting of the piece.

Note: Bare spot where the zinc plating has popped off. This area needs to be repaired with two coats of zinc-rich paint (three dry mils).

Rejectable Guardrail Conditions Continued

Bent Rail Continued

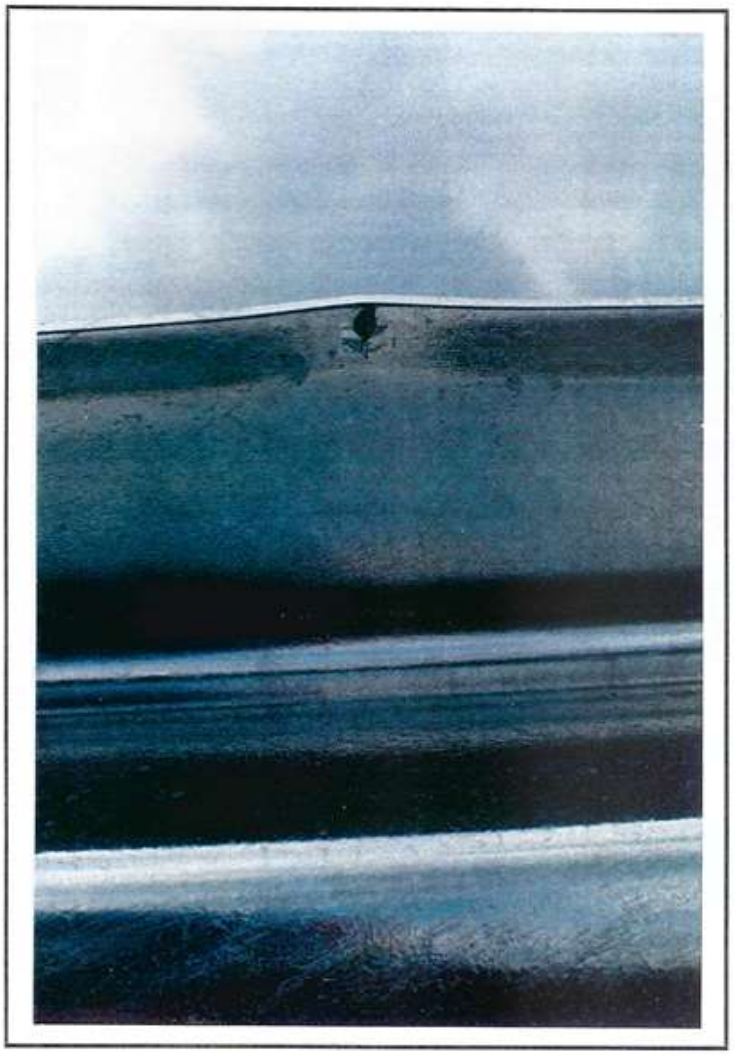


Photo 61 *Condition*: Bent Rail (Cracked or Broken Galvanization)

Causes: Bending of steel after plating

Effect: Lack of protection for the steel resulting in the rusting of the piece.

Note: Bare spot where the zinc plating has popped off. This area needs to be repaired with two coats of zinc-rich paint (three dry mils).

Rejectable Guardrail Conditions Continued

Bent Rail Continued

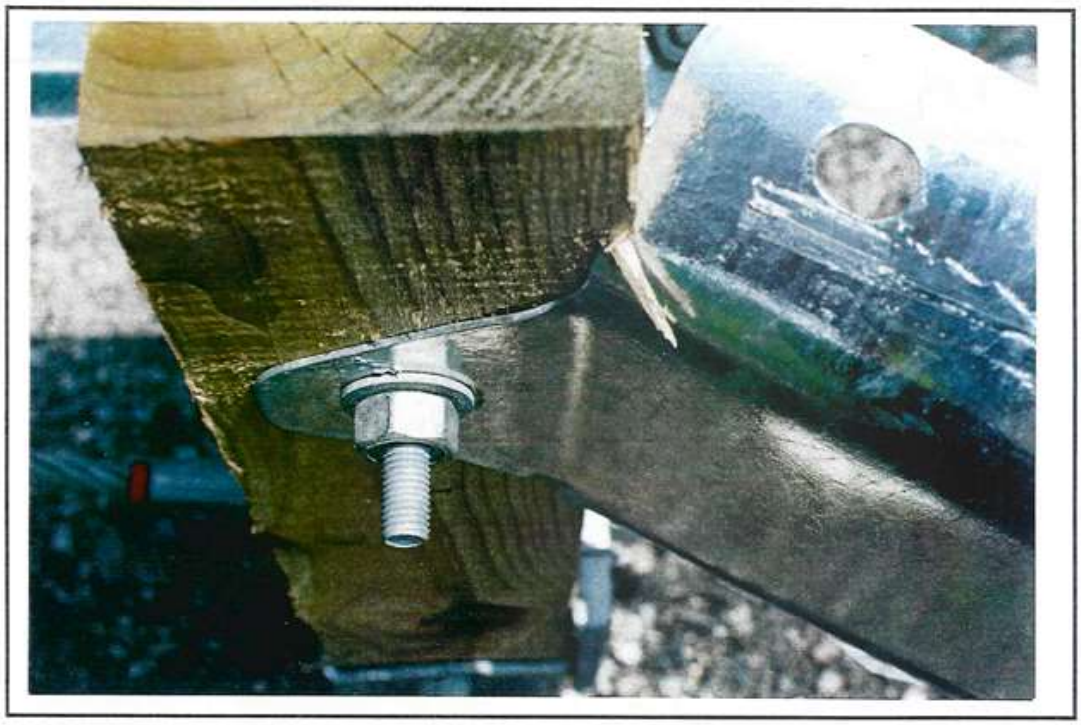


Photo 62 *Condition*: Bent Rail (Cracked or Broken Galvanization)

Causes: Bending of steel after plating. Piece field bent.

Effect: Lack of protection for the steel resulting in the rusting of the piece.

Photographs Listed in Table 3 – Rejectable Guardrail Conditions

Bent Plate

Photograph 63

Photo 63 *Condition*: Bent Plate

Causes: Improper handling or transportation.

Note: Improper storage of materials. Material is in contact with the ground surface.

Photographs Listed in Table 3 – Rejectable Guardrail Conditions

Field Bending

Photograph 64

Photo 64 *Condition*: Field Bending (Field Fabrication)

Causes: Bending of steel by striking with a hammer or prizing against the piece. Reshaping the piece to serve use other than the one it was fabricated for.

Effect: Galvanization may crack and break off resulting in Bare Spots (Exposed Steel). Lack of protection for the steel resulting in rusting of the piece. Piece may become work hardened.

Photographs Listed in Table 3 – Rejectable Guardrail Conditions

Flux Inclusion

Photographs 65-66

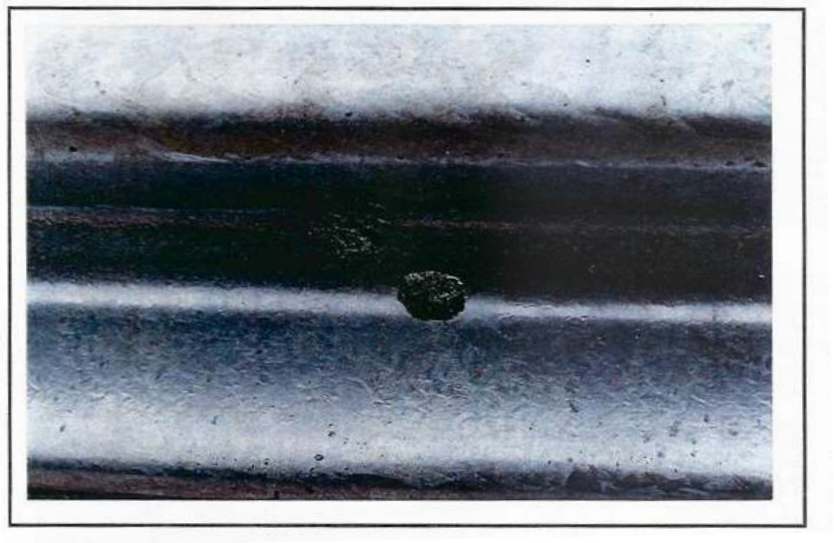


Photo 65 *Condition*: Flux Inclusion

Photo 66 *Condition*: Flux Inclusion

Photographs Listed in Table 3 – Rejectable Guardrail Conditions

Excess Holes

Photographs 67-69

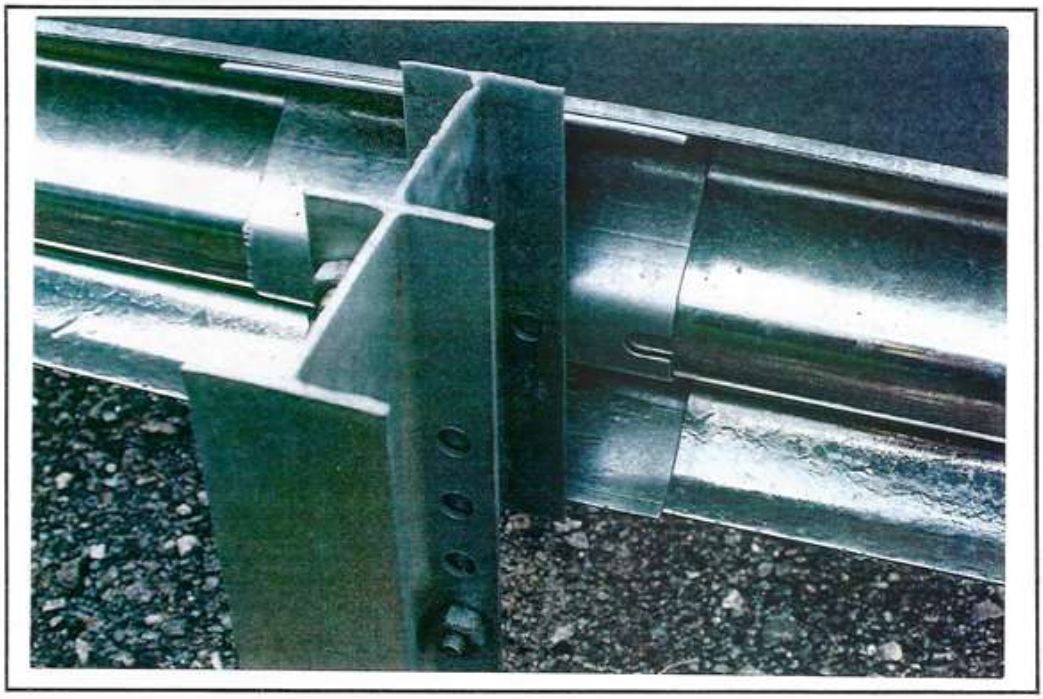


Photo 67 *Condition*: Excess holes in backup plate

Causes: Extra holes punched into steel during fabrication.

Effect: Ripping of the piece during impact if hole near edge of piece. Loss of stiffness of piece. Bolts may pull through oversized holes.

Material is rejected.

Rejectable Guardrail Condition Continued

Excess Holes Continued

Photo 68 *Condition*: Excess holes in backup plates.

Photo 69 *Condition*: Excess holes in backup plate

Causes: Extra holes punched into steel during fabrication.

Effect: Ripping of the piece during impact if hole near edge of piece. Loss of stiffness of piece. Bolts may pull through oversized holes.

Material is rejected.

Photographs Listed in Table 3 – Rejectable Guardrail Conditions

Wood Post Without AWW Stamps

Photograph 70

Photo 70 Wood guardrail post. Post should have stamps on both ends indicating that it has been inspected and accepted by NCDOT Consultant Inspectors. Wood post without stamps on both ends should not be used.

Photographs Listed in Table 3 – Rejectable Guardrail Conditions

Laminations

Photograph 71

Photo 71 *Condition*: Laminations

Causes: Defects in the steel (laminations) de-bonded by heat of the plating baths.

Effect: May break off resulting in Bare Spots (Exposed Steel). Lack of protection for the steel resulting in rusting of the piece.

Photographs Listed in Table 3 – Rejectable Guardrail Conditions

Wet Storage Stains (White Rust)

Photographs 72-74

Photo 72 *Condition*: Wet Storage Stains (White Rust)

Causes: Storage of close packed pieces under damp conditions. Packing pieces while damp. Lack of ventilation during storage.

Effect: Protective value of coating lessened in extreme cases due to prevention of formation of protective film of zinc carbonates. Light staining will eventually wear off due to weathering with no effect on the protective value of the coating.

Rejectable Guardrail Conditions Continued

Wet Storage Stains (White Rust) Continued

Photo 73 *Condition*: Wet Storage Stains (White Rust)

Causes: Storage of close packed pieces under damp conditions. Packing pieces while damp. Lack of ventilation during storage.

Effect: Protective value of coating lessened in extreme cases due to prevention of formation of protective film of zinc carbonates. Light staining will eventually wear off due to weathering with no effect on the protective value of the coating.

Rejectable Guardrail Conditions Continued

Wet Storage Stains (White Rust) Continued

Photo 74 *Condition*: Wet Storage Stains (White Rust)

Causes: Improper storage. The material should not be in contact with the ground surface or decaying matter.

Table 4 – Guardrail Material Storage

Photograph Number	Description
75-76	Storage at Producer's Facility
77	Wood post storage
78-86	Improper storage procedures
87	Proper storage procedures

Table 5 – Examples of Good Guardrail Production and Installation

Photograph Number	Description
88-90	Clean rail element and end pieces stored on site
91-95	Installed good, clean guardrail without imperfections.

Photographs Listed in Table 4 – Guardrail Material Storage

Photographs 75-87

Storage at Producer's Facility

Photographs 75-76

Photo 75 Guardrail stored at producer's facility.

Material should be stored out of the weather if it will be held for an extended period before shipping. Material should also be stored at an angle to help in draining moisture from the product.

Storage at Producer's Facility Continued

Photo 76 Guardrail stored at producer's facility.

Material should be stored out of the weather if it will be held for an extended period before shipping. Material should also be stored at an angle to help in draining moisture from the product.

Photographs Listed in Table 4 – Guardrail Material Storage

Wood Post Storage

Photograph 77

Photo 77 Properly stored and identified wood posts. Each bundle of wood posts should have at least three tags located on the bundle in addition to a stamp on each end of every post.

Photographs Listed in Table 4 – Guardrail Material Storage

Improper Storage Procedures

Photograph 78-86

Photo 78 Wood guardrail posts. Notice the blue bucket of nuts and bolts. They should be stored in closed containers to keep moisture out.

Guardrail Material Storage Continued

Improper Storage Procedures Continued

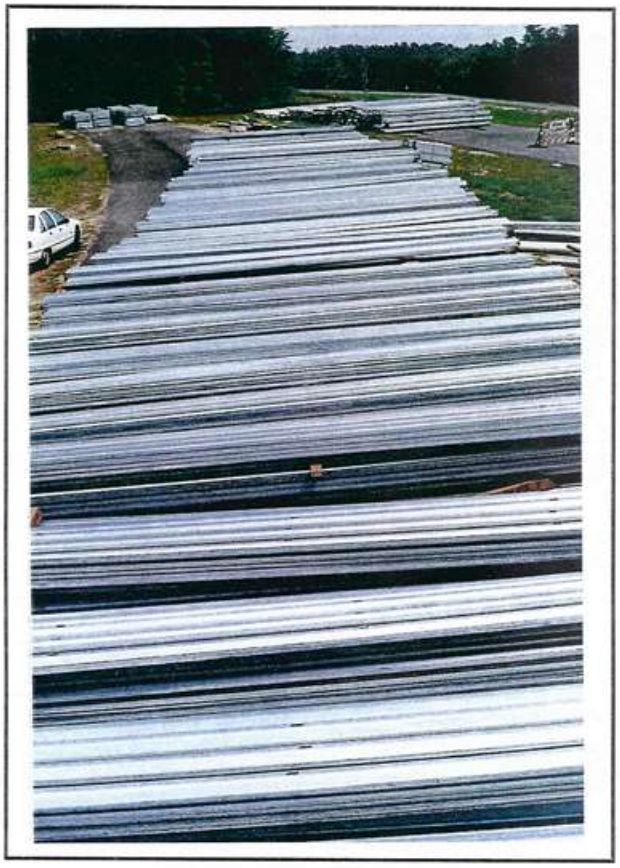


Photo 79 Materials stored at construction site. The rail is slanted to aid in moisture runoff. However, if the material is to be stored for over one month, it should be covered.

Guardrail Material Storage Continued

Improper Storage Procedures Continued

Photo 80 Improper Storage. Decaying matter is in contact with galvanized materials.

Photo 81 Improper storage. Galvanized material should not be exposed to or stored in contact with the ground surface.

Improper Storage Procedures Continued

Photo 82 Improper storage. Material is in contact with decaying matter and the ground surface.

Guardrail Material Storage Continued

Improper Storage Procedures Continued

Photo 83 Improper storage. The leaves will help keep moisture on the items and they will also decay adding to the corrosion process.

Guardrail Material Storage Continued

Improper Storage Procedures Continued

Photo 84 Improper storage of hardware. These materials are rejectable.

Photo 85 Improper storage. None of the containers have lids on them to keep rainwater or other moisture from getting into containers. Additionally, materials are stored in contact with the ground surface.

Guardrail Material Storage Continued

Improper Storage Procedures Continued

Photo 86 Improper storage. Material should not be in contact with the ground surface or decaying matter. Also, this particular orientation prevents drainage of the pieces, allowing water to collect in the items.

Photographs Listed in Table 4 – Guardrail Material Storage

Proper Storage Procedures

Photograph 87

Photo 87 Proper storage of guardrail material. All materials are placed on pallets and all containers have lids.

Photographs Listed in Table 5 – Examples of Good Guardrail Production and Installation

Photographs 88-95

Clean Rail Elements and End Pieces Stored on Site

Photographs 88-90

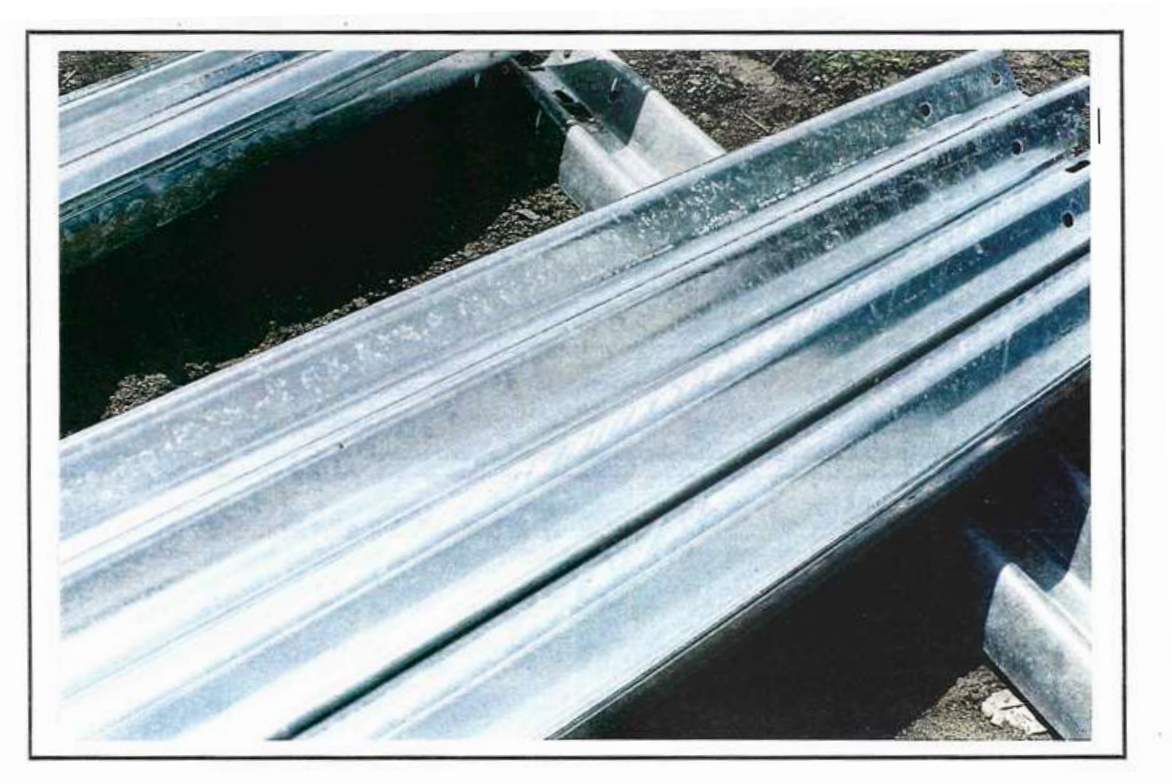


Photo 88 Example of clean rail elements.

Photo 89 Example of good, finished products.

Photo 90 Example of clean guardrail material after galvanizing.

Examples of Good Guardrail Production and Installation Continued

Clean Guardrail

Photographs 91-95

Photo 91 Example of good guardrail.

Photo 92 Example of good guardrail.

Photo 93 Example of good guardrail.

Photo 94 Example of good guardrail.

Photo 95 Example of good guardrail.

Appendix F

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION

ROY COOPER
GOVERNOR

J. ERIC BOYETTE
SECRETARY

April 27, 2023

SUBJECT: SOP for Guardrail and Guardrail Anchor Units

Objectives:

The Standard Operating Procedure (SOP) provides a means for the inspection, the acceptance and the reporting of guardrail and anchor units.

This SOP is a quick reference guide and does not cover any specialty items. Inspection of the specialty items will require the technician to reference the project plans or contract special provisions.

Materials Inspection and Acceptance:

Guardrail inspections should be completed after material is installed, and when requested by the Engineer and/or project inspector.

All materials must come from an Approved NCDOT manufacturer who participates in the Departments Brand Registration program.

All materials and installation must meet Section 862 of the current NCDOT Standard Specifications and AASHTO M 180

Rail elements and terminal sections shall meet AASHTO M 180 for Class A, Type 2, unless otherwise specified. (If more detail is needed than the SOP references, please refer to AASHTO M 180)

Anchor and Anchor Assemblies with welded components shall be galvanized after welding in accordance with ASTM A123. (If more detail is needed than the SOP references, please refer to ASTM A123)

All other metal parts shall be galvanized in accordance with ASTM A153, except where otherwise specified in Article 1046-1, 1046-2 and 1046-3 of the NCDOT Standard Specifications. (If more detail is needed than the SOP references, please refer to ASTM A153)

All AASHTO and ASTM specifications can be referenced through the internet by NCDOT employees with the link below:

https://inside.ncdot.gov/TransportationServices/_layouts/15/guestaccess.aspx?guestaccesstoken=6EiilzuALHPKn9SuHH%2f6h7S4aSRhrj6ek4R3qLX76Gw%3d&docid=2_1b82554ecd3f14bd5806cab2d8d50661e&rev=1

Safety Equipment List:

1. Safety Shoes with ANSI Z 41 rating
2. Hard Hat with ANSI Z89.1 rating
3. Safety Vest
4. First Aid kit
5. Safety Glasses (optional)
6. Ear Plugs (optional)
7. Sun Block (optional)
8. Lifting Belt (optional)
9. Dust Mask (optional)
10. Poison Ivy Wash (optional)

Safety Concerns:

1. Vehicular Traffic (Spotter needed in some situations)
2. Sharp Edges
3. Heavy Equipment/Backing Incidents
4. Trip/ Fall Hazards
5. Venomous Snakes/Insects

Equipment Required for Guardrail Inspection:

1. Tape Measure
2. Magna gauge (Calibrated Annually by Materials and Tests Unit Chemical Lab)
3. Micrometer
4. Calculator
5. Pen or Pencil
6. Guardrail Inspection Field Worksheets

Material Inspector's Duties for Guardrail Inspection:

1. Periodically review the Guardrail Inspection SOP.
2. Review Section 862 of the NCDOT Standard Specifications and AASHTO M 180

3. Review contract special provisions and/or plans for type of guardrail and anchor units to be inspected.
4. No inspection will be made without Bill of Lading.
5. All guardrail inspections will be inspected after installation.
6. Pre-Inspection Process
    a. M&T technician will be contacted by Engineer or project inspector administrating the contract to inspect guardrail and/or anchor units.
    b. Determine the location and amount of guardrail and/or anchor units to be inspected.
    c. The technician will record approximate locations of rail and/or anchor to be inspected on Guardrail Field Worksheet.
    d. Review contract special provisions and/or project plans for type of rail and anchor units to be inspected.
        - Alternates for the anchor units will be listed in the contract special provisions.
        - Installation plans and parts list will be furnished by installer for each style of anchor unit.
        - FHWA approval letter will be furnished with each type of anchor unit.
7. Inspection Process
    A. Guardrail Inspection (Straight Rail)
        1. The test lot for straight rail is 25 LF for every 2000 LF or fraction thereof.
        2. The technician will randomly select a 25 LF section of rail for inspection for every 2000 LF of installed rail.
        3. The technician will perform triple spot inspection for zinc coating, gauge thickness, dimensions, and check for poor workmanship/damage. All posts, blocks, bolts and nuts will also be inspected in this section. Technician will record these readings along with heat or coil #'s on the Guardrail Field Worksheet.
        4. If any failures are determined in these sections, then a closer interval inspection is warranted.
    B. Guardrail Inspection (Shop Curve Rail)
        1. The test lot for shop curve rail is 12.5 LF for every 500 LF or fraction thereof.
        2. The technician will randomly select a 12.5 LF section of shop curve rail for every 500 LF or less of shop curve rail.
        3. The technician shall perform a triple spot inspection for zinc coating, gauge thickness, dimensions, poor workmanship and any damage. All posts, blocks, bolts and nuts will also be inspected at this section. Technician will record these readings along with heat/coil # on the Guardrail Field Worksheet.
        4. If any failures are determined with either of the inspections, then a closer interval of the inspection is warranted.
    C. Guardrail Inspection (Anchor Units)
        1. Test lot for anchor units are a minimum of 50 % or a fraction thereof for each type of anchor unit installed.
        2. The technician will randomly select anchor units for inspection.
        3. The technician will perform a triple spot inspection on the rail for the zinc coating, gauge thickness, dimensions, and check for poor workmanship/damage. The

technician will record these readings along with heat/coil # on the "Guardrail Field Worksheet".

4. Welded galvanized components used in anchor units shall be accepted in accordance with ASTM A123 when determining coating thickness.
5. If any failures are determined with the inspections than a closer interval of the inspection is warranted.

D. Inspection of Zinc Coating for Rail (AASHTO M 180)

1. There are two methods in determining the weight of zinc coatings.
2. The single spot method requires a reading with the magna gauge in the front of an item and reading again on the back in the same location.
3. The triple spot method requires the identical reading at a single spot except the triple spot is an average of three readings on the back and the average of three readings on the front.
4. Technician shall use a calibrated magna gauge to measure zinc coatings in the field.
5. Minimum allowed zinc coating for guardrail and anchor units in oz. per sq. ft.

Item	Single Spot	Triple Spot
Rail	3.60 oz.	4.00 oz.
Post	1.80 oz.	2.00 oz.
Bolt & Nuts	1.00 oz.	1.25 oz.
Washers	1.00 oz.	0.85 oz.

6. The magna gauge measures or reads in mils. Technician will perform a calculation to convert mils into ounces per square foot. An example of the calculations is below:

Front of Rail	Back of Rail
3.6	3.6
3.4	3.2
+3.5	+3.3
10.5=total mils	10.1=total mils

- Total the number of readings from both sides.
  Example: 10.5 + 10.1 = 20.6

- Divide the total by the number of single spot readings to get the average.
  Example: 20.6 / 3 = 6.9 mils

  Note: Technician will enter the average mils on the HiCams Guardrail FIR report for acceptance not ounces of zinc coating.

- To convert average mils to ounces square foot divide by 1.7 mils/ounces square foot
  Example: 6.9 / 1.7 = 4.1 oz/ft^2 Meets Specs.

- Determine if each side has minimum of 40% (AASHTO M 180) of the required zinc coating by averaging the readings on each side and dividing by 1.7 mils and then compare with the required minimum of 1.6 oz/ft^2 (2.7 mils)

  Example: Front = (10.5 / 3) / 1.7 = 2.1 oz/ft^2
  Back = (10.1 / 3) / 1.7 = 2.0 oz/ft^2

E. Inspection of Zinc Coating for Anchor Heads Etc. (ASTM A123)

1. Articles larger than 160 in² of surface area must be divided into three separate test specimens (or parts). Articles smaller than 160 in² must have three articles/specimens to check. If article(s) have more than one steel thickness range shown on Table 1, then this will contain one specimen. Each specimen test area must have a minimum of five separate magna gauge readings and averaged. Continue to average the three averages together. All readings will be recorded and calculated on the "Guardrail Field Inspection Worksheet". Once readings are calculated, compare them to Table 1 and Table 2 of the ASTM A123 specification (shown below). Note: Most of our inspections on guardrail will be "Structural Shapes".

Example: If you were inspecting a SKT 350 head unit. Gauge the material to determine thickness. Select a steel thickness from Table 1. A SKT head would fall under "Structural Shapes" category on Table 1. If the material gauged reads 0.125" or 1/8" in thickness with micrometer, then the material would be classified as a "75" coating grade. Using Table 2 find the column listed as "Coating Grade" and find "75". Follow this line to the right and you will see 3.0 mils or 1.7 oz/ft^3. This will be the required coating thickness.

TABLE 1 Minimum Average Coating Thickness Grade by Material Category

Material Category	All Specimens Tested Steel Thickness Range (Measured), in.					
	$<1/16$	$\geq 1/16$ to $<1/8$	$\geq 1/8$ to $<3/16$	$\geq 3/16$ to $<1/4$	$\geq 1/4$ to $<5/8$	$\geq 5/8$
Structural Shapes	45	65	75	75	100	100
Strip and Bar	45	65	75	75	75	100
Plate	45	65	75	75	75	100
Pipe and Tubing	45	45	75	75	75	75
Wire	35	50	60	65	80	80
Reinforcing Bar	...	...	...	...	100	100

TABLE 2 Coating Thickness Grade[A]

Coating Grade	mils	oz/ft^2
35	1.4	0.8
45	1.8	1.0
50	2.0	1.2
55	2.2	1.3
60	2.4	1.4
65	2.6	1.5
75	3.0	1.7
80	3.1	1.9
85	3.3	2.0
100	3.9	2.3

- If a discrepancy arises with zinc coating, slugs shall be taken randomly from the heat, coil, or lot number in question. A minimum of three slugs per heat, coil or lot will be taken and sent to NCDOT Materials and Tests Chemical Lab.

- If a discrepancy arises with zinc coating on bolts, nuts or washers, a sample shall be taken with a minimum of three pieces each and sent to the Materials and Tests Chemical Lab.

- If a discrepancy arises with zinc coating on a material that cannot be slugged or sampled, the SMS and/or AME will be contacted for an investigation of the material in question.

- If zinc coating is damaged from shipping or installation, then repair damaged coating in accordance with Article 1076-7 of the NCDOT Standard Specifications.

F. Gauge
   A. The technician will take gauge readings with a micrometer.
   B. All measurements will be recorded on the Guardrail Field Worksheet.
   C. Below is a list of common guardrail items used in the NCDOT. Some of the materials listed may have to be inspected per AASHTO M 180, installation plans, project plans or special provisions.

      - Rail = 12 gauge (.109” with minimum thickness of .100”)
      - Shop Curve Rail = 12 gauge (.109” with minimum thickness of .100”)
      - Transitions = 12 gauge (.109” with minimum thickness of .100”)

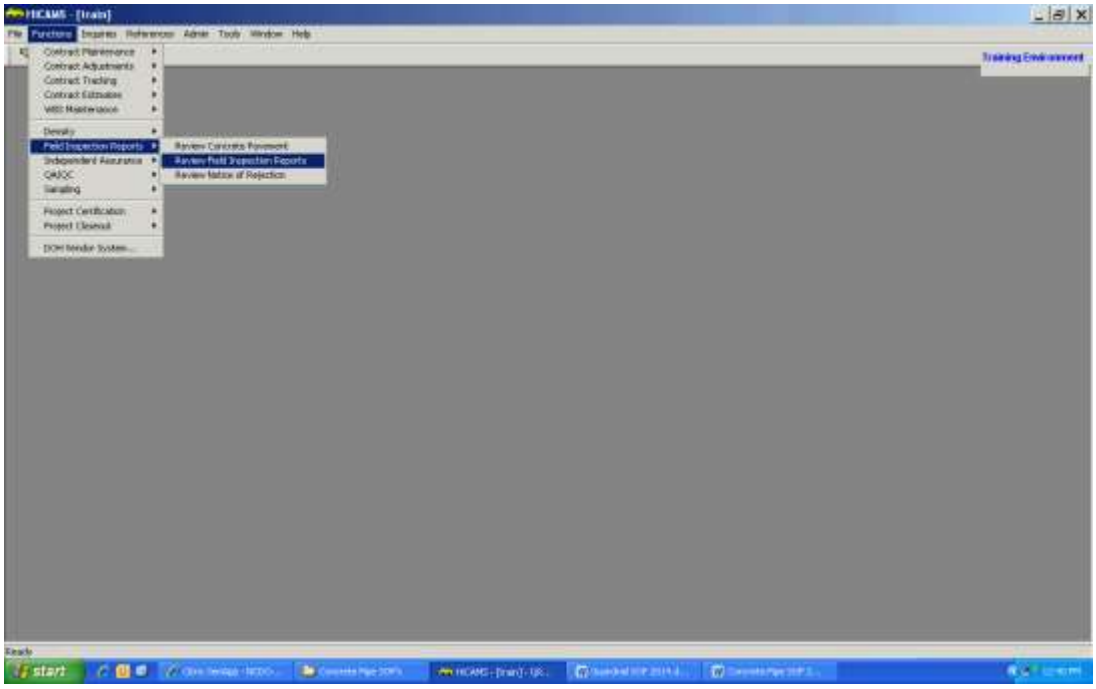
- Bridge/End Shoes = 10 gauge (.138” with minimum thickness of .129”)

G. Dimensions
   A. The technician will take measurements with a tape measure.
   B. All measurements will be recorded on the Guardrail Field Worksheet.
   C. Below is a list of common rail items used by NCDOT. Some of the materials may have to be inspected per AASHTO M 180, installation plans, project plans or special provisions.

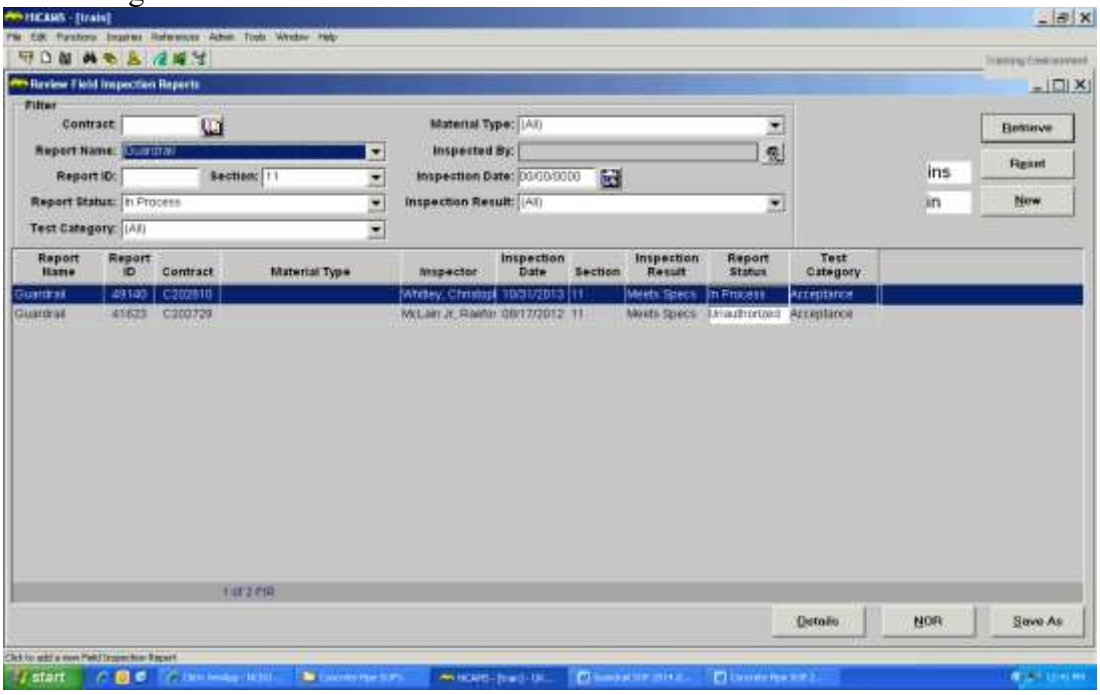
- “W” beam rail = 12-1/4” width (+- ¼”)
- Three or Triple corrugated beam rail = 20” width (+- ¼”)
- W Posts = W6 x 8.5 or W6 x 9.0 (8.5 & 9.0 represents lbs. per LF)
- C-shape Posts = 4.5” x 6.0”
- Anchor Units = Check dimensions with installation plans (These will be furnished by installer)

Test & Sample Entry:

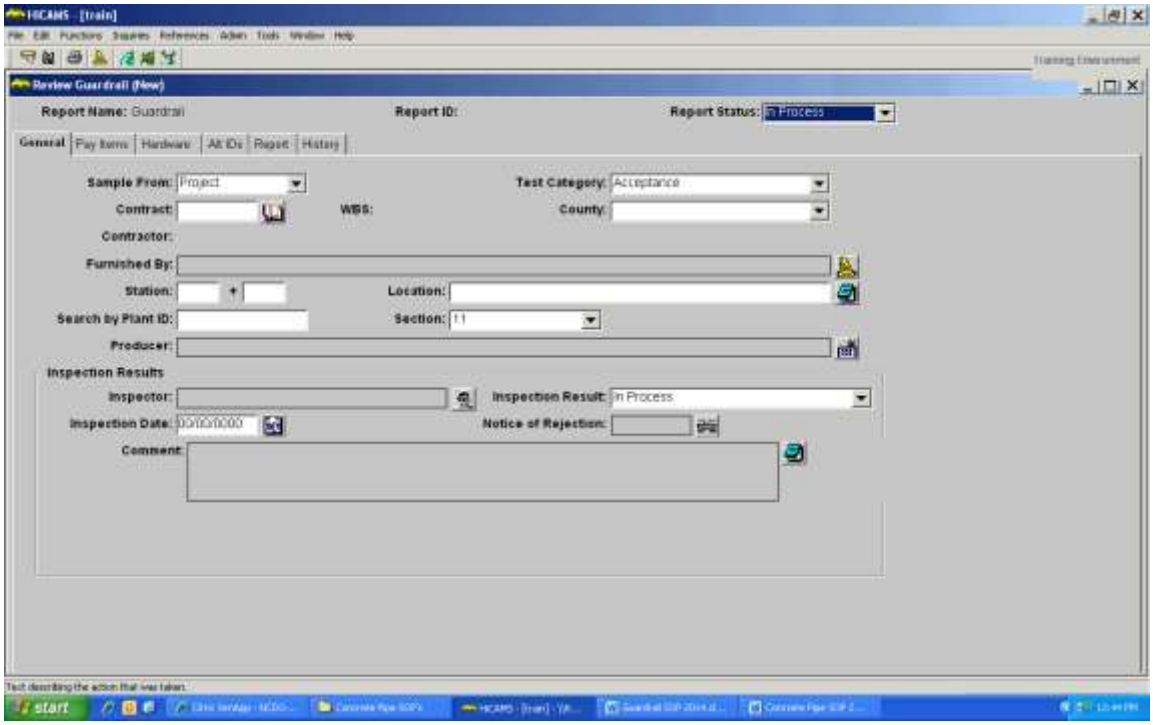
1. Listed below are screenshots of HiCams concerning entry of a Guardrail Field Inspection Report.



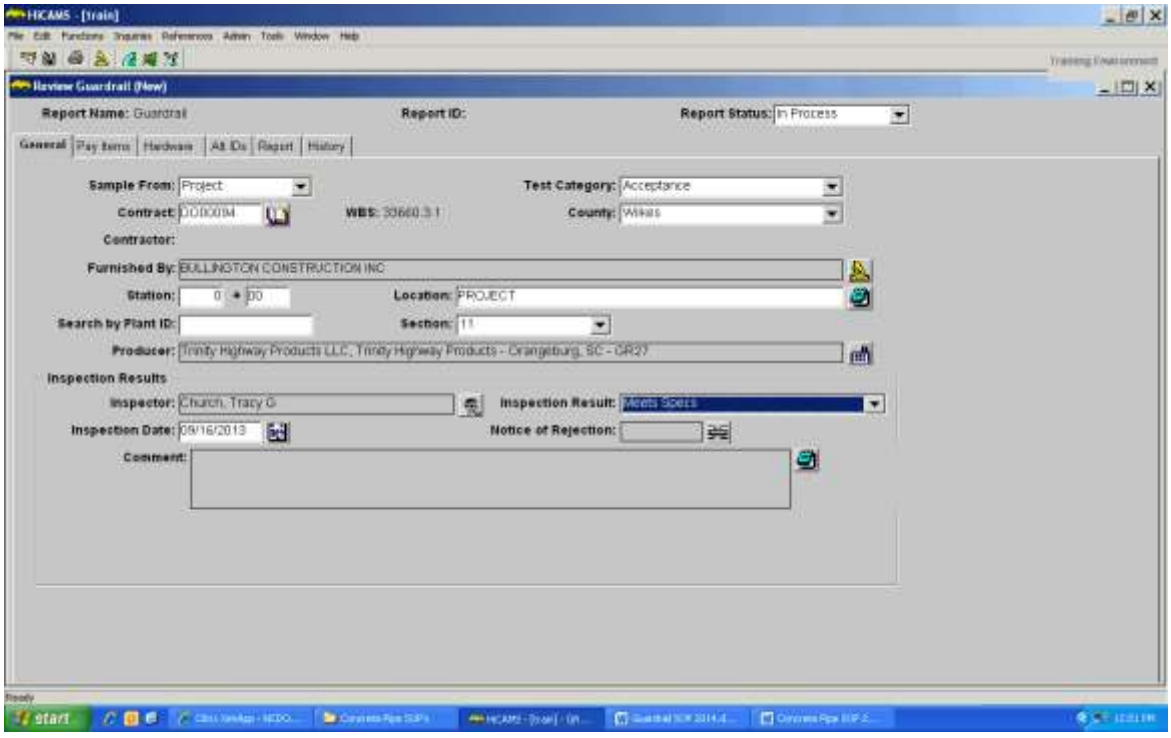
a. Log into Hicams and create a FIR



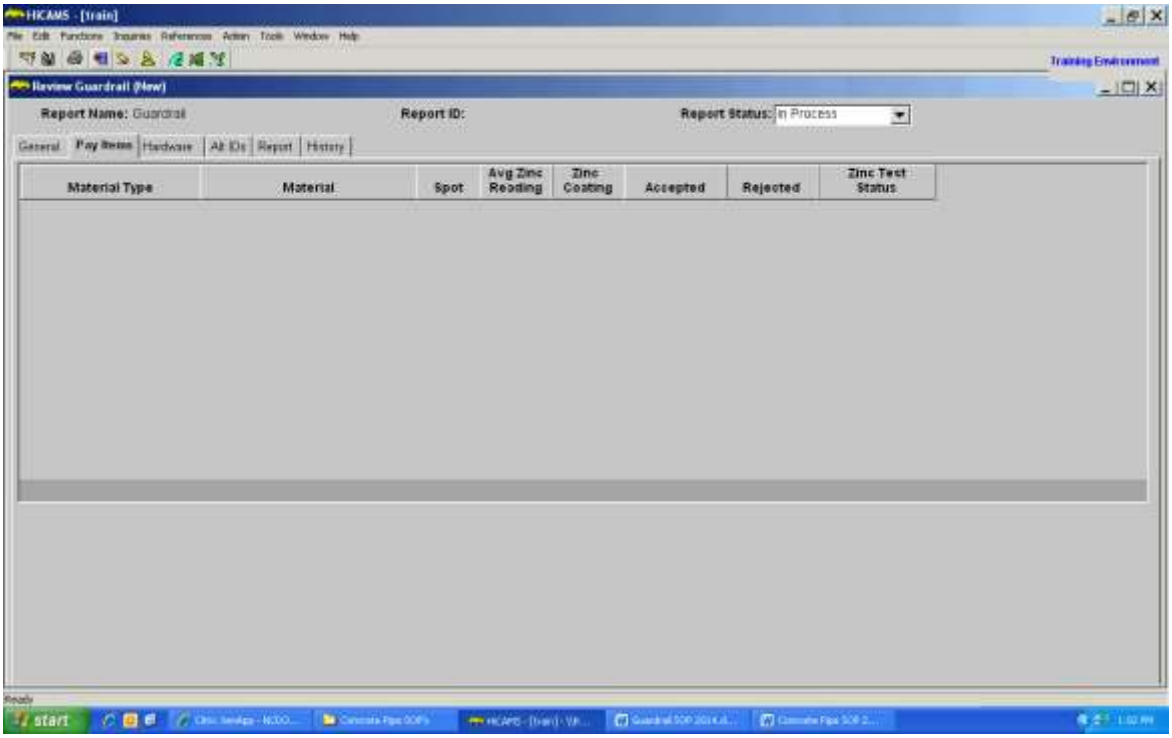
b. Select Guardrail for the Report Name. Then click “New” tab. This will create a new guardrail FIR.



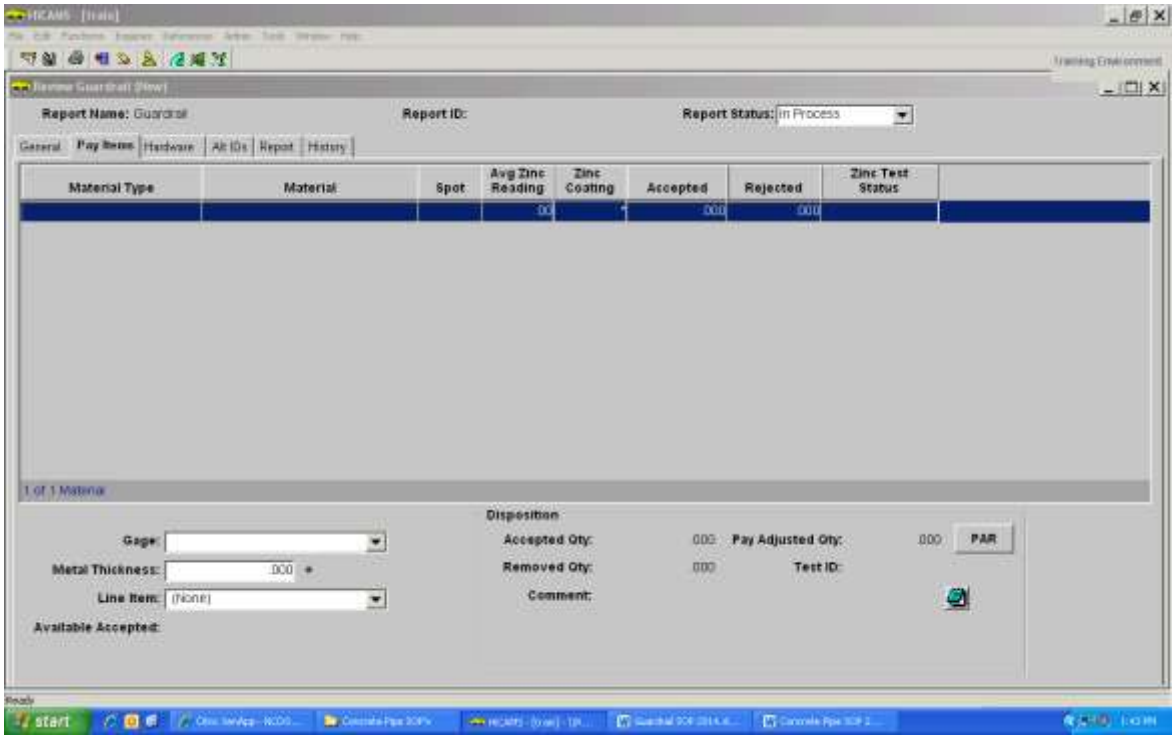
c. Once a FIR is created it has four tabs that will need information.



d. The information needed in the "General" tab are as follows. Contract #, Furnished By, Station, Location, Producer, Inspector, Inspection Date and Inspection Results.



e. The next tab will be the "Pay Items" tab. All test results for the guardrail will be entered in this location.



f. Once on the "Pay Items" tab you will need to insert critirea for the guardrail

g. The "Pay Item" tab is for materials that have a line item in the contact. Example: guardrail, guardrail shop curve, anchor units and extra length posts. All other items inspected that do not have a dedicated line item will be placed in the "Hardware" tab.

Entry for "Material Type" will be guardrail steel beam or anchor unit

Entry for " Material" will be what type of guardrail or anchor units that was inspected.

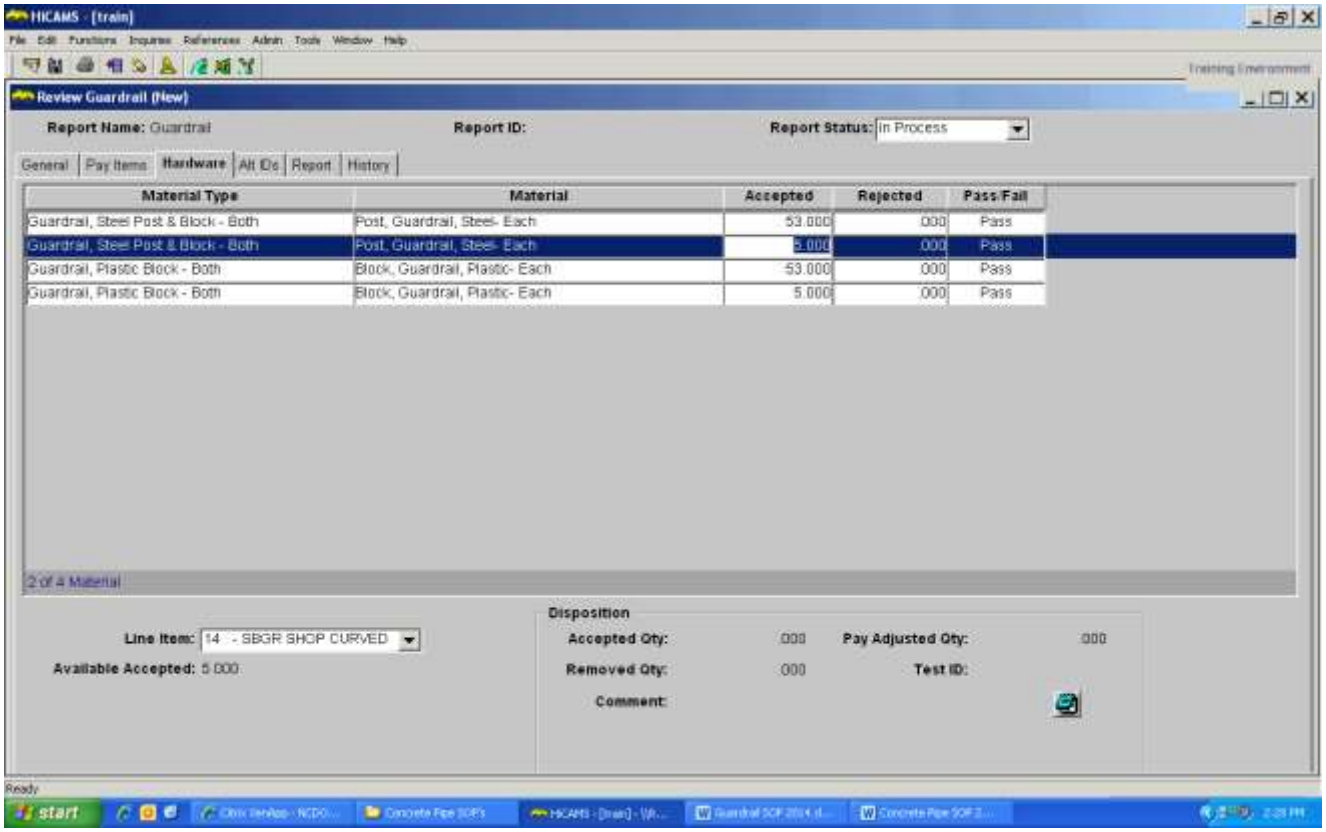
Entry for "Spot" is refering to a triple or single spot reading for zinc coating. When applicable triple spots tests should be first test administered.

Entry for "Avg. Zinc Reading" is referring to the average mils read and calculated by the magna gauge. Hicams will convert the average mils into ounces per square foot of zinc.

Entry for "Accepted" will be the approved quantity.

Entry for "Rejected" will be the rejected quantity.

Entry for "Zinc Test Status" will determine if zinc coatings meet the minimum requirements.

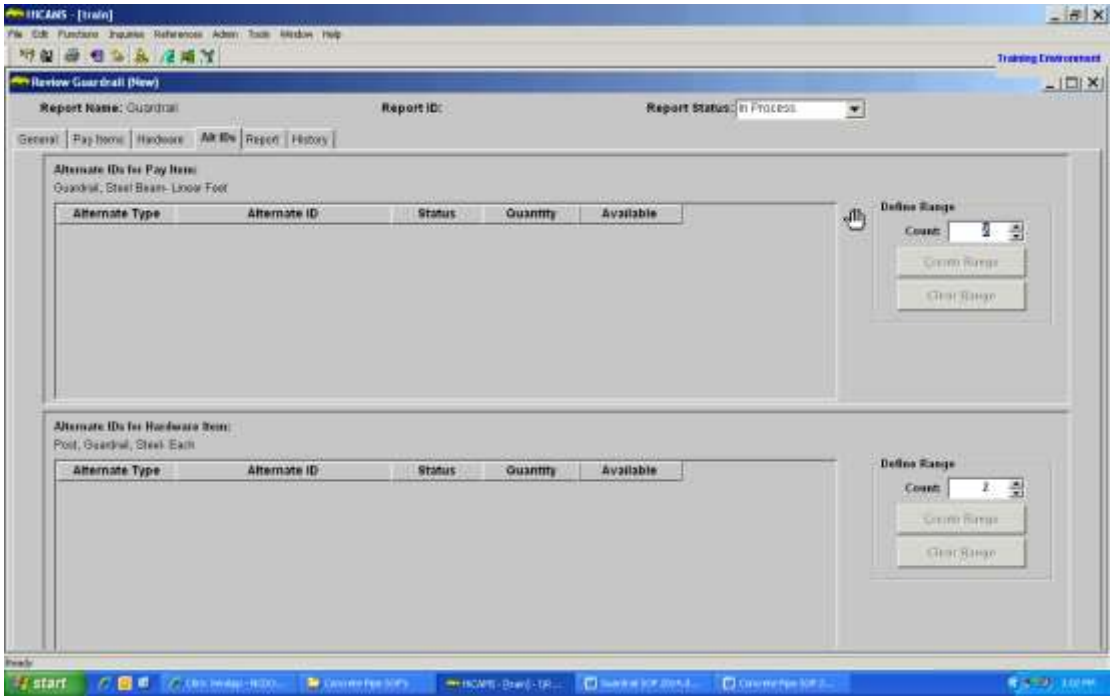


h. The "Hardware" tab shall be used for the materials that do not have a dedicated line item in the contract. An example would be: Posts, Blocks, Nuts, Bolts, Washers, End Shoes and etc.

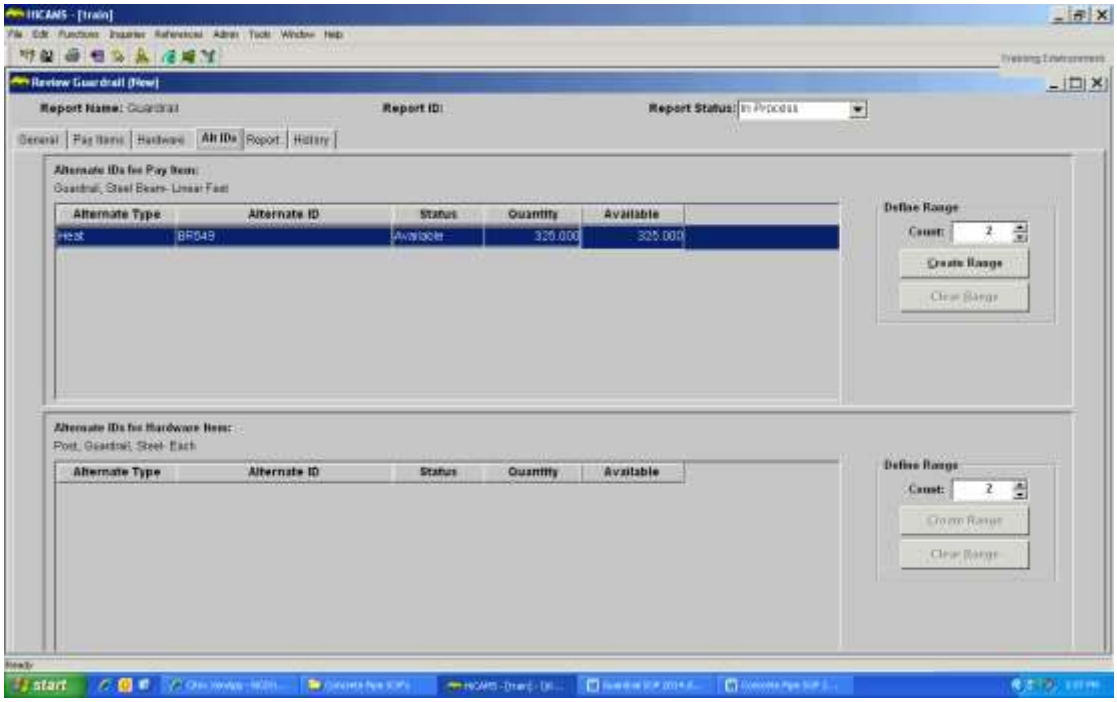
Posts and plastic blocks must be assigned to the line item with guardrail & guardrail shop curve (As seen on the lower left of the above screen shot). Technician shall determine how many posts and blocks were used. Below is a calculation used to determine this.

LF of guardrail x 0.16 = # of posts or block

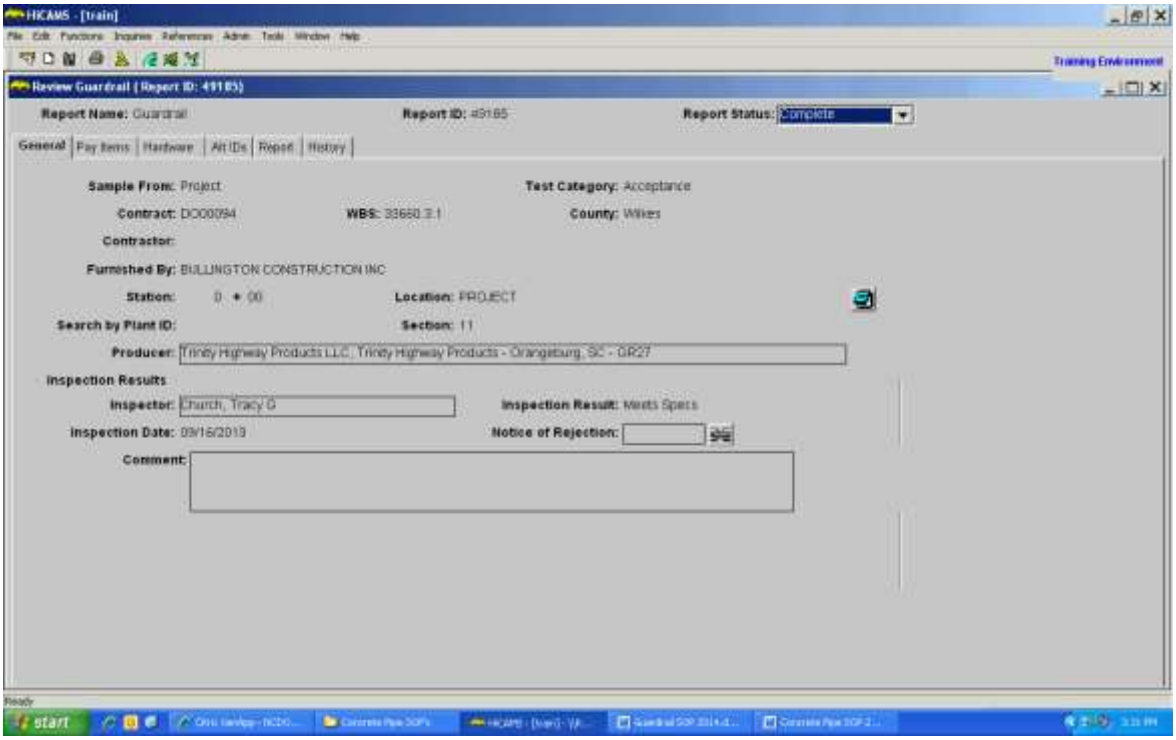
*Note: Some guardrail items will not be required to be entered onto a FIR for Hicams. However this does not elevate the technician from performing the inspection and recording their findings on the "Guardrail Field Inspection Worksheet".



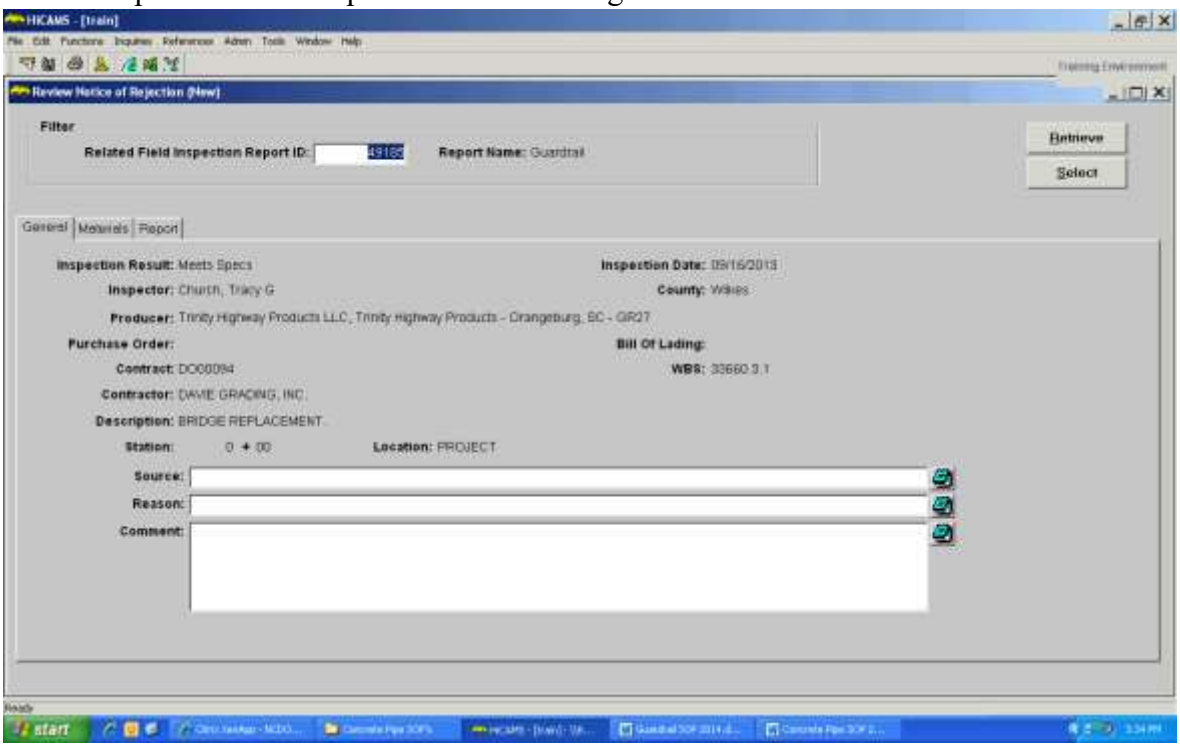
i. The "Alternate Id" tab must be completed for each item that has been entered on the "Pay Item" tab.



j. The alternate type will be "Heat". Record number from item inspected and enter as alternate id. These numbers will be used for tracking if any issues arise with the rail items. Quantity accepted also must be entered.



k. Once all information is entered, than the report status can be change to complete & report saved. A report id # will be assigned to the FIR.



l. Notice of Rejection must be completed and saved if any items are rejected.

Documentation Submittal:

1. The Engineer administering the contract will be notified immediately of inspection results.
2. The technician will complete FIR on HiCams within two working days of the inspection. FIR will be reviewed and authorized by Section Materials Specialist within two working days after being completed.
3. A hard copy of the Guardrail Field Inspection Worksheets, BOL and copy of FIR will be filed by technician.

NCDOT Guardrail Field Inspection Worksheet

Materials and Test Unit

Project No: _____ Division: _____ Installer: _____ Date: _____

Material Inspector: _____ Producer: _____ FIR No.: _____

Anchor Unit 350:	(AVG of 3 Spots)	Location 1 Readings (Mils)		Location 2 Readings (Mils)		Location 3 Readings (Mils)		
Type (SKT,X-Lite, etc):		1:		1:		1:		
# of Units:		2:		2:		2:		
Lot # on Unit		3:		3:		3:		
Gage (Unit):		4:		4:		4:		
Hardware Coating(Pass/Fail):		5:		5:		5:		
		Avg 1:		Avg 2:		Avg 3:		
Final Average (Mils): (Avg. 1 + Avg. 2 + Avg. 3) /3 =			mils	Final Reading in Oz. (Final Average/1.7)			oz.	

Straight Rail @ 350:	(Triple Spot)	(1) Galvinization (Mils)		(2) Galvinization (Mils)		(3) Galvinization (Mils)		
		Front:		+ Front :		+ Front :		= (1)
# of Pieces/LF:								
Heat/Coil # (Rail):		Back :		+ Back :		+ Back :		= (2)
Gage (Rail):								
Production Wk./Yr.(Rail):								
Hardware Coating(Pass/Fail):		Avg of Readings: (1+2)/3 =			mils	Oz. (Average of Readings / 1.7)=		oz.

Anchor Unit 350:	(AVG of 3 Spots)	Location 1 Readings (Mils)		Location 2 Readings (Mils)		Location 3 Readings (Mils)		
Type (SKT,X-Lite, etc):		1:		1:		1:		
# of Units:		2:		2:		2:		
Lot # on Unit		3:		3:		3:		
Gage (Unit):		4:		4:		4:		
Hardware Coating(Pass/Fail):		5:		5:		5:		
		Avg 1:		Avg 2:		Avg 3:		
Final Average (Mils): (Avg. 1 + Avg. 2 + Avg. 3) /3 =			mils	Final Reading in Oz. (Final Average/1.7)			oz.	

Straight Rail @ 350:	(Triple Spot)	(1) Galvinization (Mils)		(2) Galvinization (Mils)		(3) Galvinization (Mils)		
		Front:		+ Front :		+ Front :		= (1)
# of Pieces/LF:								
Heat/Coil # (Rail):		Back :		+ Back :		+ Back :		= (2)
Gage (Rail):								
Production Wk./Yr.(Rail):								
Hardware Coating(Pass/Fail):		Avg of Readings: (1+2)/3 =		mils		Oz. (Average of Readings / 1.7)=		oz.

Anchor Units:	(Single Spot)	Galvinization (Mils)		Anchor Units:	(Single Spot)	Galvinization (Mils)	
Type(CAT-1,AT-1):		Front:		Type(CAT-1,AT-1):		Front:	
# of Units:		+		# of Units:		+	
Gage (Unit):		Back:		Gage (Unit):		Back:	
Hardware Coating(Pass/Fail):		=		Hardware Coating(Pass/Fail):		=	
		Total:	mils			Total:	mils
		Oz.(Total/1.7)	oz.			Oz.(Total/1.7)	oz.

Straight Rail @:	(Triple Spot)	(1) Galvinization (Mils)		(2) Galvinization (Mils)		(3) Galvinization (Mils)		
CAT, AT, etc.:		Front:		+ Front :		+ Front :		= (1)
# of Pieces/LF:								
Heat/Coil # (Rail):		Back :		+ Back :		+ Back :		= (2)
Gage (Rail):								
Production Wk./Yr.(Rail):								
Hardware Coating(Pass/Fail):		Avg of Readings: (1+2)/3 =		mils		Oz. (Average of Readings / 1.7)=		oz.

Anchor Units: T-III	(Single Spot)	Galvinization (Mils)		Anchor Units: T-III	(Single Spot)	Galvinization (Mils)	
		Front:				Front:	
# of Units:		+		# of Units:		+	
Heat/Coil # (Rail):		Back:		Heat/Coil # (Rail):		Back:	
Gage (Rail):		=		Gage (Rail):		=	
Production Wk./Yr.(Rail):		Total:	mils	Production Wk./Yr.(Rail):		Total:	mils
Hardware Coating(Pass/Fail):		Oz.(Total/1.7)	oz.	Hardware Coating(Pass/Fail):		Oz.(Total/1.7)	oz.

Straight Rail:	(Triple Spot)	(1) Galvinization (Mils)		(2) Galvinization (Mils)		(3) Galvinization (Mils)		
		Front:		+ Front :		+ Front :		= (1)
# of Pieces/LF:								
Heat/Coil # (Rail):		Back :		+ Back :		+ Back :		= (2)
Gage (Rail):								
Production Wk./Yr.(Rail):								
Hardware Coating(Pass/Fail):		Avg of Readings: (1+2)/3 =		mils		Oz. (Average of Readings / 1.7)=		oz.

Post for Str. Rail:	(Single Spot)							
	(1) Galvinization (Mils)		(2) Galvinization (Mils)		(3) Galvinization (Mils)		(4) Galvinization (Mils)	
	Front:		Front:		Front:		Front:	
	+		+		+		+	
	Back:		Back:		Back:		Back:	
	=		=		=		=	
	Total:	(1)	Total:	(2)	Total:	(3)	Total:	(4)
		Avg. of Readings (1+2+3+4)/4 =		mils		Oz. (Average of Readings / 1.7)		oz.

Straight Rail:	(Triple Spot)	(1) Galvinization (Mils)		(2) Galvinization (Mils)		(3) Galvinization (Mils)		
		Front:		+ Front :		+ Front :		= (1)
# of Pieces/LF:								
Heat/Coil # (Rail):		Back :		+ Back :		+ Back :		= (2)
Gage (Rail):								
Production Wk./Yr.(Rail):								
Hardware Coating(Pass/Fail):		Avg of Readings: (1+2)/3 =		mils		Oz. (Average of Readings / 1.7)=		oz.

Post for Str. Rail:	(Single Spot)							
	(1) Galvinization (Mils)		(2) Galvinization (Mils)		(3) Galvinization (Mils)		(4) Galvinization (Mils)	
	Front:		Front:		Front:		Front:	
	+		+		+		+	
	Back:		Back:		Back:		Back:	
	=		=		=		=	
	Total:	(1)	Total:	(2)	Total:	(3)	Total:	(4)
		Avg. of Readings (1+2+3+4)/4 =		mils		Oz. (Average of Readings / 1.7)		oz.

Shop Curved Rail:	(Triple Spot)	(1) Galvinization (Mils)		(2) Galvinization (Mils)		(3) Galvinization (Mils)		
		Front:		+ Front :		+ Front :		= (1)
# of Pieces/LF:								
Heat/Coil # (Rail):		Back :		+ Back :		+ Back :		= (2)
Gage (Rail):								
Production Wk./Yr.(Rail):								
Hardware Coating(Pass/Fail):		Avg of Readings: (1+2)/3 =		mils		Oz. (Average of Readings / 1.7)=		oz.

Post for Curv'd Rail:	(Single Spot)	(1) Galvinization (Mils)		(2) Galvinization (Mils)		(3) Galvinization (Mils)	
		Front:		Front:		Front:	
		+		+		+	
		Back:		Back:		Back:	
		=		=		=	
		Total:	(1)	Total:	(2)	Total:	(3)
	Avg. of Readings (1+2+3)/3 =		mils		Oz. (Average of Readings / 1.7)=		oz.

Posts and Block:			
Total # of Steel Posts:		Total # of Composite Blocks:	

Also on Site/Calculations:				
Type:		Heat:		Production Date:

Calculations:

Special Note: 1) For straight and curved rail, determine if each side has minimum of 40% of the required zinc coating (See SOP for Guardrail Inspection for example.) **2)** The gage for rail should range between .101-.109 to be accepted by HICAMS, but thicker is