GalvInfoNote 7	**Protecting Galvanized Steel Sheet Products from Storage Stain** Rev 2.1 Aug-03

Introduction - What is Storage Stain

Storage stain, when related to galvanized sheet products, is a corrosion-formed stain that is typically white, but which can also take the form of a grey or black deposit on the surface. Since the most common form of discoloration is a white appearance, storage stain is often called **white rust**. Storage stain can occur when sheets of galvanized steel which are closely wrapped (such as when the product is in coil form or stacked in lifts or bundles) get wet, either by moisture intrusion, or by condensation from the air that is trapped between adjoining sheets. The discoloration is due to the corrosion products that remain on the surface of the sheet after zinc reacts with moisture in the absence of the free circulation of air.

Building erected using sheets from a bundle of galvanized sheets that had extensive amounts of white rust.

Note: The voluminous amount of white rust, as seen here, does not occur during normal exposure of building cladding. Normally, the products of zinc corrosion simply get washed off the surface. The surface accumulation noted here occurred while the sheets were stored in a bundle.

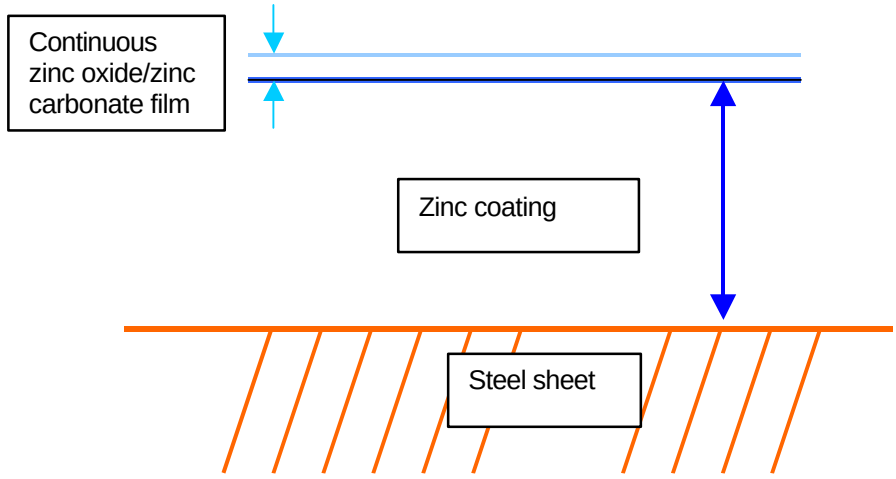
Before discussing the issue of **storage stain** in more detail, let's first discuss some of the general features of what happens when a galvanized (zinc) coating corrodes in the environment.

Why Does Zinc Protect Steel?

Zinc, by its very nature, is a "reactive" metal. That is, it tends to corrode quite readily when exposed to moisture. Why then does it protect steel when the coated sheet is exposed to rainfall?

When zinc corrodes in the presence of moisture, it undergoes a chemical reaction. In this reaction, the zinc actually changes chemical form; the metallic zinc on the surface changes to other chemical compounds, primarily zinc hydroxide. As the surface dries, the hydroxide film on the surface is converted to either a form of zinc oxide or zinc carbonate (formed by reaction between the zinc hydroxide and carbon dioxide in the air). These compounds form a relatively continuous protective film on the surface of the zinc. Thus, when the surface

is again exposed to rain or condensation, the protective film serves as a barrier between the moisture and the zinc coating, protecting the zinc underneath. These types of chemical films are called passive films. It is the presence of this passive film that slows down the reactivity of the zinc, thereby dramatically reducing the rate of corrosion of the zinc coating.



A through-thickness schematic drawing that shows the continuous, protective oxide/carbonate film that forms on galvanized sheets in the atmosphere.

Typically, low-carbon steels do not form a continuous, protective, passivating film on the surface when they corrode. The products of the corrosion reaction between iron and moisture are iron oxide and/or iron hydroxide, and typically do not form a continuous film; instead, they tend to spall or develop cracks in the oxide layer. Thus, moisture and air are not kept away from the surface of the iron, and the corrosion reaction is not slowed. **The difference in oxide film-forming behaviour between iron and zinc when they are exposed to moisture is the main reason that a galvanized coating provides an extended life to steel.**

In most applications, the passive surface film that forms on zinc is not totally protective, and continued corrosion does occur when the zinc coating is exposed to moisture. Because the passive film is present, however, the rate of corrosion is diminished substantially.

Why is Zinc Susceptible to Storage Stain (White Rust)?

As stated above, zinc is very reactive metal. It exhibits a low corrosion rate only because a continuous passive film forms on the surface of the zinc coating. A key part of the corrosion reaction is that the surface needs to dry in the presence of air in order to develop and maintain the passive film. It is during the drying part of a rain cycle that the zinc carbonate/zinc oxide passive film is developed.

The zinc coating needs to dry thoroughly to develop a passive film on its surface and provide good corrosion resistance. What happens when the product gets wet while still in coil form or when stacked into bundles at a roll-forming plant or at the jobsite? As many of you have seen, this condition can lead to the formation of an excessive amount of storage stain.

What is “storage stain” or “white rust”? It is simply the chemical compound, *zinc hydroxide*, which forms initially when zinc is in the presence of moisture. Why doesn’t it convert to the passive film of zinc oxide/zinc carbonate? The answer is that the zinc hydroxide is never allowed to dry; nor are the tightly wrapped sheets freely exposed to carbon-dioxide containing air. Thus, the protective zinc carbonate/zinc oxide film never forms, and corrosion

of the zinc surface continues to occur. Since the corrosion reaction continues to proceed as long as the surface is wet and starved for carbon-dioxide containing air, a large accumulation of zinc hydroxide can form. Zinc is a reactive metal in the presence of moisture under conditions that do not allow the protective passive film to form.

When "white rust" does occur, there is an actual loss of zinc coating, and some of the zinc that is intended to protect the coated-steel product when it is eventually exposed in its application is lost. The extent of the damage is primarily dependent on:

1. the time of exposure to moisture,

2. the temperature that is experienced during storage, and

3. the presence of accelerating corrosive agents, such as chloride-containing salts.

Often, the amount of "white rust" appears to be quite heavy when, in fact, the amount of zinc corroded is quite small. This occurs because the zinc hydroxide is somewhat flocculent, and remains in the area of the wetness. If the application is not aesthetically critical, the galvanized coating should perform very well and should meet the requirements and expectations of the end user. In most instances that involve outdoor exposure, the white rust will disappear over time as it is either washed off by rainfall[1] or is converted to zinc carbonate/zinc oxide.

The surface of the zinc coating in the area that experienced white rust is "etched"; thus it no longer has the bright, reflective appearance of as-produced galvanized sheet. Removing the white rust will not eliminate the etched appearance. This is why, for applications where the appearance is critical, white-rusted galvanized sheet may no longer be acceptable.

There are times, albeit seldom, when the sheets have been wet for a long time; times long enough that the amount of corrosion of the zinc coating can be severe. In these cases, the product may no longer provide the corrosion resistance desired for the application. It takes a trained observer to determine whether or not the amount of rusting that has occurred is severe or not.

Preventing Storage Stain

Clearly, it is very desirable to avoid storage stains on galvanized sheet products. Often, the customer's application requires the aesthetic appearance of a bright galvanized surface, and no amount of storage stain is acceptable. Fortunately, there are of practices in place today that allow the shipment and storage of galvanized sheets without subjecting the product to storage stains.

Chemical Passivating Treatments

The best way of minimizing the chance of white rust forming, either during shipment and storage of coils, or shipment and storage of lifts of sheared blank sheets, or shipment and storage of stacked bundles of roll-formed panels at a jobsite, is the application of a "surface passivation treatment" by the steel-sheet manufacturer. This passivation coating is applied on the galvanizing line. It is very thin, and usually invisible. The most common type of passivation treatment is a water-based chromate coating. It is applied by spraying a water-based solution onto the surface, or dipping the sheet into a liquid bath containing the solution. After the liquid is applied to the surface, the excess is "squeeged" off using rubber-coated rolls. Following this, the water-based passivating film is dried thoroughly before recoiling at the exit end of the galvanizing line.

These clear passivation coatings have been in use for many years, and their performance is very exceptional with respect to minimizing the tendency for staining when the sheets get wet while in coil form or bundles. Steel-sheet manufacturers use the term "passivation treatment" or "chemical treatment" to

[1]The removal can be assisted by the use of a stiff bristle brush. If the stain is not too severe it can be removed by washing with a 10% acetic acid solution, followed immediately by a thorough rinsing with water. The original bright, metallic surface will not return, however.

define this surface treatment. Both terms are often used interchangeably. **When an order is placed, the customer needs to specify whether this treatment "is" or "is not" required.**

It is important to remember that mill-applied passivation treatments **minimize** the tendency for storage stain; they **do not eliminate** its occurrence if the product is subjected to very adverse conditions. An example would be having a coil get wet during transit to a customer's warehouse, and then allowing the coil to sit in the warehouse for a long period without any attempt to dry it. Even if the product is ordered with a chemical treatment, it is still important to keep moisture from between the wraps while in coil form, blanked sheets, or in bundles.

Surface passivation treatments also assist the product in a less well known way. When the product is put into service and exposed to the atmosphere, a surface passivation treatment helps to maintain the bright, shiny appearance for a longer period of time. Eventually, the brightness is lost, but the passivation treatment helps to maintain the shiny, metallic appearance for a noticeably longer timeframe. The exact amount of this effect depends on the environment and the relative corrosivity and cleanness of each specific application. Also, as the surface dulls, it tends to do so in a more uniform fashion than if the sheets were unpassivated.

Passivating Oils

Besides the use of chromate chemical passivation treatments, there are other surface treatments in use today. Perhaps, the most common are rust-inhibitive oils. These are oils that contain very specific chemicals called corrosion inhibitors. The inhibitor actually provides the protection from storage stain; the oil serves as the carrier solution that is applied to the sheet. As with the chromate treatments, the oil is applied by the steel-sheet manufacturer in the galvanizing line. One common way to apply the oil is by the use of an electrostatic applicator. These oils are not intended to provide good lubrication for applications such as deep drawing, but they do provide some amount of lubricating qualities and can assist with some forming operations. Another type of oil is a called a "vanishing oil". That is, the oil is a volatile compound that evaporates when exposed to air; it leaves behind some amount of corrosion inhibitor on the sheet surface.

Which Treatment to Apply

Often, the end use defines whether a chromate passivation treatment or rust-inhibitive oil should be applied. Typically, when the end use is one that does not involve painting, the chromate passivation method is best. If the application requires painting in the manufacturer's plant, a rust-inhibitive oil is usually best.

There are a number of applications where the best method of protection from white rust requires discussion between the steel manufacturer and the customer. It is possible to order the product with both a chemical treatment plus oil. Typically, this combination provides better white-rust protection than either chemical treatment or oil used separately, and should be considered when harsh storage conditions are expected.

When the end use involves spot welding or painting it is also possible to order the product unpassivated. When this is the case, there must be absolute certainty that it does not get wet before it is used. Precautions that can be taken are explained below.

Other Ways to Protect Galvanize from White Rust

Besides the use of oils or chemical treatments, there are other ways to minimize the tendency for storage stain. A common one involves "wrapping the coil" by the sheet manufacturer. Today, there are plastic wrapping materials as well as paper wrapping materials in use. The packaging material may have a corrosion inhibitor impregnated into it to provide better protection than just the packaging material itself.

In addition, the prevention of storage stain is strongly influenced by the methods and practices used for shipment from the steel manufacturer to the customer. It is vital to prevent water intrusion and to use practices

that minimize the tendency for condensation during transit and storage. It is especially important to maintain controlled temperature storage (sometimes even during transit), to prevent condensation that can occur if the temperature of drops and passes below the dew point.

How do Coils Get Wet?

Coils or bundled sheets get wet in two ways:

1. Water from rainfall gets between the sheets while the product is in transit or while it is sitting at a jobsite
2. Condensation.

Condensation occurs when the coil or stacked sheets are below the dew point of the local atmosphere. One way for this to occur is when coils are shipped in the wintertime, and then placed into a warehouse that is warmer than the galvanized steel and where the humidity is not at a controlled low level. Under these conditions, the moisture simply condenses onto the steel's surface as the "cold coil" causes the local air temperature to drop. This is similar to the condensation of moisture onto a cold windowpane.

Condensation can occur in other ways that are not as obvious as that above. For example, even if the coil temperature and the temperature inside the local warehouse are about the same when the coil arrives at a customer's plant, but the warehouse is not temperature controlled, cooling overnight might allow condensation to occur between the adjacent wraps. Once moisture condenses, it takes a long time for the moisture to dry because there is so little air movement between wraps in a coil or bundle.

Because there is no absolute way to totally prevent storage stain once the material gets wet, it is important for the best practices to be applied at all steps in the process.

Best Practices

1. The steel manufacturer needs to apply the chemical treatment and/or oil in a controlled manner to cover the entire surface area of the sheet.
2. If possible, the coils should be wrapped with either paper or plastic that is specially made for this application.
3. The shipper needs to protect the steel during shipment to the customer's plant. Ship only in covered, watertight conveyances. If it is necessary to use an uncovered conveyance, wrap completely with a tarp to assure no water intrusion if it rains while in shipment. Avoid tearing the paper.
4. The customer should store the coils in a climate-controlled warehouse. Use the material promptly. Whenever possible, do not allow the product to remain in storage for extended periods of time (in excess of two months).
5. For shipping from the customer's plant to the final location, the product again needs to be protected, especially if the sheets are in intimate contact with each other. In this case, the product is again very susceptible to storage stain as the sheets will not dry properly if they get wet.
    a. Paper wrapping is one way to protect the sheets while in transit or during storage at a jobsite. Be careful to not wrap the bundle while the sheets are wet. This traps moisture in the bundle and prevents drying.
    b. Do not wrap the sheets tightly in plastic. Allow the product to "breathe" by providing air circulation.
    c. Store the lifts of sheets indoors if possible.

d. Store the panels above ground; at least 12 inches to allow air circulation beneath the bundle.

e. Inspect frequently to assure that the panels have not gotten wet.

f. Elevate one end of a bundle of sheets to allow water to egress if moisture has gotten into the lift of sheets. Make sure there are no low spots along the length so that water can flow freely if necessary.

Summary

Storage stain or “white rust” is a condition associated with the corrosion of galvanized sheet product that occurs when sheets get wet while tightly bundled (either in coil form or in a lift of blanked sheets or roll-formed panels), and then not allowed to dry. The continual wetness prevents the formation of a protective passive film on the surface of the zinc coating. The result is a stained, discolored sheet that is virtually impossible to return to its original shiny, metallic appearance.

It is important that white rust be prevented by paying careful attention to the product at all times, especially while sheets are in intimate contact (coiled or bundled sheets), and free air flow is not available to dry the surfaces.