# FastenerTalk

Number 107

*Metal Building Systems Information*

ATLAS Fasteners For Construction

## A New Approach To Metal Roof, Siding, and Fastener Corrosion

*The accompanying article was commissioned by Atlas Bolt to try to determine if there was any truth to rumors that the use of stainless steel with Galvalume roofing could give rise to galvanic corrosion.*

*As the article clearly shows, laboratory tests will indeed confirm that because of the dissimilarity of the two metals, this is not a good combination.*

*Our concern, which I am sure is shared by readers and anybody else who is involved with the metal building industry, is that we had seen no real evidence that this was a major problem in actual practice.*

*Atlas had been, and continues to be, a pioneer in the development of corrosion-resistant fasteners for metal buildings. We first introduced nylon-headed fasteners nearly 20 years ago. Our current product line encompasses stainless steel fasteners - both austenitic and martensitic - Oxyseal® post-plating film and the UltiMate® fastener with a zinc-alloy cast head. We are dedicated to manufacturing the finest corrosion-resistant fasteners possible.*

*We sincerely trust that this article sheds more light on an age-old problem and we welcome any comments, or research, that others may have to offer.*

*In the meantime, for those of you who are still wondering why there are not more reported cases of galvanic failure, we believe that today's use of paint, and/or post-plating film, the zinc or cadmium platings which are applied to fasteners, and the use of EPDM sealing washers, all serve to greatly reduce the failure rates in actual practice.*

From time to time stories have circulated about fasteners causing metal roofs and siding to corrode, and vice versa. As a major manufacturer of self-drilling, self-tapping screws for attaching metal siding and roofs, Atlas Bolt & Screw is naturally concerned: do these stories have basis in fact? If actual cases cannot be documented, could it happen? Does it happen?

Going back to basics, what is necessary for corrosion to take place? First, because buildings are exposed to the weather, we can limit our review to corrosion which takes place at ambient temperatures (say freezing to maybe 160 to 180 degrees F and with water as a medium.

So, what is necessary for corrosion to happen on metal buldings? A corrosion couple has to be present. A corrosion couple is comprised of:

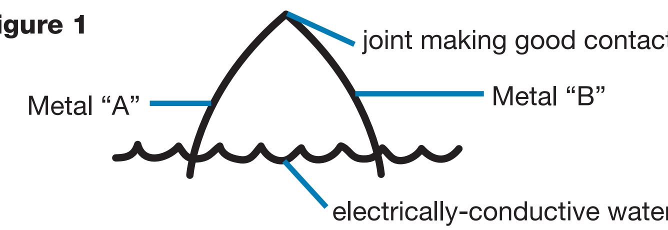
1. two dissimilar metals ...

2. joined together, or touching firmly enough to make good electrical contact...

3. with portions of each metal in contact with water which has enough chemicals dissolved in it to make it electrically conductive. Some common chemical could be salt, sulfuric acid (battery acid), hydrochloric acid (muriatic acid), or nitric acid.

A simple corrosion couple could look like this:

**Figure 1**




What happens when corrosion takes place? A portion of either Metal "A" or Metal "B" is dissolved in the water, and an electrical current flows through the water and through Metals "A" and "B':

Corrosion can take place when this couple is totally immersed in the conductive water, or when only a portion of each metal is in contact with the water.

Corrosion would not occur (that is, a couple would not be complete) if the water were pure and could not conduct electricity; or if Metal "A" and Metal "B" were not different (i.e. were identical); or if Metal "A" and "B" were not in good contact to permit an electrical current to flow.

### On Metal Buildings

In the situation of a screw fastening sheet metal to a building, we have good electrical contact between the screw and the metal siding or roofing at the point where the screw has pierced the siding or roofing. So we have one element of the corrosion couple.

The head of the fastener and the metal coating (galvanizing or other) on the siding or roofing are most often of dissimilar metals, so we have a second element of the corrosion couple.

So all we need is water with chemical dissolved in it (to make the water electrically-conductive), where water is in contact with both the head of the fastener and the metal coating on the siding. Then, we would have the third element of the corrosion couple in place and corrosion would take place. This water can come from weather, from ponding or from by-products of construction.

## Acid Rain

"Pure" rain has enough carbon dioxide (you exhale carbon dioxide when you breathe) dissolved in it to make it slightly acidic and thus electrically conductive. It has a pH of about 5.6.

Acidity or alkalinity of water can be described by a pH number. Distilled water has a pH of 7 (which is considered as neutral); lye water has a pH of 12 (very alkaline). Orange juice has a pH of 3.9, vinegar has a pH of 3 (quite acidic) and battery acid has a pH of 1 (very acidic).

Thus, the lower the pH number, the more acidic the water.

Neutral water (pH of 7) will not conduct electricity. But, the farther away the pH is from 7, either up or down, the better the water will conduct electricity.

Because "pure" rain water is not very acidic, it is not a very good conductor of electricity. So, if it completes a corrosion couple, corrosion will not go very fast. On the other hand, battery acid conducts electricity quite well; and, if it were to complete a corrosion couple, we would expect corrosion to go fast.

The acidity of rain has increased over the past 20 years, particularly east of the Mississippi River in the U.S. Over time, the higher acidity in rain (the acidity varies during a rainfall with the most acid rain falling first, then with the acidity diminishing as the rain continues) has been measured in the Appalachian and Adirondacks regions. This higher acidity has become more acid, changing from around 4.6 pH in the 1950s to around 4.1 pH in the 1970s. This increasing acidity (lower pH) makes the rain a better conductor of electricity.

So, we can expect rain which falls in industrial areas and in heavily populated areas to be sufficiently conductive to supply the third element to create a corrosion couple between the fastener and the roof or siding metal.

## Don't Panic

Some notes of comparsion: While a pH of 4.1 sounds ominous, remember that your breakfast orange juice is about 3.6 pH and your carbonated soft drink is about 4.3 pH.

Secondly, remember that water has to be present to make a conductive solution. When the water evaporates, it may leave behind a residue, but the electrically-conductive part of the corrosion couple and the circumstances necessary for corrosion to proceed are gone - at least until the next precipitation or dew. Thus we could expect corrosion to proceed more in areas of ponding or other situations (such as damp, drifted debris) which hold water in contact with the fastener and surrounding sheet metal.

## More About Acid Rain

Analysis of the higher acidity rain has shown both sulfuric acid and nitric acid to be present. The nitric acid comprises about 30% and there is a general trend of this percentage increasing.

In seacoast locations, the rain also contains salt (mostly as sodium and magnesium chlorides, those compounds most prevalent in ocean water). While salt water is not considered to be either acidic or alkaline, it is electrically conductive. Thus, salty rain will complete the corrosion couple and allow corrosion to take place.

Other sources of chemicals that could make water which comes in contact with metal buildings electrically conductive may be; acid washes used to clean brick during construction, water-saturated insulation, wet corrugated cardboard, wet gypsum board, de-icing compounds, fertilizer (chemical, animal & bird droppings), and earth. So, you could expect water containing these chemicals to complete the corrosion couple and permit corrosion to proceed.

## Dissimilar Metals & Corrosion

In tendency to corrode, all metals are not created equal. Those metals which tend to dissolve more in a corrosion couple are called "active". Those which tend to dissolve to a lesser degree are called "noble." The name "noble" comes from the noble metals, gold and platinum, which have been observed to be very resistant to corrosion.

If an active metal is joined to a noble metal to form a corrosion couple, the active metal will take on a negative (-) electrical polarity and the noble metal will take on a positive (+) polarity. As the corrosion proceeds, the metal with the negative polarity will be dissolved (eaten away) while the metal with the positive polarity will not dissolve. If a given active metal is teamed with a more noble metal, it will be dissolved away faster (other conditions being the same) than if it were teamed with a less noble metal.

This tendency for the active metal to dissolve away can be measured because it shows up as an electrical voltage between the active and the noble metal, even when no current is flowing. The higher the voltage, the more tendency for the active material to dissolve away when in a corrosion couple.

The rate at which the active metal is being dissolved away in a corrosion couple can also be measured. This rate shows up as an electrical current flowing through the conductive water and through both metals. The greater the current, the faster the active metal is being dissolved away.

## Bench Testing Various Fastener and Roofing Materials

To explore the corroding tendencies of various combinations of fastener and metal roofing materials, we ran tests under controlled laboratory conditions. These tests created corrosion couples between fasteners made from different materials and different roofing materials. Then electrical measurements were made to show the tendency to corrode and how fast the active metal was being dissolved away.

For the conductive water required to establish a corrosion couple, we started with distilled water (which is non-conductive) and added either table salt, nitric acid or sulfuric acid to make 3 different sample solutions of conductive water. These added chemicals are the ones most commonly encountered in rain and precipitation (including fog) in industrial areas and in seacoast areas. All solutions were made up to have equivalent chemical concentration.

## Bench Test Set-Up

The screw under test and the sample of roofing material be ing tested were partially immersed in the conductive water in a simple test set-up, as shown in Figure 1. The head of the screw was immersed in a way such that the conductive water covered that portion of the screw head normally exposed to the weather.

The cut edges of the roofing material coupon were coated with an electrically-insulating sealing enamel (Glyptal), so that only the galvanized surfaces would show. The end of the coupon was immersed 1-1/2” deep into the conductive water. The screw head and the coupon were about 2-1/2” apart.

The voltage generated between the screw and the coupon was measured with a voltmeter having 20,000 ohm/volt sensitivity. This insured that making the voltage measurements would not affect the corrosive action taking place in the couple.

The current generated in the couple was measured with a micro- or milli-ammeter as appropriate.

## What We Tested

We used two different building metals; ordinary bare 26 ga. galvanized steel and 24 ga. Galvalume AZ55, both bare and painted.

A variety of screws were tested including those made from 1022 carbon steel, 304 stainless steel, 410 stainless steel, UltiMate® (cast Zamak zinc alloy over steel shank).

In addition, to establish a point of reference for a very noble, corrosion-resistant metal, we substituted platinum (in the form of a spiral 1-1/4” across, made from .020” dia. x 10” long wire) for the screw in some of the experiments. We used the spiral because we couldn’t afford a platinum screw - and besides, platinum is too soft to drive well!

To insure that we were testing the basis screw material itself, any anti -seize or corrosion resistant coatings present on the screw heads were removed by pickling in 10% nitric acid and then sand-blasting with fine sand.

## Some Test Results

Very condensed data from runs with a 2” x 4” coupon of bare Galvalume are summarized in Figure 2.

In most cases, the polarity indicated that the coupon (or more precisely, the zinc-aluminum alloy coating on the coupon) was being dissolved away.

The current indicates the rate at which the coupon coating is being dissolved away; the higher the current, the faster the rate of dissolution.

As theory predicts, the more noble metals, such as platinum and stainless steel, cause accelerated corrosion of the less noble Galvalume coating on the coupon.

Extrapolating this to the real world of roofs and siding, one would expect that stainless steel screws would, under corrosive conditions, be very corrosion resistant in themselves but would cause accelerated corrosion of the Galvalume sheet metal near the screw.

The closer the screw head material and the Galvalume coating are together in compositon (i.e., the less noble the screw material), the lower is the tendency to cause corrosion of the Galvalume (as shown by the low voltage) and the lower the rate of corrosion (as shown by the lower current flowing). This is shown in Figure 2 by the low voltage and currents produced by couples between the zinc aluminum coated Galvalume and the zinc-coated 1022 steel screw and also the zinc-alloy-headed UltiMate® screw.

Extending this to the real world, one would expect that, although zinc-coated or zinc-alloy- headed screws are less corrosion resistant (less noble) than stainless steel screws, they would cause less corrosion of the Galvalume material near the screw.

## More About the Testing

Our test can tell the difference between ordinary galvanized steel and Galvalume. As shown in Figure 3, a 304 stainless screw causes the ordinary galvanized steel to dissolve (corrode) faster than Galvalume.

Colored, coated panels of Galvalume were carefully prepared by triple-sealing the raw edges with insulating enamel (for one set) and with epoxy (for another set). These were then tested in a couple with a 304 stainless steel screw.

To our astonishment, appreciable current flowed, indicating that the zinc-aluminum coating beneath the color coating was dissolving, see Figure 4. This means that the coatings are porous, probably because solvents driven from them in baking or setting leave porosity.

Extrapolating this to the real world of buildings, one would expect that color coatings on Galvalume function mostly as aesthetic enhancement. Other than offering some physical protection to the metal beneath (from blowing sand, for example), they contribute little to corrosion resistance.

From a corrosion standpoint, this is good because inevitable scratches and nicks in the color coating would have no appreciable concentrating effect on the corrosion of the underlying metal, as they would if the color coating were a corrosion-protecting barrier.

Incidentally, the higher numbers shown in Figure 4 for the white color-coated panel leads us to suspect that the basis material may be ordinary galvanized steel rather than Galvalume.

## Conclusion

These tests predict that:

1. More corrosion~resistant screws, such as those made from stainless steel, may cause accelerated corrosion of the galvanized steel (or Galvalume) near the screw.

2. To minimize corrosion, that portion of the screw exposed to the weather should have a composition approaching that of the coating on the metal surrounding the screw. Thus, less corrosion-resistant fasteners (with lesser corrosion resistance than, for example, stainless steel) may contribute to longer overall roof or siding life.

3. For corrosion to take place, all elements of a corrosion couple have to be present;

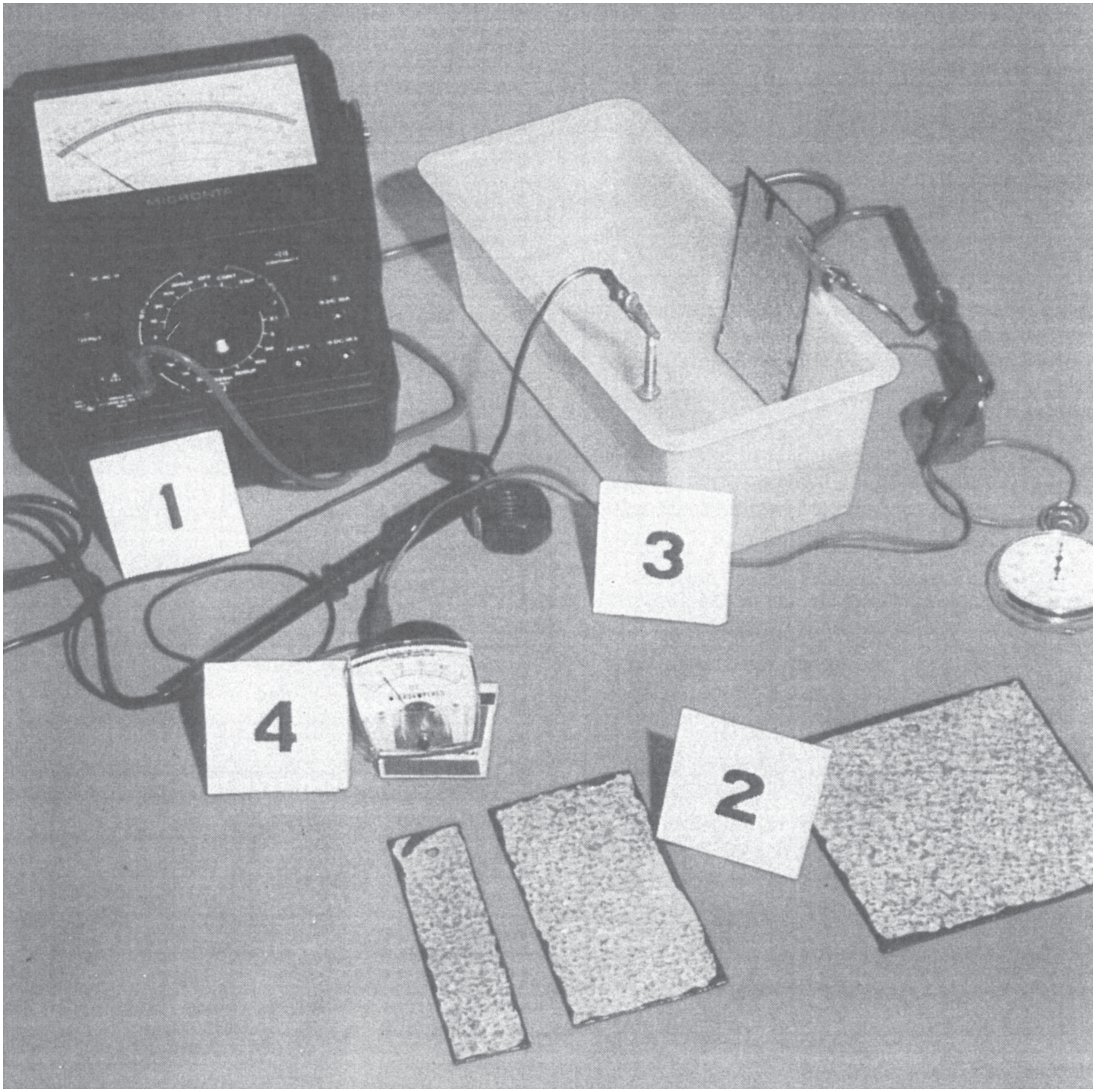
    a. a conductive liquid,

    b. contacting dissimilar metals,

    c. which are connected by a conductive path other than that provided by the liquid.

If any of these are absent, corrosion will not happen.

4. Many color coatings are applied for aesthetic purposes and contribute no appreciable added corrosion resistance. In these coatings, scratches which do not penetrate the galvanized coating on the steel beneath have no effect on the corrosion-resistance of the galvanized coating.




1. Voltmeter

2. Galvalume test coupons

3. Test cell showing screw with portion of head immersed
   and test coupon with bottom end immersed in
   conductive water

4. Microammeter (showing 10 microamp current flowing)

**Figure 2**
In corrosion couple with 2” x 4” Galvalume coupon

| In 0.01N sulfuric acid water | Voltage, open circuit | Current, microamps |
|---|---|---|
| UltiMate screw | .045 | 6 |
| 1022 steel screw, with zinc coating | .038 | 200 |
| 1022 steel screw, bare | .40 | 550 |
| 410 stainless screw | .38 | 580 |
| 304 stainless screw | .75 | 870 |
| Platinum spiral | 1.25 | 1100 |

| In 0.01N nitric acid water | Voltage, open circuit | Current, microamps |
|---|---|---|
| 1022 steel, bare | .03 | 2 |
| 1022 steel, with zinc coating | .016 | 8 |
| UltiMate | .09 | 13 |
| 410 stainless | .18 | 23 |
| 304 stainless | .17 | 22 |
| Platinum spiral | .72 | 150 |

| in 0.01N salt (sodium chloride) water | Voltage, open circuit | Current, microamps |
|---|---|---|
| UltiMate | .075 | 3 |
| 1022 steel, with zinc coating | .10 | 4.5 |
| 1022 steel, bare | .53 | 150 |
| 410 stainless | .55 | 80 |
| 304 stainless | .42 | 100 |
| Platinum spiral | .64 | 280 |

**Glyptal** is a trademark of General Electric Co.
**Galvalume** is a trademark of Bethlehem Steel Co.
**UltiMate** and **ColorMate** are trademarks of
Atlas Bolt & Screw Co.

**Figure 3**
For 304 stainless steel screw run in corrosion couple with 2” x 4” coupon

| In 0.01N nitric acid water | Voltage, open circuit | Current, microamps |
|---|---|---|
| Galvalume | .17 | 22 |
| Ordinary galvanized | .77 | 800 |

| In 0.01N sulfuric acid water | Voltage, open circuit | Current, microamps |
|---|---|---|
| Galvalume | .75 | 870 |
| Ordinary galvanized | .77 | 930 |

| In 0.01N sodium chloride water | Voltage, open circuit | Current, microamps |
|---|---|---|
| Galvalume | .42 | 100 |
| Ordinary galvanized | .56 | 115 |

**Figure 4**
For 304 stainless steel screw run in corrosion couple with 4” x 4” coupons

| In 0.01N sulfuric acid water | Voltage, open circuit | Current, microamps |
|---|---|---|
| Bare Galvalume | .37 | 180 |
| Bronze color coated* | .35 | 50 |
| White color coated** | .55 | 210 |

| in 0.01N nitric acid water | Voltage, open circuit | Current, microamps |
|---|---|---|
| Bare Galvalume | .29 | 60 |
| Bronze color coated* | .21 | 14 |
| White color coated** | .36 | 110 |

| in 0.01N sodium chloride water | Voltage, open circuit | Current, microamps |
|---|---|---|
| Bare Galvalume | .47 | 90 |
| Bronze color coated* | .41 | 65 |
| White color coated** | .46 | 97 |

* silicone polyester coating
** polyvinylfluoride-acrylic coating

ATLAS
Fasteners For Construction

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