



WET STORAGE STAIN

**A Guide to Minimizing and Treating Wet
Storage Stain on Hot-Dip Galvanized Steel**

Hot-Dip Galvanizing for Corrosion Protection

Hot-dip galvanizing, used in myriad applications, combats corrosion throughout the world. Hot-dip galvanized steel is the most economical, maintenance-free corrosion protection system available. A key feature of hot-dip galvanized (HDG) products is longevity in various environments. The time to first maintenance of hot-dip galvanized steel is directly proportional to the thickness of the zinc coating; therefore, it is important to monitor any issue that may decrease the coating thickness.

Like any manufacturing process, hot-dip galvanizing requires an inspection of the finished product to ensure compliance with applicable specifications. One factor closely scrutinized during inspection of hot-dip galvanized steel is the finish and appearance of the galvanized surface. Some aspects of the final appearance can be controlled by the galvanizer while others cannot. One surface condition is known as wet storage stain (commonly referred to as white rust), which can occur after galvanizing.



San Diego Central Library utilizes galvanized steel



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Figure 1: Wet Storage Stain

What is Wet Storage Stain?

Wet storage stain (*Figure 1*) is a white or gray powdery deposit that can develop on newly galvanized articles. It may be found on nested or stacked products where moisture gets trapped between the articles restricting adequate airflow to the zinc surfaces, or when galvanized steel is exposed to rain, dew, or high humidity conditions. Wet storage stain is the visible formation of zinc oxide and zinc hydroxide on the surface of the galvanized steel.

It is important to note the hot-dip galvanizing process does not contribute to the formation of wet storage stain. The stain occurs after the coating reacts with the environment, not during the coating process. The galvanizer is responsible for producing a high-quality galvanized coating in accordance with ASTM specifications and following best practices for avoiding wet storage stain on articles stored at the galvanizing facility. When those best practices are followed, the galvanizer is not responsible for wet storage stain developed at his facility, during transit, or storage at the job site prior to use.

Natural Weathering of the Zinc Coating

Zinc, like all metals, begins to change when exposed to the atmosphere. As the fresh zinc surface interacts with the wet and dry cycles in the environment, a protective layer of zinc corrosion products, collectively known as the zinc patina, builds on the surface.

Once the galvanized zinc coating is exposed to free flowing air, a thin layer of zinc oxides forms on the surface starting the natural weathering process. Then, when the piece comes in contact with moisture – rainfall, dew, humidity – the zinc oxide particles capture the water to form porous, gelatinous zinc hydroxide. As the surface of zinc hydroxide and zinc oxide interacts with carbon dioxide in the atmosphere, a thin, compact, and tightly adherent layer of mostly zinc carbonate is formed.

The rate of the patina formation varies according to the environmental conditions, but typically takes 6-12 months to fully develop. The fully developed patina is a passive, stable, water-insoluble film on the zinc surface that does not wash off in rain or snow. As the zinc patina develops, the galvanized coating appearance will turn a matte gray color and the protective film of the patina will slow the corrosion rate to about 1/30th the rate of steel in the same environment.

Zinc patina formation is critical to the long lasting corrosion resistance of hot-dip galvanized steel in atmospheric exposures. Because the patina relies on natural wet and dry cycles found in the environment, the results of accelerated salt spray or other corrosion tests using constant wet exposure, are not accurate in predicting the life of galvanized coatings in the real world.

Wet Storage Stain Development

When newly galvanized articles are deprived of adequate airflow, moisture can be trapped on the coating surface altering the natural development of the zinc patina. The trapped moisture presents a different set of conditions creating a reaction that will rapidly create a white powdery zinc corrosion product on the surface.

When a drop of water is flattened between two surfaces, the zinc surface near the middle of the water drop gets a different supply of oxygen than the zinc surface on the edge of the water drop. The varied exposure leads to a difference in the electrolytic potential of the zinc. The central area can become anodic and the edge area can become cathodic, creating a potential corrosion cell (Figure 2).

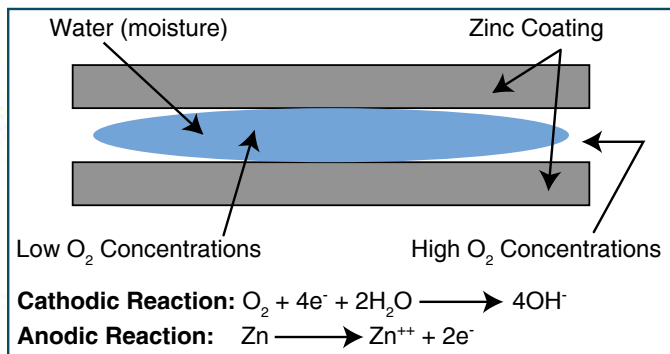


Figure 2: Wet Storage Stain Chemical Reactions

If this corrosion cell forms, the anodic area begins to corrode, while the cathodic area is unchanged. Corrosion products similar to the soluble zinc hydroxide of the zinc patina form on the surface (Figure 3). Because zinc hydroxide remains fairly stable under these conditions, zinc ions continue to leave the coating to bond with water, forming a thick and visible white powdery substance. As long as the area is restricted of oxygen, it is also limits

the flow of carbon dioxide hindering the conversion to zinc carbonate.

The extent of the zinc coating consumption by the wet storage stain depends on the duration of exposure to trapped moisture without free flowing air. If the trapped moisture contains chlorides – from sea water, sulfur compounds, flux residues – the attack will be accelerated because these contaminants will increase the water’s electrical conductivity, increasing the attack on the zinc metal of the galvanized coating. During transit, chloride-rich moisture from road salts can be trapped on the steel, even under a tarp, and cause wet storage stain.

However, even water alone can cause wet storage stain formation in a relatively short period of time. Exposure to heavy rains, dews, or very high humidity conditions after the galvanized coating is formed can start the visible formation of zinc oxides and zinc hydroxides. Wet storage stain corrosion products are voluminous – about three to five times greater than zinc metal – so any attack may appear more serious than it actually is. Wet storage stain is very unsightly, but often results in very little zinc metal loss; and therefore, will not have a significant effect on the life of the coating.



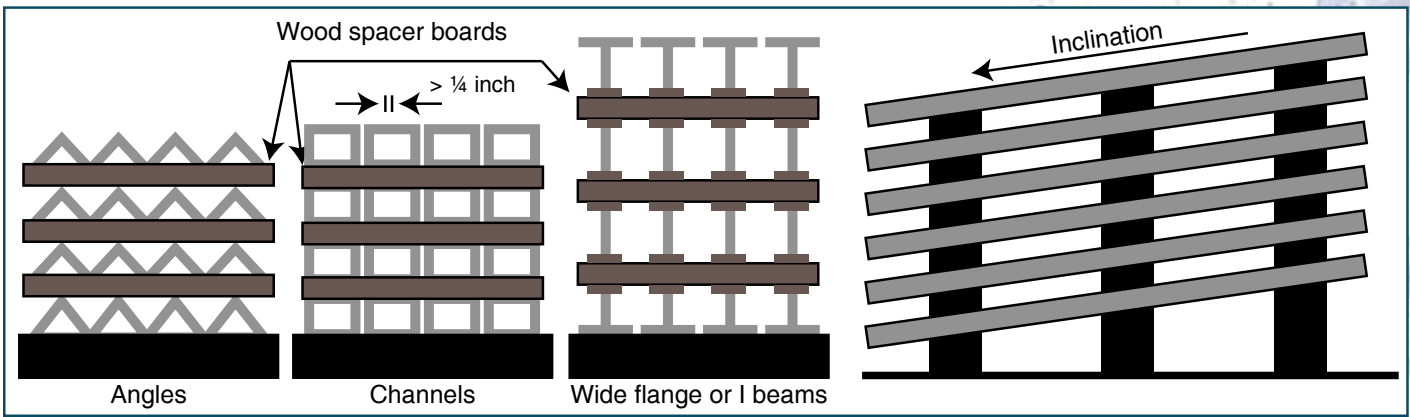


Figure 5: Examples of proper storage methods

Minimizing Wet Storage Stain

There are a number of simple guidelines to consider following when storing or transporting newly galvanized steel which will remain stacked closely together without freely flowing air. Here are some guidelines to consider:

- Whenever possible, avoid nested stacking (Figure 4)
- Provide adequate ventilation between stacked pieces
- Incline parts to allow for maximum drainage
- Use spacers and tarp material during shipping if there is the likelihood of condensation or moisture
- Stagger or cross stack galvanized pieces
- Elevate and separate articles stacked outdoors with strip spacers (poplar, ash, spruce) (Figures 5 and 6)
- Avoid stacking on wet soil or decaying vegetation
- Thoroughly dry small items that are quenched before packing in storage containers
- Include a dehumidifying agent in sealed containers
- Whenever possible, store material under cover in dry, well-ventilated conditions, away from doorways open to the environment
- Ensure the final product is free of flux residues
- Treat with a passivating agent
- Remove road salts from galvanized articles



Figure 6: Storage of galvanized steel, utilizing spacers to increase freely flowing air

Passivating Agents

Fabricated assemblies that fully expose the galvanized surfaces to freely circulating air typically do not need a post-treatment to prevent the formation of wet storage stain. Most after-fabrication hot-dip galvanized products are shipped without any post-treatment, but the need for a post-treatment largely depends on the fabrication's configuration and anticipated storage and shipping conditions.

Various surface treatments are available to reduce the possibility of wet storage stain, including:

- Waxes and oils for products such as wire, sheet steel, and fencing
- Passivation treatments
- Duplex or powder coatings

Proper storage is still recommended even if a passivating agent has been applied. If the galvanized surface will be painted or powder coated, post treatments should be avoided as they may interfere with adhesion.

Cleaning Wet Storage Stain

Wet storage staining is often superficial, despite the possible presence of a chalky, white product. Light and medium wet storage stain do not require cleaning nor effect the service-life of the zinc coating.

The first step to treating wet storage stain is to arrange the articles so the surfaces can dry fully and as quickly as possible. Once dry, the galvanized surfaces should be examined to identify the severity (light, medium, heavy, or extreme) of the wet storage stain, as the treatment will vary accordingly.



Figure 7: Light wet storage stain

Light (Figure 7) and medium (Figure 8) wet storage stain can be left to weather naturally as long as it will have adequate airflow (*Case Study*, next page). In time, the storage stain will convert to zinc carbonate as it reacts with carbon dioxide, completing the development of the zinc patina. If airflow will be restricted, or the surface is likely to have standing water on it, the wet storage stain must be removed by brushing with a stiff-bristled, nylon (not wire) brush. Then the part can be installed and exposed to the service environment.



Figure 8: Medium wet storage stain

Heavy (Figure 9) and extreme (Figure 10) wet storage stain must be removed in order for the galvanized coating to fully form the zinc patina. If this type of wet storage stain is not treated, the service life of the zinc coating and underlying steel could be affected.



Figure 9: Heavy wet storage stain



Figure 10: Extreme wet storage stain

Removing Wet Storage Stain

To remove wet storage stain, brush with a stiff-bristled, nylon brush and a cleaning solution. The AGA conducted a study to determine which cleaning products affect the coating finish the least. There were five products identified that do not damage the coating appearance: CLR[®], lime juice, Naval Jelly[®] Rust Dissolver, Picklex[®] 10G, and white vinegar. For more information on the study and results, contact the AGA for the Galvanizing Note *Cleaning Wet Storage Stain from Galvanized Surfaces*.

After removing the storage stain with the nylon-bristle brush and cleaning solution, the surface should be rinsed with tap water and dried. Finally, it is best to measure the zinc coating thickness after cleaning to ensure an adequate coating remains on the base steel.

If heavy white deposits or red stains have formed due to prolonged exposure to poor conditions, the damaged areas should be repaired according to ASTM A780, *Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings*. In extreme cases, wet storage stain becomes black (Figure 10), indicating a significant amount of zinc coating has been consumed, and the steel must be stripped and regalvanized to meet ASTM specification requirements.

Natural Weathering Case Study

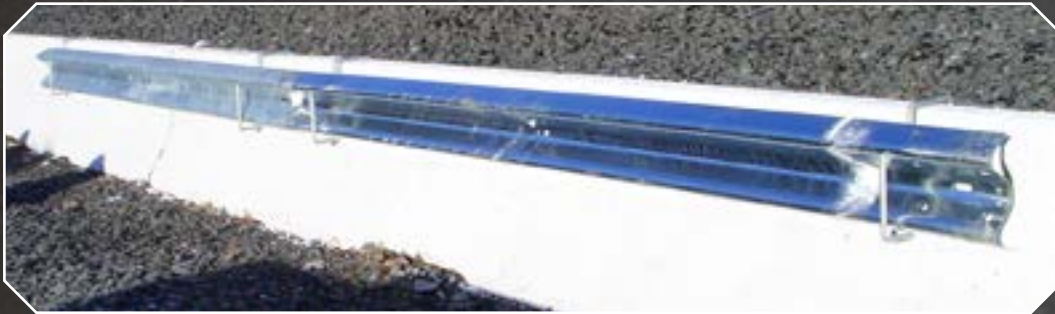


Figure 11: December

As stated, light to moderate cases of wet storage stain do not require remediation to weather naturally. This pictorial case study shows the natural weathering of a hot-dip galvanized part which developed wet storage stain.

Figure 11 shows two pieces of guardrail, one shiny and one matte-gray. These two pieces were galvanized in the same batch on the same day. The guardrail section on the right was stored under cover and exposed to free flowing air, while the section on the left was exposed to moisture (humidity or rain) but no free-flowing air and developed wet storage stain. After one week, the two pieces were hung side by side to weather naturally.

Figure 12 shows the same two guardrail sections after a little more than three months exposure. The left section of guardrail, which had wet storage stain, is now identical to the right piece which was originally bright and shiny. Once, the hot-dip galvanized steel with light to moderate wet storage stain is exposed to free flowing air, the zinc corrosion products react with carbon dioxide to form the matte gray zinc carbonate film known as the zinc patina. The right section naturally weathered to develop the same stable zinc patina which provides hot-dip galvanized steel with its incredible resistance to corrosion. Once the pieces are allowed to weather naturally, not only the appearance but also corrosion protection of both sections is identical.



Figure 12: March

Summary

Hot-dip galvanizing is a mainstay of North American industry, and new technologies and creative chemistry continue to evolve the process. Once used only as a means of corrosion protection, hot-dip galvanizing is now specified for many reasons including: lower initial and life-cycle costs, durability, longevity, availability, versatility, sustainability, and aesthetics.

Like any manufactured product, there are best practices and process controls to ensure a high-quality piece. Proper planning throughout the process and during storage and handling before installation are key to successful galvanized projects. By following the simple guidelines here, wet storage stain can be minimized, ensuring the hot-dip galvanized steel will transcend time with little environmental or economic impact while providing superior corrosion protection for generations.



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