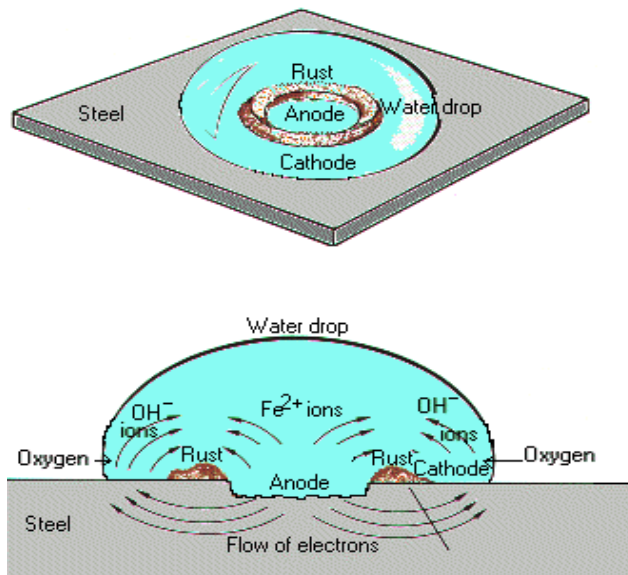




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Eight Forms of Corrosion

The fundamental corrosion of an iron or ferrous metal is an electrochemical process. Corrosion is the product from a reaction that is created from an electrochemical process that is consisted of three basic elements. The basis of most corrosion that occurs on metal substrates occurs when water from rain or ambient humidity that has converted to an **electrolyte compound** (a water molecule containing mobile ions causing it to be more electrically conductive), comes in contact with a metal or typically an **iron or ferrous metal** in an **oxygen** atmosphere. This combination forms the electrochemical process that equates to the formation of general corrosion metal compounds.



The absence of any one of these elements in the reaction will retard corrosion from occurring to any significant extent.

In 1978, Mars Fontana and Norbert Greene coauthored a book entitled, *Corrosion Engineering*, which became a highly regarded book on the subject of corrosion. It is one of the comprehensive manuals on the subject of corrosion and its etymology still in use today.

The *Corrosion Engineering* handbook further classifies corrosion into 8 forms and provided an unambiguous delineation of each form of corrosion. These definitions are guidelines used by structural engineers, metallurgist and polymer formulators to develop effective anticorrosion coatings from base metals to high performance alloys.

Based on Fontana and Green's analysis, corrosion of any metal substrate can be classified by the behavior in which it manifests its existence. Each form can be identified and classified by mere visual observation of its resulting behavior. But under closer analysis, a methodology of the reaction can clearly be established based on the type of failure, the degree of failure and the logical reason why corrosion occurred and surmised the Eight Forms Of Corrosion.



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The Eight Forms Of Corrosion Are:

- Uniform, or general attack
- Galvanic, or two-metal corrosion
- Crevice corrosion
- Pitting
- Intergranular corrosion
- Selective leaching, or parting
- Erosion corrosion
- Stress corrosion

The listing is arbitrary and covers all known quantifiable forms of corrosion presence and its root cause. The forms listed above are not arranged in any particular order of importance but all are progressively interrelated.

The process of engineering an anticorrosion program begins by clearly classifying and validating the type of corrosion that is likely to occur and then formulate a suitable solution that will provide a formidable first line of defense.

The primary design of an effective anticorrosion coating regardless of its form is to exclude or isolate the substrate from oxygen. This is accomplished by creating hermetic coating that will envelope the metal structure from the presence of oxygen.

An effective anticorrosion coating will consist of:

1. A durable polymer resin that exhibits impermeability to oxygen or any liquid, resistance against mechanical stress and durability against the assaults of the environment.
2. A functional anticorrosion pigment dispersed in the polymer that will inhibit any electrochemical reaction that can occur if a liquid with an anionic (negative ion) or cathodic (positive ion) charged particle comes in contact with the metal substrate.
3. Supporting chemical additives that aid the coating against the assault from the environment such as ultraviolet exposure, thermal oxidation, physical damage from ambient temperature fluctuations and resistance to degradation from both acidic and alkaline compounds that comes in contact with the metal under normal use.

The synergy of these elements produces an effective anticorrosion coating that demonstrates a strong aptitude to contradict the formation of corrosion.

These Are The Basis For Engineering and Formulation Of
STRYK 5388 FACS
Against the 8 forms of Corrosion



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Uniform Attack Corrosion

Uniform attack is the most common form of corrosion. It is normally characterized by a chemical or electrochemical reaction, which proceeds uniformly over the entire exposed surface or over a large area. The metal becomes thinner and eventually fails. For example, a piece of steel or zinc immersed in dilute sulfuric acid will normally dissolve at a uniform rate over its entire surface.

These steel poles were coated with an epoxy-based anticorrosion primer and a protective topcoat. Epoxy binders are excellent polymer resins but lack resistance from the damaging effects of ultraviolet exposure. Upon extended outdoor exposure, it becomes brittle and loses its ability to expand and contract with the substrate's coefficient of thermal expansion and contraction. Subsequently, its film continuity cracks and fails from maintaining a hermetic seal against elements from the ambient weather. Corrosion propagates and shows the same degree of rusting over its entire outside surface.



Uniform attack, or general overall corrosion, represents the greatest destruction of metal on a tonnage basis. This form of corrosion, however, is not of too great concern from a structural standpoint. Upon initial detection, it is more evident as an aesthetical failure rather than a structural concern. But left untreated, the corrosion will progress exponentially and cause catastrophic structural failure.



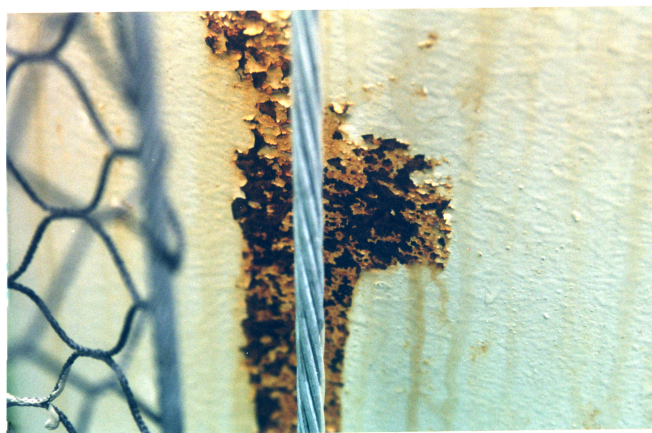
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Galvanic or Two-Metal Corrosion

If two metals of different composition are in contact, the inherent difference in its composition creates an electron flow between the two metals. The ions in the metal with lower noble metal is increased and attack of the more resistant material is decreased, as compared with the behavior of these metals when they are not in contact. The less resistant metal becomes anodic and the more resistant metal cathodic. Usually the, the cathode or cathodic metal corrodes very little and the less noble metal, which corrodes quite profusely.

Note the 'two-metal corrosion' on the weld joints. The steel pole is of a different alloy than the metal composite used to weld the two pieces. The same galvanic corrosion has occurred on the center and right photograph where an inspection plate of a different alloy than the steel pole was welded; note the localized corrosion area as well.



Filler metal (electrode material) improperly chosen for the environmental conditions the weld joints will be exposed to can make them corrosion-sensitive as well.



Galvanic corrosion will occur if the electrode composition is sufficiently dissimilar to the materials welded, or the materials are dissimilar themselves. Even between different grades of nickel-based stainless steels, corrosion of welded joints can be severe despite that they rarely undergo galvanic corrosion when mechanically joined.



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Crevice Corrosion

Intense localized corrosion frequently occurs within crevices and other shielded areas on metal surfaces exposed to corrosive compounds. This type of attack is usually associated with small volumes of stagnant solution caused by holes, gasket surfaces, lap joints, surface deposits, and crevices under bolt and rivet heads. As a result, this form of corrosion is called crevice corrosion or, sometimes, deposit or gasket corrosion.

Note the density of the corrosion on the bottom lap joint of this salt-water condenser tank. The shoulder protrusion acts as a reservoir where salt water and other corrosive compounds collect and promote the localized corrosion.



This corrosion failure is concentrated due to the close proximity of the metal substrate to the ground where cyclic irrigation of the grass and with the use of the chemical fertilizer that promotes extreme acidity and alkalinity within the immediate environment of the metal pole.





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Corrosion from Pitting

Pitting is typically concentrated or localized corrosion that results in holes in the metal as well in the protective coating. These holes may vary in size or diameter, but in most cases they are relatively small but concentrated. Pits are sometimes isolated or so close together that they look like a rough surface. Generally a pit may be described as a cavity or hole with the surface diameter about the same as or less than the depth.

Pitting is one of the most destructive and insidious forms of corrosion. It is often difficult to detect pits during the application of the protective coating due to it is almost invisible by the naked eye.



Surface pitting starts out as microscopic air bubbles on the surface of the coating and is caused by the poor de-aeration or release of the air bubbles from the coating. During cure of the coating, the entrapped air bubbles concentrate on the surface of the coating creating a colony of weak spots in the film continuity.



The sub-micron thin skin of the bubble called a "lamella" is all that is protecting the base metal substrate from the ambient atmosphere, upon exposure to ambient conditions the lamella deteriorates rapidly due to the weakened strength of thin walls in comparison to overall thickness of the applied coating. Once the lamella is breached, these voids present an avenue for moisture to come in direct contact with the base metal, which will immediately create corrosion. The corrosion propagates from beneath the coating and any adjacent air bubbles entrapped within the coating will result in a domino-effect failure.

Pitting in most anticorrosion coatings is greatly influenced by the method of application, ambient conditions and coating formulation itself. The thickness of the lamella will dictate when the pits will be visible as the initiation of the corrosion. Pitting is particularly vicious because it is a localized and intense form of corrosion, and failures often occur with extreme suddenness.



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Intergranular Corrosion

Intergranular corrosion refers to preferential corrosion along grain boundaries of the microscopic grains or "crystals" that constitute the microstructure of the metal. The attack is related to the separation of specific elements or the formation of a compound along its boundaries. Corrosion then occurs by preferential attack on the grain-boundary or in the zone adjacent to it that has lost an element necessary for corrosion resistance. This sector is then becomes anodic relative to the remainder of the surface. The attack usually progresses along a narrow path along the grain boundary and can cause severe grain-boundary corrosion. Entire grains may be dislodged due to complete deterioration of their boundaries. In any case the mechanical properties of the structure will be seriously affected. Under certain conditions, the boundary interface is very reactive causing rapid progression of the intergranular corrosion.

Once corrosion propagates, the alloy disintegrates and loses its inherent strength and the crystal structure collapses.

Another cause of the corrosion is the impurities in the metal itself. During the alloying process of the metal, the enriching element may be incorporated in the wrong proportion. This imbalance will induce the grain-boundary areas.

An iron alloy with an imbalance proportion of iron in aluminum, have been shown to segregate in the grain boundaries and cause intergranular corrosion.

Steel Alloy



Stainless Steel



It has been shown in some grades of stainless steel metals and other corrosion resistant metals can corrode readily based on surface tension of the alloying element, brass for example shows that the zinc content is higher at the grain boundaries thus creating an imbalanced alloy that is susceptible to intergranular corrosion.

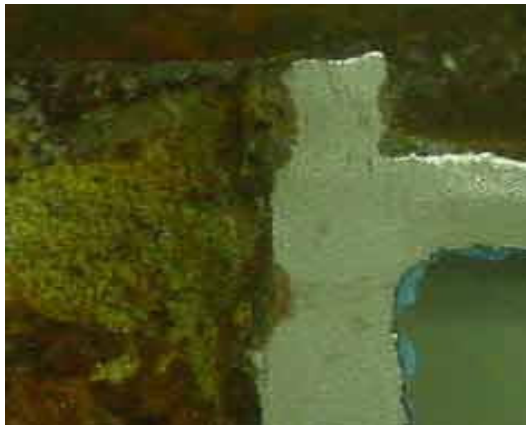


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Selective Leaching corrosion

Selective leaching is the removal of one element from a solid alloy by corrosion processes. The most common example is the selective removal of zinc in brass alloys (dezincification). Similar processes occur in other alloy systems in which aluminum; iron, cobalt, chromium and other elements are leached away. Sometimes identified, as “dealloying” its kinetics is that of selective leaching. Its use precludes the creation of terms such as dealuminumification, decobaltification, dezincification, etc.

Failure of brass or bronze compounds is very common example of selective leaching failure. Copper dezincification examples are shown below. In both cases, failure initiated as a result of dezincification followed by fatigue crack propagation through the copper substrate.



Although Intergranular Corrosion and Selective Leaching Corrosion are more relative to the composition of base metal and its respective fabrication, the anticorrosion coating is still an integral part against corrosion. It should be durable enough to maintain proper surface wet-out and adhesion to the varying surface tensions of base metal and alloying metals.

Improper wet-out and poor uniformity of adhesion of the anticorrosion coating will yield corrosion failure similar to overall corrosion,



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Erosion Corrosion

Erosion corrosion is the increase in rate of deterioration due to the physical wear or continuous abrasion caused by the relative movement of an electrolytic fluid or corrosive water onto the metal surface. Once the coating has failed and the base metal is exposed, the corrosion exponentially increases. Corroded metal is removed from the surface as dissolved ions, which are mechanically swept from the metal surface.



Erosion corrosion is characterized in appearance by grooves, gullies, waves, rounded holes, and valleys and usually exhibits a directional pattern. In many cases, failures because of erosion corrosion occur in a relatively short time, and they are unexpected largely because evaluation corrosion tests were run under static conditions or because the erosion effects were not considered.





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Stress-corrosion cracking of the anti corrosion coating

Stress-corrosion cracking of the protective coating refers to cracking or fissuring of coating due to cyclic tensile stress that is applied unto the concentration are or its fulcrum. During stress-corrosion cracking, the coated metal is virtually unattacked by cyclic elongation and compression forces and it is failure will occur at the structures point of fulcrum.

This cracking phenomenon has serious consequences since it can cause instantaneous failure of the structure the concentrated and defined corrosion upon the point of fulcrum.

This steel 80-foot pole erected vertically demonstrates the structural damage caused by stress cracking of the anticorrosion coating. Once the coating fails a visible concentration of corrosion can be noticed on the areas of structural fulcrum. The structural load is applied as the pole undulates from the force imposed by wind energy wind and physical ground movement. This cyclic tensile and compression load creates micro fissures at its point of fulcrum that rapidly progresses to gross structural failure.





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Performance Characteristics Of

STRYK 5388 FACS

**Flexible Anti-Corrosion System
Against The Eight Forms Of Corrosion**

Product Description

STRYK 5388 FACS is a novel anticorrosion coating system that is specially engineered for protecting ferrous or iron substrates that are prone to corrosion. It is a single component or “one step” anticorrosion system that can be directly applied onto the based substrate without the need of zinc or chromate rich primers.

STRYK 5388 FACS is dispersed in an AQMD exempt solvent (SCAQMD Rule 102, Group II Solvents and Rule 1113, Architectural Coatings For Metals) providing compliant protection from corrosion and other extreme environmental conditions.

STRYK 5388 FACS is a “One Step System” that can be directly applied unto the metal substrate demonstrating fast dry times that imparts excellent opacity and substrate wet-out on steel and other alloyed metal substrates. Upon cure it provides resistance to the damaging effects of UV radiation and air pollutants from direct outdoor exposure. Its resistant to cracking or film fissuring caused by dimensional instability of the substrate caused by thermal expansion and contraction as well as mechanical movement, such as bending or flexing.

STRYK 5388 FACS exhibits a high degree of impermeability to water and resistance to acidic and caustic compounds that accelerate coating failure. Comparative anticorrosion coatings such as polyurethanes, alkyds and epoxies deteriorate upon similar chemical exposure, thermal cycling, which is the origin of most corrosion proliferation.

STRYK 5388 FACS will adhere to most ferrous metals with proper surface preparation in accordance to NACE 2/ SSPC-SP-10 guidelines.

The STRYK 5388 FACS low surface tension (30 to 32 dynes/cm) and immiscibility with water makes it an excellent direct to metal coating. It will displace any ambient humidity or water molecule off the surface to be coated. This reduces the occurrence of air bubble entrapment that can cause localized and accelerated corrosion such as pitting or “flash rusting”.

During cure, the applied coating coalesces to a continuous film with excellent color opacity even at coating thickness of 0.004 inch or 4 mils. Upon cure the applied coating develops a low surface energy characteristic that is resistant to water wettability, permeation and it will not support fungal growth or bacterial colonization.



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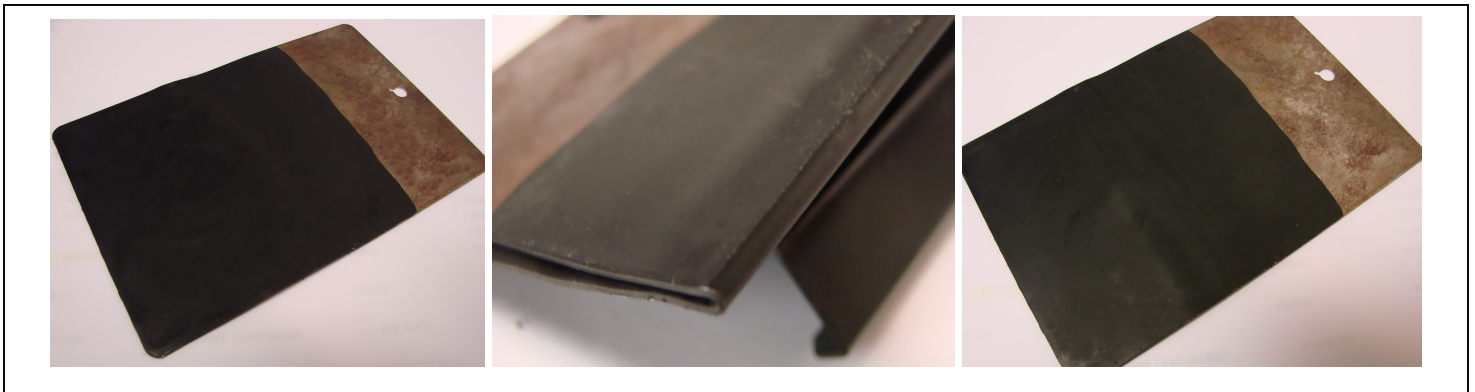
Functional Engineering Of the STRYK 5388 FACS Resin Binder

In applications where the dimensional stability of the metal substrate is highly influenced by the temperature fluctuations or deformation from load application, the main binder resin that constitutes the integral coating network must overcome and endure these strain factors.

Polymers such as epoxy, acrylics, alkyds and some polyurethane binders demonstrate poor endurance to these factors due to their rigidity and poor film resiliency. Upon repeated flexing and expansion and contraction of metal substrate, the polymer binder will cause internal stress and may fail to rebound to its original state without sustaining damage to the film integrity or its hermetic barrier.

STRYK 5388 FACS is formulated from a proprietary polymer base resin that is resilient and can withstand cyclic movement of the base metal substrate even at temperatures below freezing. It can also endure repeated elongation and compression caused by temperature variations without fissuring, fracturing or embrittlement STRYK 5388 FACS binder resin is engineered to rebound to its original matrix without loss of its functional hermetic seal against oxygen or corrosive compounds,

NOTE THE ABSENCE OF ANY COATING BREACH AFTER THE TEST PANEL WAS FOLDED 180 DEGREES AND THEN RE-FLATTENED



<p>STRYK 5388 FACS APPLIED ON COLD ROLLED METAL Q-PANEL 10 MILS DRIED FILM THICKNESS OR DFT</p>	<p>STRYK 5388 FACS APPLIED ON Q-PANEL 10 MILS DFT FOLDED 180 DEGREES</p>	<p>STRYK 5388 FACS RE-FLATTENED TO ITS ORIGINAL DIMENSION</p>
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NOVEL ANTICORROSION PIGMENT

The second line of defense of an anticorrosion coating is the specialty pigments incorporated into the coating formulation. Its function in an anticorrosion coating is as essential as the oxygen-free environment that the resin binder creates.

STRYK 5388 FACS utilizes several none-heavy metal anti corrosion pigments in lieu of environmentally and health hazardous zinc and toxic chromate compounds.

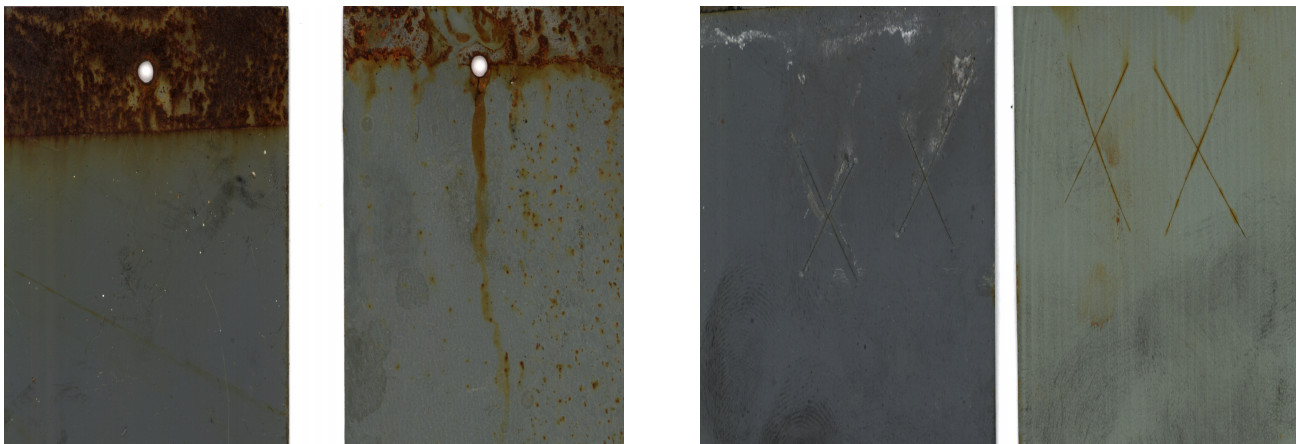
It utilizes 3 methods of anticorrosion kinetics that yields an exceptional synergistic efficacy.

The key anticorrosion pigment induces an ion exchange reaction with the metallic substrate thus neutralizing the electrochemical process of corrosion reaction. Next is the sub-micron and homogenous distribution of an acicular shaped mineral pigment that provides anticorrosion performance and polymer reinforcement. Lastly, the use of an organic pigment that provides high UV opacity lowering the binder resin's susceptibility to free radical degradation. This efficient combination provides the synergistic relationship between the anti-corrosion pigments and the binder resin composition.

Figure 1 illustrates the performance of STRYK 5388 FACS over zinc rich anti-corrosion systems.

Figure 2 demonstrates the synergy of the anticorrosion pigments. The STRYK 5388 FACS coated panel remained corrosion free even when the coating was breached.

FIGURE 1
STRYK 5388FACS Zinc Rich Epoxy Coating **FIGURE 2**
STRYK 5388 FACS Zinc Rich Epoxy Coating



Cold rolled steel panels were coated to 5 mils dry film thickness and subjected to 500 hours of cyclic salt spray exposure. The zinc rich coating showed signs of corrosion after 70 hours and the test water run off tested positive for zinc compounds.



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SURFACE PREPARATION

Coating performance is, in general proportional to the degree of surface preparation. To optimize the unique anti-corrosion quality of this system, it is highly recommended that the applied come in contact with bare metal. The surface profile and porosity of the substrate will greatly affect the dried film thickness that must be applied.

Prepare ferrous metal that results in a surface condition equal to or supersedes the requirements of NACE 2/ SSPC-SP-10

Prepare galvanized substrates use SSPC-SP 8, Pickling

Prepare pre-coated substrates use SSPC-SP 5/NACE No. 1, White Metal Blast Cleaning

All other commercially clean substrates

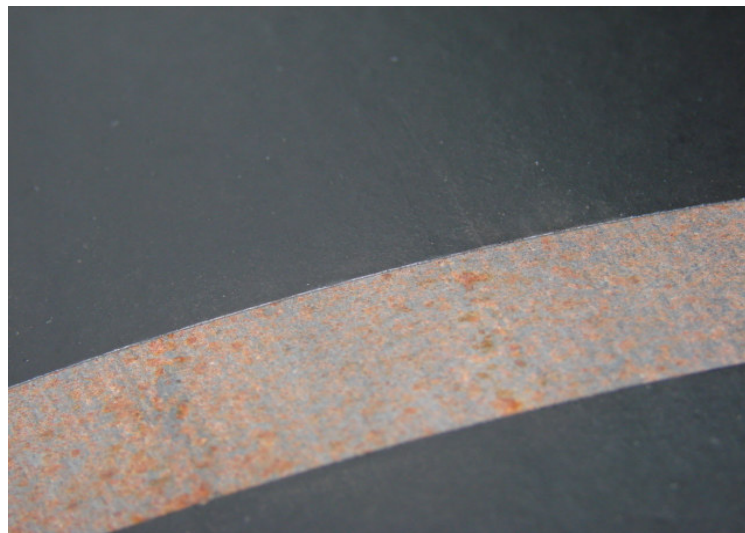
Remove loose rust and any old coating, if possible, by abrasive blasting, wire brushing, or by chemical stripping treatment. Surface oils, grease and other contaminants should be cleaned with an industrial detergent and water.

Application

STRYK 5388 FACS is formulated with strict compliancy to EPA and Air Quality Management District mandates as one of its main governing guideline. It is a fast drying system specially developed for roller or brush applied application where the application or transfer efficiency is greater than 95%.

A single coat (roller applied, ¼ inch nap hair 2 inch diameter) will yield approximately 3 to 5 mils dry film thickness per application. To achieve an optimum 10 mils (0.010 inch) dry film thickness, 2 to 3 coats is required. Apply the first coat and let it dry-to-the-touch (5 to 10 minutes at 75 °F), apply subsequent coats to yield a minimum of 7 mils DFT. Full cure will be achieved in 36 hours.

3 coats (10 mils applied on steel pole)



This application technique will yield 180 to 220 square feet per gallon coverage. Always wear OSHA approved vapor mask and adequate ventilation when applying this product.



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Physical Properties

Form	Black Liquid (Or Custom Color)
Viscosity- ASTM D1084	13,000 +/- 500 at 25°C
Solids Content, Heat And Vacuum Evaporation Process	40.0% Minimum
Density ASTM D1475	11 pounds per gallon
Flash Point ASTM D1310	Greater than 200°C
Solvent- ASTM D3960-05	Chlorinated Aliphatic Solvent Exempted Under SQAMD Rule 102 Clean Air Act, Group 2.
DOT Shipping	Perchloroethylene
DOT Hazard Class	ORM-A
DOT UN Number	UN 1897
SARA/Title III: 311/312 sec.313	Not an extreme hazardous material in section 302
Other information:	Contains California Prop. 65 designated chemicals.

Mechanical Properties

Tensile Strength– ASTM D882	900 PSI
100% modulus – ASTM D882	320 PSI
Hardness – ASTM D2440	50 Shore A
Elongation at break – ASTM D882	140%
Electrical Properties - ASTM D257	
Volume Resistance	10 ¹⁵ Ohms-cm
Dielectric strength	780 Volts/mil

Outdoor Weatherability *ASTM D1006

QUV	>4000 hours
100% Ozone Chamber	>1000 hours
Cold Flex, 180° bend over a 1 inch diameter mandrel at -100°C	No Cracking fissuring or delaminating



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Chemical Resistance (ASTM D1308)

Reagent	2 Weeks Immersion % Weight Gain	% Change in Tensile Strength
Tap Water	0.4	<10 %
Sea Water	0.5	<10 %
Acetic acid (5% Solution)	1.3	<10 %
Sulfuric Acid (5% Solution)	0.2	None
Phosphoric Acid (60% Solution)	0.0	None
Boric Acid (3% Solution)	0.0	None
Oxalic Acid (3% Solution)	0.9	None
Nitric Acid (15% Solution)	4.5	>20
Lactic Acid (4% Solution)	1.7	<10
Sodium Chloride (2% Solution)	0.5	None
Sodium Carbonate (3% Solution)	0.7	None
Potassium Hydroxide (5%)	0.1	None
Ammonium Hydroxide (3%)	0.9	<5 %
Ammonium Nitrate (50%)	0.0	None

PROPER STORAGE

STRYK 5388 FACS should be stored in a cool dry place. Do not store above 30°C (86°F) for prolonged period. Do not allow open containers to stand for prolonged periods. Replace the lid or cover tightly to prevent evaporation of the carrier solvent. An increase of viscosity and poor ease of application will occur due to loss of solvent. For thinning or clean up, use perchloroethylene or VMP Naphtha. (Caution: VMP Naphtha is a flammable solvent, refer to the manufacturers MSDS for proper handling. Perchloroethylene is a non-flammable solvent. STRYK 5388 FACS has a shelf life of one year from the date of shipment.

IMPORTANT NOTICE

The information contained herein is based on data believed to be accurate at the time of publication. Data and parameters cited have been obtained by using materials under controlled conditions. Data of this type should not be used for specification for fabrication and design. It is the user's responsibility to determine this product fitness for use.

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The user's exclusive remedy and the manufacturer's liability are limited to refund of the purchase price or replacement of the product within the established warranty period.

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