DISTEK N.A. LLC ArmorGalv®

Environment-friendly Thermal Zinc Diffusion Galvanizing

ArmorGalv® - THE ONLY TRULY "GREEN", HIGH PERFORMANCE, CORROSION PROTECTION FOR STEEL.

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WINNER OF 2006 US EPA MVP^2 AWARD

ArmorGalv® Thermal Zinc Diffusion - Environment-friendly, cost effective corrosion protection - licensed by Distek N.A LLC

The **ArmorGalv®** technology is an environment-friendly process that offers superior corrosion protection and wear resistance as well as anti-galling properties. Following are some highlights of the **ArmorGalv®** technology which is, in fact, a modern, greatly improved, version of the well established Sherardizing zinc/iron diffusion process:

ArmorGalv® is not merely a sacrificial coating. By diffusing zinc atoms into steel, it creates layers of zinc/iron alloy on any steel part, including wrought and/or forged steel, castings, powdered metal (with no impregnation required!), and all grades of stainless steel, to create a surface that is:

- Highly Corrosion and abrasion resistant.
- Excellent anti-galling properties – **a replacement for Cadmium**.
- Controllable and precise - thicknesses from 0.0007" to 0.0060" (20-150 microns)
- Hard, non-magnetic, weldable and spark-free.
- Chip proof and can withstand crimping and bending.
- Highly heat resistant 1200^0F (650^oC) continuous service.
- Excellent base for paint, powder coating and rubber bonding
- Particularly interesting for powder metal parts, requiring no impregnation and providing not only extremely good corrosion protection, but also improved mechanical properties.
- Hydrogen and molten metal embrittlement free. Not subject to strain aging (unlike HDG). High tensile, heat treated parts can safely be coated and protected.
- Works extremely well in harsh marine environment.
- Totally heavy metal free non-toxic (RoHS and REACH compliant). Recipient of the EPA's **MVP²** award (Most Valuable Pollution Prevention technology).

The unique combination of properties offered by the **ArmorGalv®** technology, make it an excellent **replacement for cadmium, hex chromium and Hot Dip Galvanizing** as well as being very interesting for a multitude of Industrial applications, from construction in corrosive environments and components on Navy ships to mining applications, oil industry, automotive, power utility etc.

ArmorGalv® Thermal Diffusion Coating is covered by ASTM # A1059.

ArmorGalv® news

- **Major power utilities in the U.S now specify ArmorGalv® as a replacement to HDG and Stainless Steel. This is part of an industry wide transition to ArmorGalv®**
- **The U.S Navy is currently in the process of equipping its fleet of hovercraft (LCACs) with new Spencer Industries lashings made of grade 120 chain and coated with ArmorGalv®. The new lashings are more than 30% lighter than the legacy equipment and have proven to significantly reduce life cycle costs and improve safety and operator friendliness.**
- **U.S Army retrofits landing craft (LCUs) with ArmorGalv® protected anchor chains and bow chains.**

History and current market

Ever since the Industrial Revolution brought about the explosive growth in the use of steel in construction, infrastructure and transportation, **corrosion** has been the major drawback in its use.

Corrosion costs the U.S economy over $300Bn/Yr (about 3% of GDP) and a proportional amount in other developed economies. Many protective systems have been devised to mitigate the corrosion problem, but most of these "traditional" solutions have either been banned, or have come under increasing pressure from environmental regulations. Many of these corrosion control systems do not provide enough long-term protection, required for infrastructure and other applications. The most effective solutions, for such long-term performance, involve the alloying of zinc and steel.

Hot Dip Galvanizing (HDG) has been the preferred zinc based solution for long term corrosion protection for over 100 years. Zinc, and even more so, the alloy of zinc and iron, offer a combination of galvanic protection (providing protection even to damaged areas in the coating, unlike paints), good wear and abrasion resistance and overall good durability in various climatic environments, including coastal areas. Much has been written about the process of Galvanic protection and Hot Dip Galvanizing, so most technical people are well acquainted with the basics of the process.

In 1902 Sherard Cowper Cole in the U.K, invented the "Sherardizing" process. Sherardizing is a process that causes zinc atoms to diffuse into the steel and create a layer of zinc/iron alloy. Unlike HDG, Sherardizing is 100% intermetallic alloy and therefore has much better abrasion and wear resistance as well as better corrosion protection than HDG. Sherardizing has been in continuous use, mainly in the UK and Europe, since 1902. The reason it did not take off and grow as HDG did, is that it is a much more complicated process to apply and manage, is more labor intensive and involves some serious health issues that are a result of using silica-sand at elevated temperatures, which may cause Pneumosilicosis.

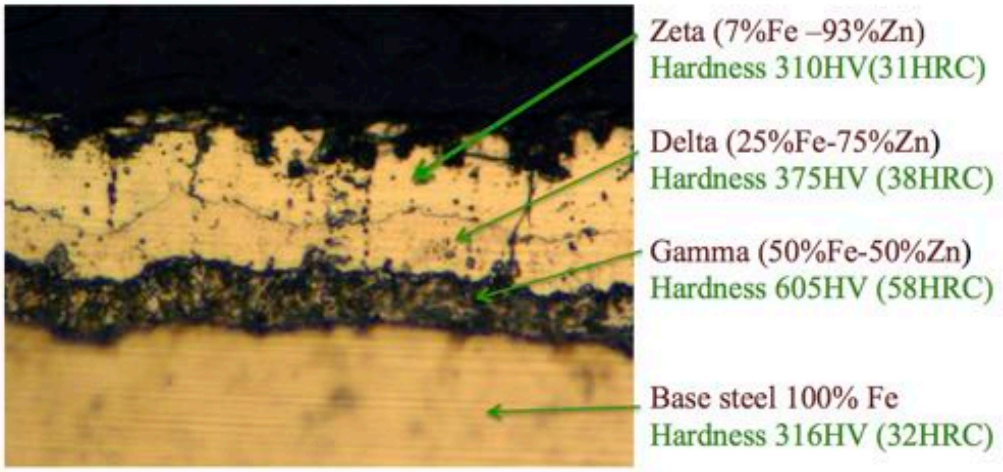
In 1993, after many years of research, Dr. Shtikan - an Israeli scientist and principal of Distek Ltd, developed the Distek Thermal Diffusion process which forms the basis for the **ArmorGalv®** technology**.** The **ArmorGalv®** process is based on a proprietary alloy of zinc, which sublimates at a relatively low temperature, far below the melting point of zinc, and causes the zinc vapor to react with the steel on the molecular level. This nano-scale reaction, creates layers of intermetallic zinc/iron alloy similar to that of Sherardizing but richer in iron content. Unlike Sherardizing, the **ArmorGalv®** process is completely environment-friendly, simple to apply and is cost effective. It is also much more user-friendly and controllable and offers superior performance to that of Sherardizing.

With ever tightening environmental regulations, many solutions for corrosion protection used in the past (such as Cadmium, Hexavalent Chrome, etc.) are no longer available. **ArmorGalv®** is now starting to take hold in many applications, with licensees around the world, serving many different industries.

We will now show why **ArmorGalv®** is the logical replacement for HDG and several other corrosion protection technologies:

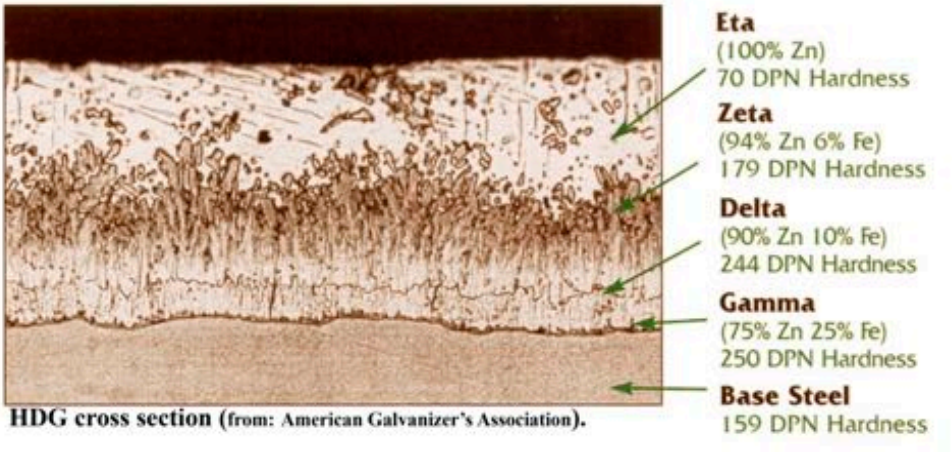
First and foremost, in terms of corrosion performance, **ArmorGalv®** has proven, in laboratory tests and real life testing, to offer corrosion protection that is, by order of magnitude, superior to HDG and other "high performance" corrosion protection coatings. In fact, in many applications **ArmorGalv®** is now used as a replacement for Stainless Steel.

Technical comparison of ArmorGalv® to HDG:



ArmorGalv® cross section

ArmorGalv® has a 100% intermetallic alloy structure, with a significant Gamma layer and a more iron rich structure than HDG. The **ArmorGalv®** layer is hard and abrasion resistant while the richer iron content also provides superior corrosion resistance.



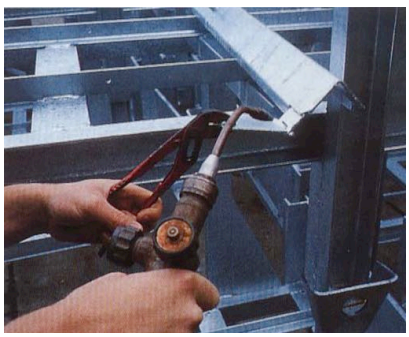
HDG cross section (from: American Galvanizer's Association).

HDG, most of the time, has a pure zinc layer that is more than half of the coating. The intermetallic alloy layers are much thinner (particularly the very thin Gamma, which is the hardest and most corrosion resistant) and poorer in Iron content.

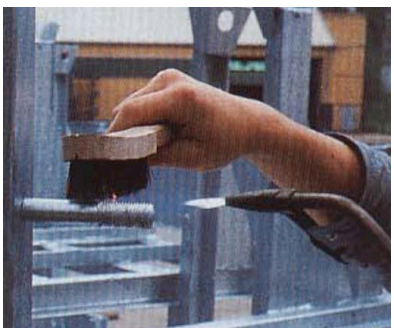
NOTE: DPN and HV hardness are identical, both are designations of the Vickers hardness test. From the above it is clear that **ArmorGalv®** is much harder than HDG and offers far superior abrasion and wear resistance.
There are some additional technical differences that should be pointed out:

Problems and issues with HDG that do not occur with ArmorGalv®

Zinc runs need to be removed and cleaned up, manually, after HDG.

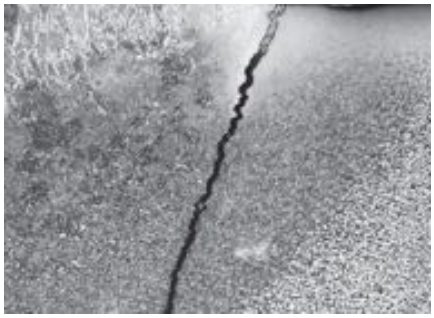


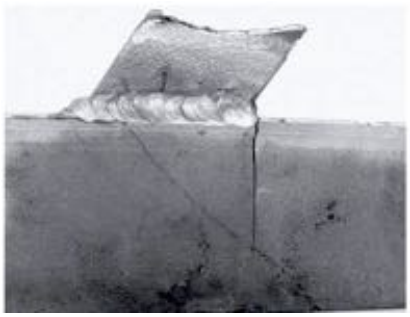
Moving parts and hinges need to be freed manually

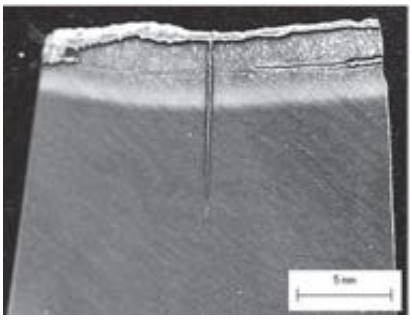


Threaded parts must be cleaned manually. Nuts are threaded after coating, so there is no protection on the inside thread.

Hydrogen and molten metal (liquid) embrittlement failures:



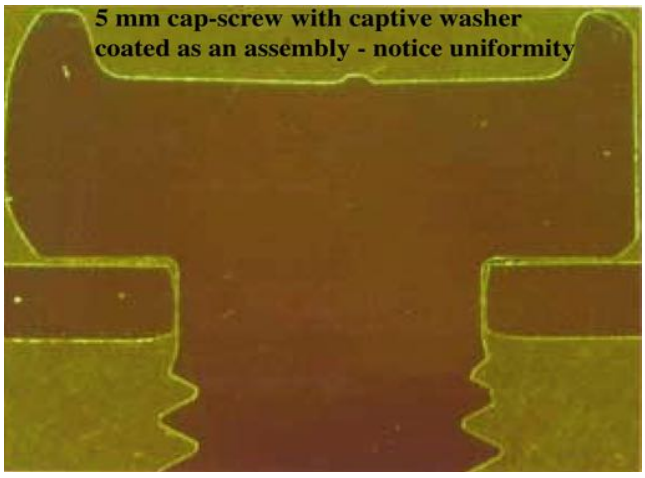


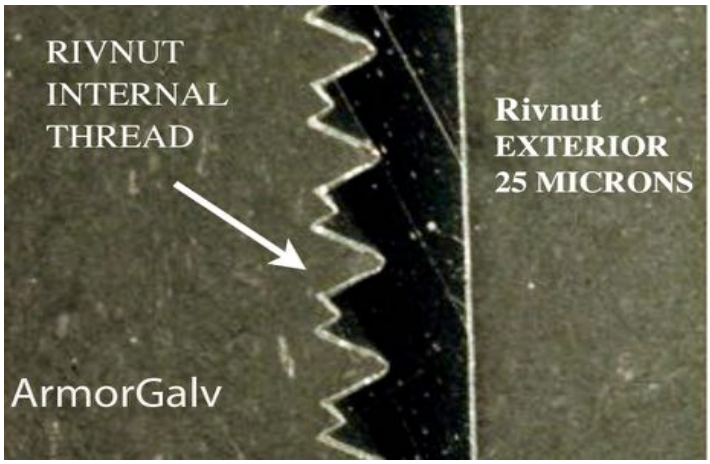


ArmorGalv® is entirely free from the above issues, and has the following additional advantages:

Precision and uniformity:

Unlike HDG, the **ArmorGalv®** technology creates an extremely uniform and controlled alloy layer. Due to the fact that we are dealing with zinc vapor (gas), which penetrates any open cavity in the part, **ArmorGalv®** is not sensitive to the geometry of the part and will coat internal surfaces of a part just like it does the external surface. This means, for instance, that unlike HDG nuts which get cut after galvanizing, leaving the inside thread unprotected, **ArmorGalv®** provides even and uniform protection to both the outside and inside threads.





As can be seen from the uniform coating even between the washer and body of the screw, **ArmorGalv® works well even on assemblies**.

Superior corrosion protection:

From "normal" salt spray tests, to cyclic automotive industry tests and real life testing by the U.S Navy, **ArmorGalv®** has shown superior corrosion protection that was better than HDG by order of magnitude and has also out-performed Stainless Steels in some tests.

Shown is a page from a side by side salt spray test, conducted for Kortick Mfg., showing **ArmorGalv®** out-performing both HDG and 316 Stainless Steel. Also, unlike HDG, **ArmorGalv®** exhibits excellent anti-galling protection.

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May 1, 2013

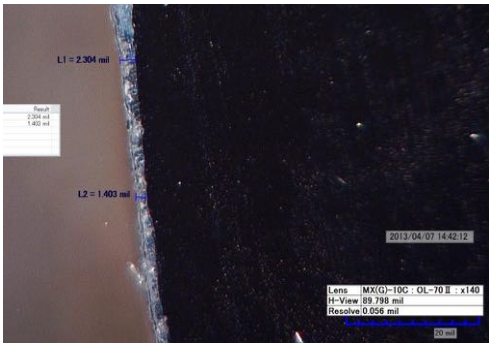
Evaluation of ArmorGalv® under Salt Fog Exposure and Partial Immersion in Saltwater

ArmorGalv® process showed limited visual signs of corrosion. (Figure 4.) There were a couple of rust colored spots that are most likely the result of surface contamination.

In addition to the visual observations, a specimen that was exposed to the salt fog environment

Figure 3 Traditional Hot Dipped galvanizing after 3000 hours in salt fog exposure

Figure 4 Armorgalv® process after 3000 hours in salt fog exposure



Unexposed specimen

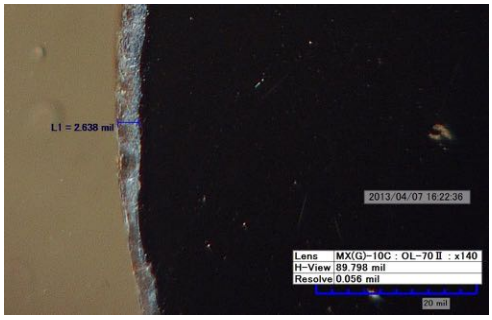


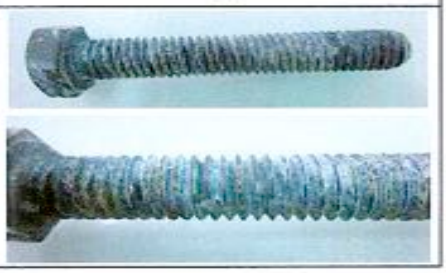
Figure 6 ArmorGalv® after 3000 hours in salt fog environment

Specimen after 3000Hrs salt spray

Part of a long-term corrosion test performed by the Florida Department Of Transportation, showing a side by side comparison of HDG and **ArmorGalv®**. While HDG coated rebar has completely failed after 3000Hrs (actually the failure started much earlier at around 600Hrs), the **ArmorGalv®** coated rebar showed no signs of corrosion at the end of the test. As can be seen from the cross section, after 3000hrs in the salt spray, the **ArmorGalv®** layer is still complete and intact.

Following above test, steel hardware on the San Pablo River Bridge in Jacksonville, FL. are protected with **ArmorGalv®**, as the first infrastructure project specifying **ArmorGalv®**.

SERCOVAM RES 103448 .

Durée : 63 cycles *Duration :*	Exposition préliminaire : Aucun *Preliminary exposition: None*	Référence : VIS TH *Reference :*	
Dégradations *Damages*	**Rappel des exigences client** *Reminder of the customer's requirements*	**Conformité aux exigences client** *Compliance with the customer's requirements*	**Photographies** *Photographs*
Corrosion blanche sur la tête de vis et le filetage. Points de corrosion rouge sur le filetage. *White corrosion on the head of screw and the thread. Spots of red corrosion on the thread. "False" rusting or "Staining" per ASTM 1059*	Pas d'exigence. *No requirement.*	Sur demande du constructeur, la déclaration de conformité au cahier des charges des pièces testées relève de la seule responsabilité de notre client et/ou de RENAULT *Upon manufacturer's request, the conformity statement according to the specification of the tested parts comes under the exclusive responsibility of the automotive equipment supplier and/or RENAULT.*	

Above is part of a test by a French government institute that is testing for the automotive industry. This is a tough cyclic test, where the maximum specification for automotive parts is 42 cycles. Above, is the test report for **ArmorGalv®** coated fasteners, that has been stopped after 63 cycles with no sign of corrosion (the "white corrosion" is actually the silicate sealer).

The inner pair of cargo lashings, manufactured by Spencer, were coated with **ArmorGalv®**. They exhibit no signs of rust after three years in the highly corrosive Gulf environment. The outer pair of legacy lashings, using standard materials and treatment, have significantly corroded over the same period.

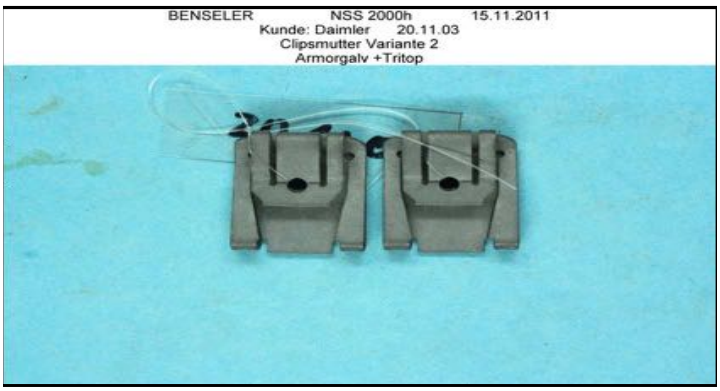
Photo courtesy of Thomas Whelan, Mechanical Engineer, ACV Branch, NSWC-PCD thomas.whelan@navy.mil

REAL LIFE TEST

After 3 years on the deck of an active U.S Navy hovercraft, HDG lashing is completely corroded while **ArmorGalv®** coated lashing, with grade 120 chain, shows no sign of wear or corrosion

No hydrogen or molten metal embrittlement and no strain aging

The **ArmorGalv®** process, by it's nature, does not allow the hydrogen embrittlement process to occur. It does not involve acids and parts are processed at temperature for extended time, forcing hydrogen out. The natural micro-porosity of the **ArmorGalv®** coating allows hydrogen to escape. This has been proven through 100 years of field experience (including Sherardizing, which has a similar metallurgical structure) as well as laboratory testing. The **ArmorGalv®** process also provides **stress relief and improves fatigue performance**.
This allows for the protection, with **ArmorGalv®**, of high tensile, heat treated parts, without the fear of failure. Parts such as springs, high-grade fasteners, high-grade chains etc. greatly benefit from corrosion protection that HDG and most other coating technologies cannot provide.



Spring clips and Automotive springs coated with **ArmorGalv®** after 2000Hrs salt spray

Grade 8 bolts for Automotive use (after 2040 hrs salt spray)

Springs on a vibratory mining screen coated with **ArmorGalv®** for corrosion protection and fatigue performance.

Economics and the environment

HDG is not very scalable, due to the need for water treatment facilities and air filtration systems. This makes HDG plants un-economic for small-scale production.

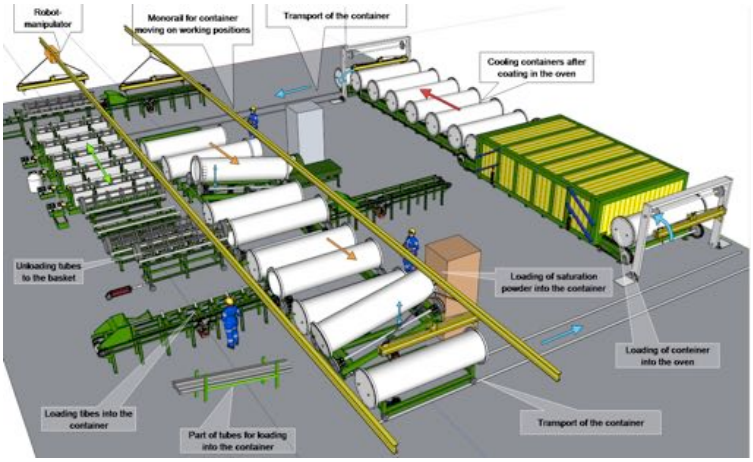
HDG coating facilities use toxic and dangerous materials such as Hydrochloric acid and Zinc Ammonium Chloride (flux), which is a toxic material that is sent to a toxic dump when spent. These features make it difficult to locate HDG facilities in many areas due to environmental considerations and if a license is granted, it involves the complexities and high costs of compliance with EPA regulations.

The ArmorGalv® process is completely "green" and can be located anywhere, without any environmental issues. In fact, it has received the prestigious **EPA mvp^2 award** (Most Valuable Pollution Prevention) as a "close to zero emission facility", following a one-year testing and evaluation process by the EPA.

ArmorGalv® processing facilities are completely scalable and are economically viable from a small facility requiring just 100m^2 (1100Ft^2), to process around 20 tons/month of product, to massive plants processing 12m long (40ft) structural elements weighing several tons each.

Small scale **ArmorGalv®** system – fits into a 100m^2 (1100ft^2) facility.

Large **ArmorGalv®** system, coating Structural elements up to 12m (40ft) long.

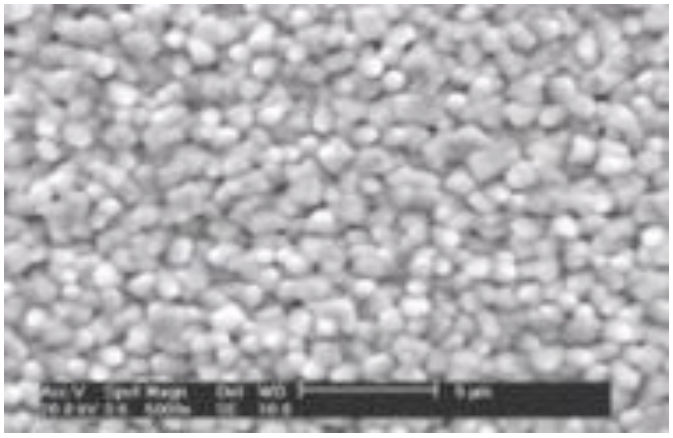


The **ArmorGalv®** process lends itself to highly automated facilities, as illustrated in the picture on the left, designed for automated processing of 3m (10ft) long tubes of various diameters. The tubes are evenly coated inside and out.

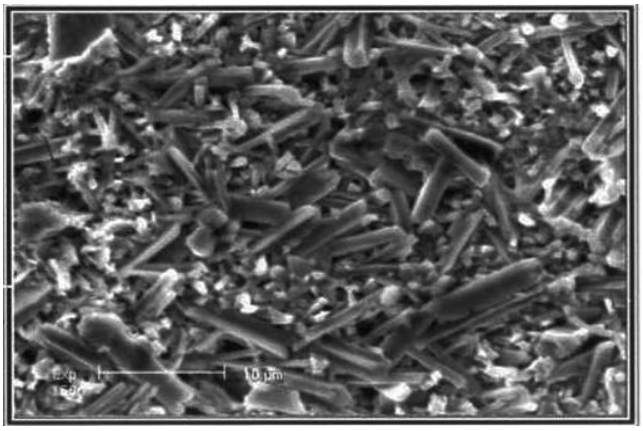
Energy consumption: The **ArmorGalv®** process uses **less than half** the energy per Kg of product coated, compared to HDG.

Paintability - It is a well known fact that HDG coated parts as well as zinc plated parts are difficult to paint and require special surface preparation such as mechanical or chemical etching to create a surface "profile" to get some minimal adhesion of paint to the surface. This is due to the fact that the HDG crystals create a "sealed" surface that does not hold paint or any other over-coating material.

As illustrated in the following pictures, it can be seen that the **ArmorGalv®** surface (the Zeta layer) is dendritic in structure and acts as a "micro sponge", absorbing any paint, rubber or over-coating and providing extremely good adhesion values.



HDG surface showing a "sealed" structure



ArmorGalv® surface is sponge like

Since paint is absorbed deep into the **ArmorGalv®** surface, it survives being drilled into concrete and then removed. Other than grinding it off, it is almost impossible to remove the paint from an **ArmorGalv®** coated and painted part.

ArmorGalv® can be formed and bent after coating without loss of coating and corrosion performance

Delnorth Steel-Flex® roadside guide post

One of the most extreme examples of the **ArmorGalv®** ability to withstand extreme deformation without loss of coating, or even paint adhesion, is the **Steel-Flex®** spring steel roadside guide-posts developed by Delnorth International (Australia) and coated by the **ArmorGalv®** licensee ArmorGalv Aust. Pty Ltd. The post is made of a specialty spring steel and coated with **ArmorGalv®**. It is then powder coated. Testing the product entails 1500 cycles of a truck driving over the post, without it losing its flexibility, corrosion resistance and the paint.

Some real life applications, projects and case studies

Marine applications

Barge towing chain in the North Sea Oil fields is coated with **ArmorGalv®** to protect this very critical equipment from corrosion as well as wear.

U.S Navy fleet of hovercraft (LCAC) is equipped with **ArmorGalv®** coated lashings with **G120 chains**, offering greatly improved corrosion and Wear-resistance as well as 30% weight reduction

Railway fasteners across Europe and Australia are protected with **ArmorGalv®**. The railway clips are made of spring steel. **ArmorGalv®** protects them against corrosion and prevents them from seizing.

Automotive applications

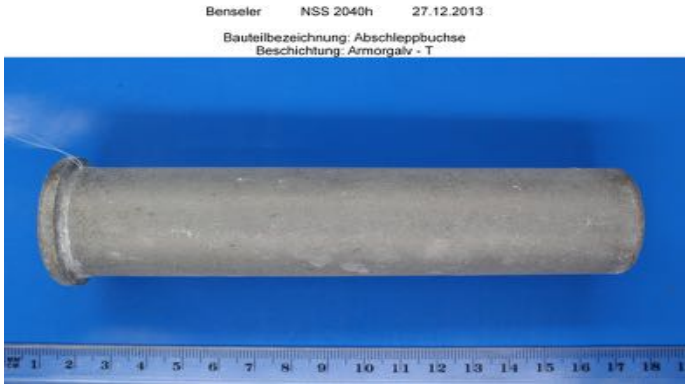
ArmorGalv® is now being specified by leading Automotive companies,

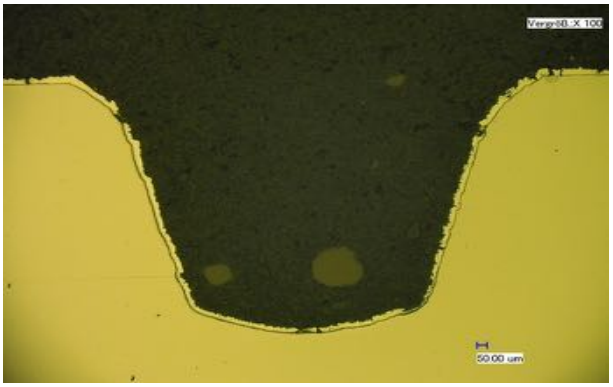
Car door hinge

Spring body clip

Automotive trunk locking mechanism

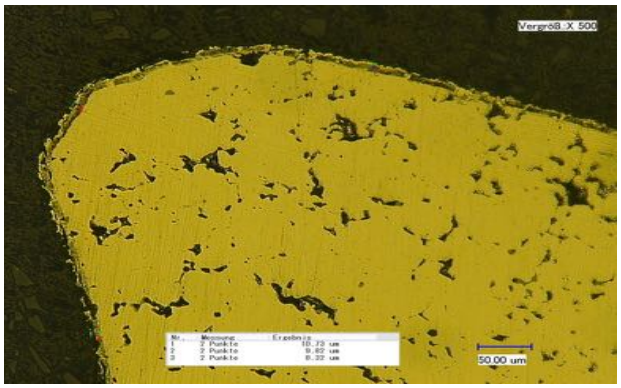
The following part is a tow bushing, which **gets welded** to the lower body frame of the car and is used to tow the car in emergency situations. After welding to the car chassis it gets e-coated together with the Chassis. **ArmorGalv®** is the only coating solution that can both be welded and can provide coating protection to the inside thread of the tow bushing to last the life of the car.





Cross section through the center of the thread

Cross section through the end of the thread



Cross section through a tooth

Sintered steel ratchet wheels (2040 Hrs salt spray)

Above parts are made from sintered steel, the most cost effective way to manufacture parts with complex geometries. **ArmorGalv®** is ideal for this application, eliminating the need for polymer impregnation and improving mechanical properties, paintability and corrosion protection.

Construction applications

From bridges in coastal areas to modular steel buildings, **ArmorGalv®** provides steel structures with decades of maintenance free endurance, even in the most adverse conditions. The implications for greatly reduced maintenance costs for infrastructure are significant.

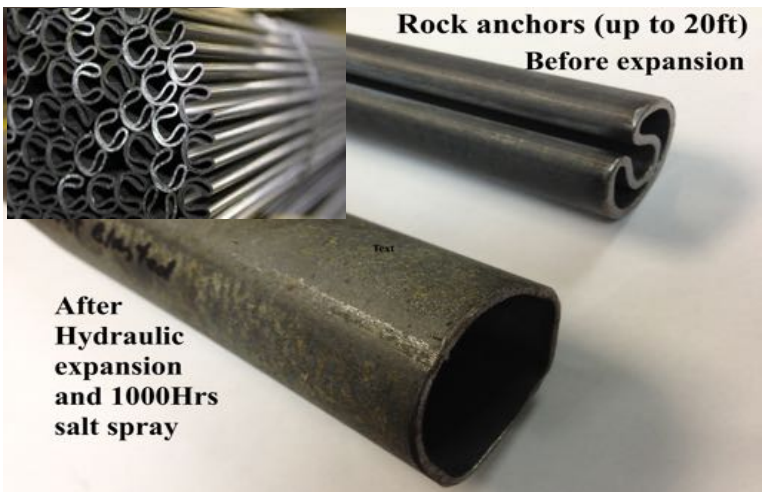
Dynamic Seawall Maintenance Systems provides a good example of using **ArmorGalv®** to protect steel in extreme marine environment, also involving high wear and abrasion resistance. After being drilled into the ground, the seawall anchor provides long term protection for the seawall from seawater and wave action. **ArmorGalv®** coated carbon steel has **replaced stainless** steel in this application.

The shaft with the helix is drilled into the ground. The bolt holding the support plate gets threaded into the end of the tube to hold the concrete seawall plate. All parts are coated with **ArmorGalv®**

Heavy construction, mining and agricultural equipment and hardware

From heavy earth moving equipment to various agricultural equipment, **ArmorGalv®** provides the ideal combination of corrosion protection as well as wear and abrasion resistance to some of the toughest environments that any machinery is exposed to.

In the extremely abrasive and corrosive environment of coal mining, equipment designers have taken advantage of the excellent abrasion and wear resistance of the **ArmorGalv®** technology, as well as the long term corrosion resistance. This is particularly true in critical applications, such as heavy equipment and the longwall hinge pins that must guarantee no seizing of the hinges due to corrosion and wear to prevent the chance of roof collapse.



The rock anchor is one of the products that take advantage of the fact that **ArmorGalv®** coated steel can be formed after coating, without losing its corrosion protection.
The rock anchor is an extreme example of this. Having gone through severe deformation, it is expected to provide long-term corrosion protection in the corrosive environment of a mine.

Collated nails and fasteners for construction

ArmorGalv® coated nails and screws provide superior corrosion protection for construction, particularly in coastal zones and hurricane zones, where extremely long corrosion resistance is essential for wood structures. Pressure treated wood, with the corrosive chemicals used to treat the wood, presents a special challenge for fasteners, which **ArmorGalv®** resolves. **ArmorGalv®** coated screws also work well with sheet metal applications due to the ability of **ArmorGalv®** to retain its full protection even after self tapping into sheet metal.

Military applications

U.S Army landing craft with **ArmorGalv®** protected anchor chain and bow chains.

ArmorGalv® provides military equipment the high performance combination of corrosion and wear resistance that helps make the equipment more reliable. It also significantly reduces maintenance and life-cycle costs.

Power utilities applications

From production to transmission and distribution, **ArmorGalv®** is currently providing long lasting, maintenance free, hardware to the power utility industry and is specified by the main utilities in the USA.

Solar panel mounting hardware and fasteners are protected with **ArmorGalv®** for long-term maintenance free performance in exposed areas.

High voltage switch. All steel parts are protected by ArmorGalv® , replacing Stainless Steel

Power utility companies are specifying **ArmorGalv®**

Conclusion

ArmorGalv® is the **"green"** answer to the high performance corrosion protection required across the economy, in most industries. **ArmorGalv®** is the future of corrosion protection solutions, in a world that is increasingly sensitive to protecting the environment and, at the same time, is in great need of a technology that will help reduce maintenance and life-cycle costs of infrastructure and equipment.

ArmorGalv® is supplied by:

Distek N.A LLC and its licensees .

Please see:
ArmorGalv Aust. Pty Ltd.
www.Armorgalv.com.au