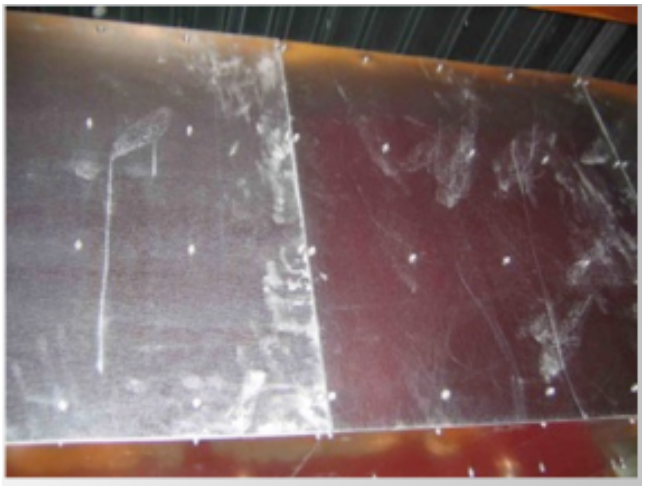
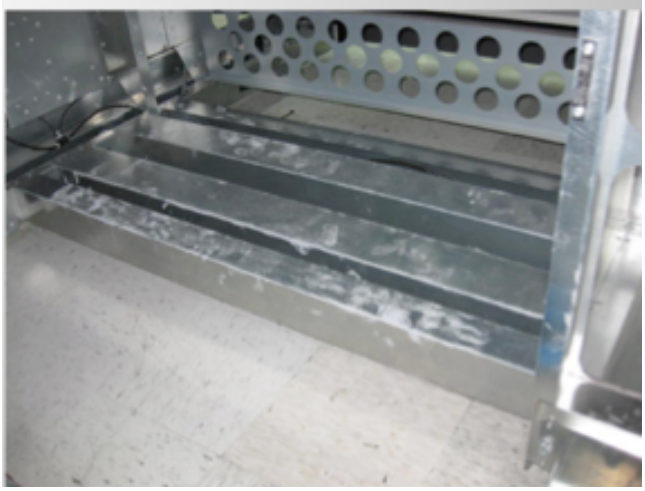
GalvInfoNote 6.3	Successfully Manufacturing Products made with Galvanized Steel Sheet REV 1.0 DEC 2017

Introduction

During the manufacture of products made with galvanized steel sheet, there are infrequent, but potentially serious surface appearance imperfections and other irregularities that can arise and sometimes result in the product being unsuitable for use. Other than storage stain (see *GalvInfoNote 6.1*), some of the more common of these issues are covered in this GalvInfoNote.

Fingerprinting





Metallic-coated sheet products are susceptible to surface marking during processing and handling. Galvanized sheet can be permanently affected by white staining due to the perspiration of workers who come in contact with it during the manufacture of products like heating and ventilating ductwork (top left photo). The same problem can happen during manufacture of metal electronic cabinets (bottom left photo). While not harming product durability, the white stains affect its esthetics when intended for an exposed end use. These stains are the result of salt and other compounds in the worker's perspiration reacting with the zinc to permanently mark the surface. Once stained in this manner it is very difficult to remove, and there is no known method of restoring the original metallic lustre. Typical mill passivation treatments do not necessarily offer resistance to this staining.

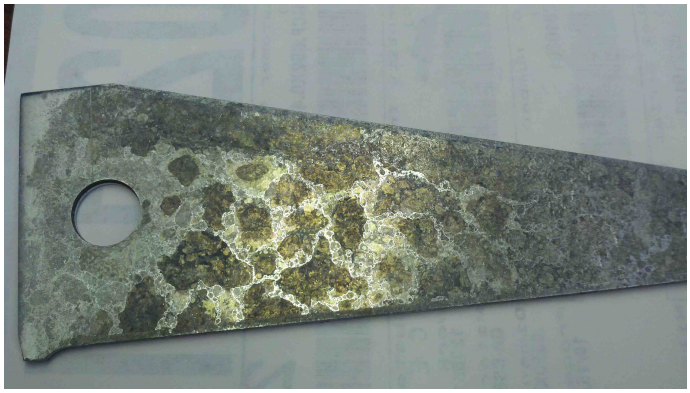
To provide a product that is resistant to marking, the industry has developed special coatings (typically acrylic-based) for metallic-coated sheet. They are applied over the zinc at the coating line using a roll-coating technique and infrared curing ovens. The coating is clear and consists of a water-soluble acrylic resin with inorganic corrosion inhibitors added. Benefits include resistance to hand and/or foot marking during handling/installation, good resistance to storage stain/transit corrosion, and retention of zinc brightness over a longer time.

To avoid fingerprinting and handling marks, the purchaser can request the galvanized sheet be acrylic treated at the time of production. Most producing mills offer this option at an extra cost. For material that is not acrylic treated, and where the final product must be free of these marks, the best option is to have the workers wear long sleeves and clean, soft cotton gloves when handling the sheets during manufacturing and installation. For more information on this problem, refer to *GalvInfoNote 2.13.*

Darkening

Premature darkening of the zinc coating can sometimes occur on galvanized sheet after a few days of exposure on new buildings[1].

It has even been reported to occur on industrial products after being placed outdoors, as shown in the photo to the left. The material on the right side of the assembly darkened appreciably, compared to that on the left, during the first night outdoors. The galvanize use to make the bright area was mill passivated, while that used to for the dark area was oiled before shipping, *but not passivated*. The significance of outdoor storage is that it can allow dew to condense on the surface of the metal, the significance of which is explained below. Of course, as soon as the dew dries, corrosion ceases, usually leaving the observer wondering what happened in such a short time. Passivated galvanize will resist such attack and allow the normal, colorless, slow-forming patina to develop. Such a patina can also form on unpassivated zinc if it is protected from aggressive corrosion when freshly exposed.



Another example of darkening is shown in the photo to the right. It is an automotive part that was out of specification for some other reason and was later noticed in an outdoor scrap bin. It triggered an inquiry because of concern that it was part of a shipment of defective zinc coating. All galvanized sheet used by the automotive industry is produced unpassivated for weldability and paintability reasons, so this piece was most likely affected by outdoor moisture that rapidly turned the surface partially black. As described above, this staining occurs very quickly by moisture that does not allow the normal oxidation of zinc in the zinc hydroxide, zinc oxide, zinc carbonate sequence that happens over longer periods.

It is most probable that it is a higher amount of sulfate ions that cause the black hue. *"The most important corrosive constituent in the atmosphere is sulfur dioxide, …and sulfate ions come more from dew than other forms of precipitation."*[2] *When heavy mists and dews occur in these atmospheres, they are contaminated with considerable amounts of acidic substances such as sulfur dioxide*[3]. Darkening is the result of forming these protective basic oxy-carbonate layers and is influenced by the presence of other atmospheric species, including sulfates and chlorides, which influence appearance (darkness). Rainwater is known to have a higher degree of mineralization, which could complex with sulfate ions, thus rendering it less aggressive than dew condensate. Whatever the cause, darkening is a fast acting corrosion process that is very superficial, but creates an unattractive corrosion product. Of course, it is especially disconcerting when it occurs adjacent to bright galvanize.

To prevent this problem from happening, unpassivated galvanize should not be applied to applications where the product will be placed outside. The surface of passivated galvanized sheet is 'deactivated' enough that atmospheric reactions are slowed to the point where its normal patina takes at least a few months to develop. Unpassivated zinc has a very active surface and experience has shown that corrosion products can form

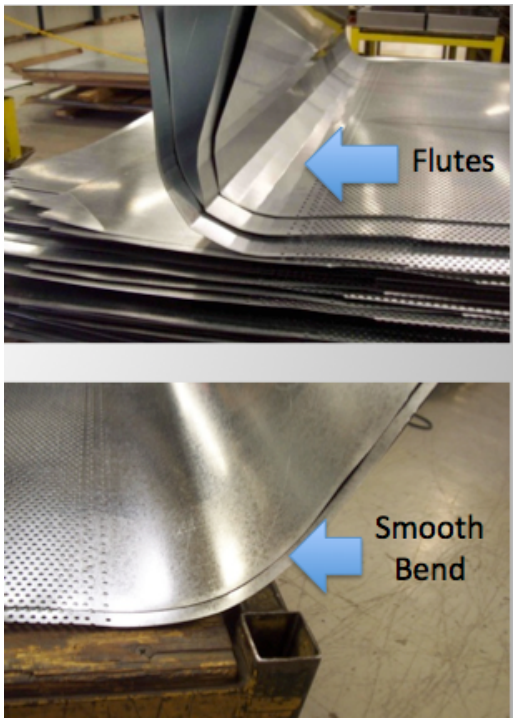
[1] Zhang, X. Gregory: Corrosion and Electrochemistry of Zinc, Plenum Press, New York, 1996, p. 262
[2] Ibid. p. 244
[3] Shreir's Corrosion, Fourth Edition (2010), vol. 3. P. 2082

quickly and have different apperances. Allowing dew or other condensate to form on unpassivated sheet should be avoided.

Fluting and Stretcher Strains

Fluting and stretching strains are marks that appear on the surface of the carbon steel sheet after forming operations. They are caused by discontinuous yielding of the steel substrate and show through the zinc coating. See page 3 of *GalvInfoNote 2.8* for more information on this phenomenon.

For many end uses it is important to suppress this behaviour, because if not done, the sheet will exhibit stretcher strains when stretch-formed, or fluting when bent.



The photos to the left show sheets that were subjected to bending using a large radius. The bottom photo shows what is what is expected to occur when sheets are bent in a controlled manner – the curve is very smooth. When discontinuous yielding is present, the sheet will bend sharply every so often (flute) into a discontinuous curve that is totally unsatisfactory.

To prevent this, and as explained in *GalvInfoNote 2.8*, a small amount of cold work imparted to the sheet by temper rolling (or leveling) suppresses the discontinuous yielding phenomenon. With this behavior having been masked, the steel can be formed with no concern about stretcher strains or fluting.

Temper rolling or leveling are processes that are performed on all galvanized sheet during the coating process (unless intentionally omitted). This ensures that the product can be formed without these problems happening.

Steel sheet that is used within a reasonable time after being received from a steel supplier should not flute or show stretcher strains when bent or stretch-formed. If it does, then it is non-conforming product. What is considered to be a 'reasonable time' differs amongst steel suppliers, but the maximum time allowed for carbon steel sheet is about 6 months. It the time exceeds this then another behavior of carbon steel can come into play, namely *ageing*.

The metallurgy of ageing (which includes strain ageing) is too complex to cover in this note, but the end result is that discontinuous yielding will return after time. To avoid this happening, the steel must be consumed within a reasonable time period. The time to return of discontinuous yielding varies, but is shortened the higher the storage temperature. As covered above, steel producers introduce enough cold work to suppress ageing for up to about 6 months, but this can be shortened if the storage period involves hot summer months. If a user encounters fluting after having had the steel for, say, one year, then suppliers will most likely not honor a claim. To minimize the chance of ageing causing a problem, manufacturers should control inventories to use the oldest steel stock first, hopefully before ageing can create forming issues. See *GalvInfoNote 1.8 Steels Used in Coated Sheet Products*, p. 4 for a more in-depth explanation of ageing.

Summary

Perhaps because of the well known excellent corrosion resistance of zinc in most atmospheric environments and the excellent formability of coated sheet, it sometimes seems that galvanized steel sheet is treated during end-use product manufacturing as if it's "almost indestructible". The issues covered in this GalvInfoNote show that this is far from the case. By being aware of the necessary precautions, manufacturers can avoid the pitfalls.