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CORROSION PROTECION ON HVAC/R UNITS

by

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What is Corrosion ?

- The chemical or electrochemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties.

- To begin to understand corrosion, and the role that water plays, we have to understand a little about how metals are constructed at the atomic level.

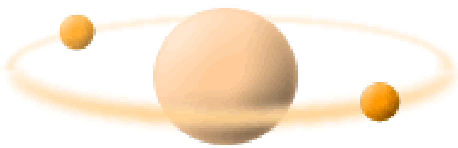
- Remember that rusting is a type of corrosion that only refers to iron. Copper or aluminum do not rust, they corrode. All metals can corrode, only iron can rust.

Corrosion Basics - Atoms

- Atoms are the microscopic building blocks that make up all substances.
- Each atom has a nucleus in the center, and electrons that spin around it.
- The nucleus has a positive charge (protons), and electrons have a negative charge, but the atom itself has no charge because the positives and negatives cancel each other out.
  - An atom with a nucleus which has a charge of "5 positive" will have 5 electrons spinning around it ("5 +" and "5 -" means that the atom has a zero charge). This is called **charge neutral**, and all atoms like to be charge neutral

Corrosion Basics - Atoms

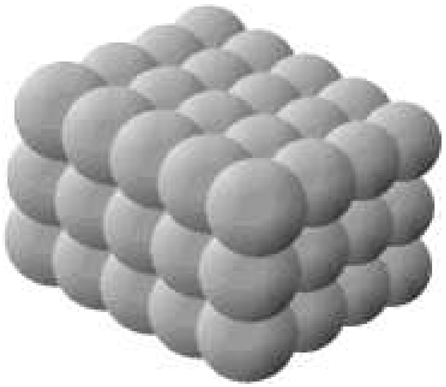
- Different substances are made of different types of atoms (Gold is made of gold atoms, Carbon Dioxide is made of carbon atoms and oxygen atoms joined together).
- It is only the central nucleus of atoms (protons) that is different. All electrons are the same.
  - A carbon atom and a gold atom will each have a different nucleus, and although gold has **more** electrons than carbon, all their electrons are identical
  - There is a difference between a gold nucleus and a carbon nucleus, but not between a gold electron and a carbon electron.



An atom

Corrosion Basics - Metals

- Metals, like all substances, are made of atoms.
- Metal atoms are arranged in a very regular pattern, like a grid. However, metals are special in the way that they are bonded.
- Most atoms cling onto their electrons tightly, but metal atoms don't - allowing some of them to float around.

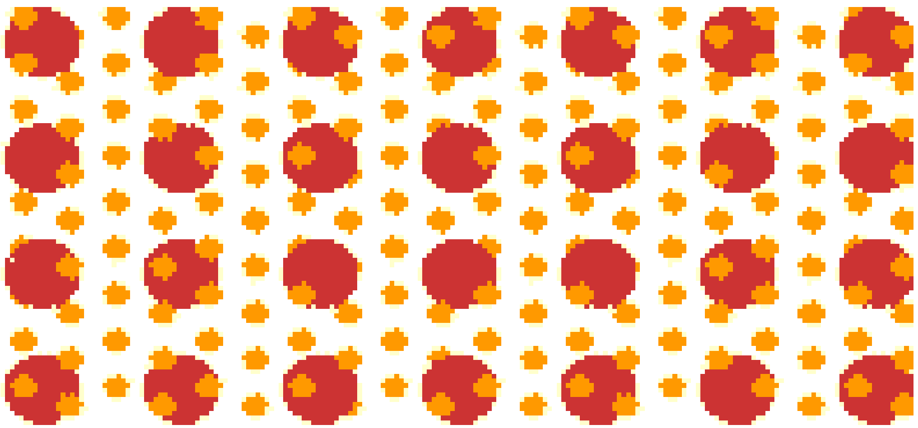


Corrosion Basics - Metals

- Because all electrons are the same, metals do not care if they lose one, as long as it is replaced by another
  - Remember that all atoms like to be charge neutral, and electrons cancel out the positive charge of the nucleus. If a metal lost electrons and they were not replaced, it would build up a positive charge.
- This means that electrons in a metal are free to flow anywhere: as long as the metal has the same number of electrons, it doesn't mind if they move around from atom to atom.

Corrosion Basics - Metals

- These free electrons give metals a special ability - they can **conduct electricity**. When an electric current travels along a piece of metal, such as a copper wire, the current is actually a stream of electrons flowing along the wire.



Corrosion Basics - Metals

- We know that a current flowing through metal (therefore electrons flowing through metal) has a direct effect on corrosion.

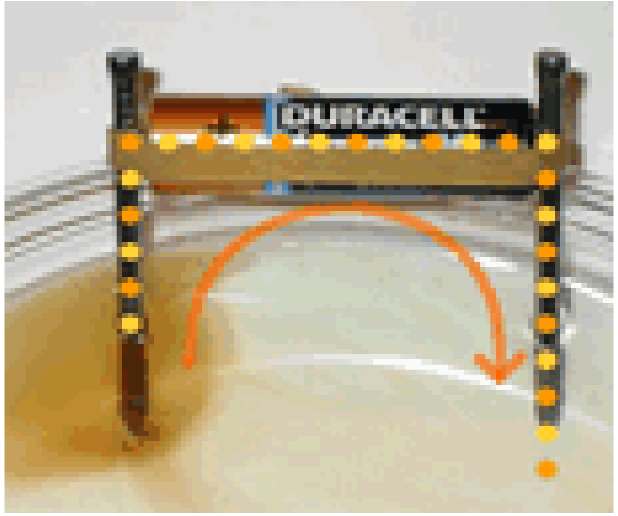
- At the negative side of the current (the place that electrons are flowing to) there was no corrosion. But at the positive side of the current (the place that the electrons are flowing from) there is corrosion.

- Electrons flow through the metal away from areas where corrosion is happening. They travel to other areas where corrosion does not happen.

Corrosion Basics - Electrons

- If electrons are flowing through the battery to the un-corroded nail on the right, there will be a lot of extra electrons in the un-corroded nail.
  - As we discussed, atoms like to have the correct number of electrons; not more; not less.
- The nail on the right must get rid of electrons in order to stay neutral

  - **where do these electrons go ?**

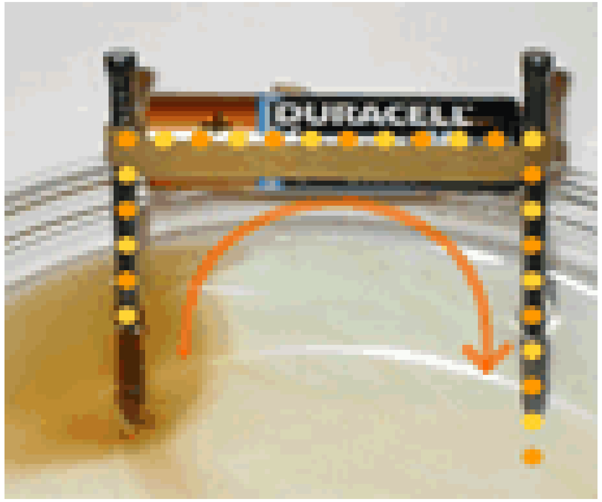


Corrosion Basics - Electrons

- All of the electrons flowing to the nail on the right come from the corroding nail on the left. Atoms in the nail on the left must be losing their electrons (becoming positively charged in the process).
- The nail on the left must either get new electrons from somewhere, or throw off these positive atoms that have lost their electrons in order to stay neutral.

Corrosion Basics - Electrons

- The nail is throwing off iron atoms into the water.
- As each iron atom is ejected, it leaves behind its electrons which can flow over to the right hand nail. The brown color that you see is iron oxide (rust), so there must be a reaction taking place in the water around the corroding nail between the ejected iron atoms and oxygen.

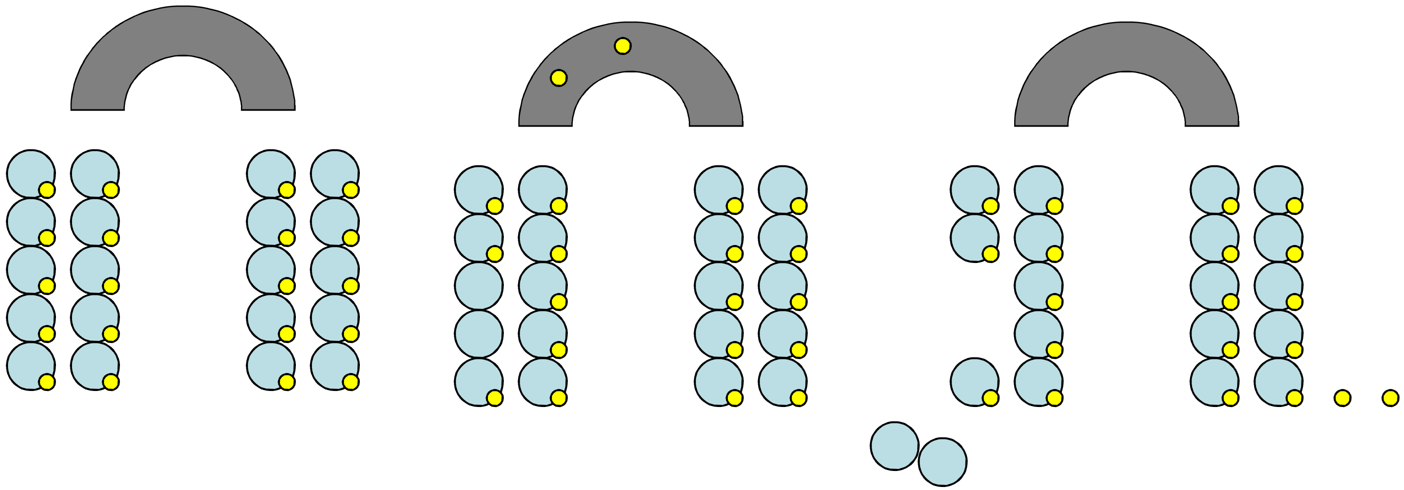


Corrosion Basics - Electrons

- In order to produce a continuous stream of electrons, the nail ejects more and more iron atoms into the water. This explains one half of the reaction - where the electrons come from. **But where do they go at the other end ?**
- Look at the animation on the left. Two iron atoms leave the nail, and float off, leaving their electrons behind (*to make the diagram simple, we show the atoms each leaving 1 electron behind. Actually they leave 2 electrons behind*).

Corrosion Basics - Electrons

- Two iron atoms leave the nail, and float off, leaving their electrons behind
- These electrons flow through the battery **as an electrical current** to the other nail, where they too **must** be passed into the water.
- The nail throwing iron atoms into the water is actually getting smaller by losing atoms - it is "rusting away", the nail throwing electrons into the water loses no iron atoms, so does not corrode at all.



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Corrosion Basics - Electrons

- So what happens at the non-corroding nail?
- Nothing is really visible there, but we know that there must be a reaction that uses up the extra electrons producing something negatively charged.
  - The reaction at the non corroding nail is between oxygen, water, and the extra electrons.
- In chemistry, the positive area that frees electrons is called the **anode**. The negative area that receives electrons is called the **cathode**. So in this example, the corroding nail is the anode, and the non-corroding nail is the cathode.

Corrosion Basics - Water

- We now know that the water needs to create the circuit in order for corrosion to happen.
- But water does not conduct electricity very well. If we increase the conductivity of water (allow it to carry current more easily) the corrosion reaction will speed up.
  - When we add salt (Salt is Sodium Chloride - Formula: NaCl) to water, it dissolves.
  - When NaCl dissolves, it splits apart into its two components; becoming Na+ and Cl- ions. These ions float around freely in the water, and can carry electrons from one area to another. This increases the ability of water to conduct electricity, and thus speeds up the corrosion process.

Corrosion Basics - Aluminum

- Aluminum does not corrode in water alone.
- The oxide that forms when aluminum atoms oxidize does not fall off like the rust on iron, but clings tightly to the surface of the aluminum.
  – Very quickly, a hard layer of aluminum oxide covers the metal, and protects the aluminum metal beneath. No more aluminum can oxidize, as it has been sealed off from the oxygen and water needed to make the reaction happen.

Corrosion Basics - Aluminum

- When salt is added to the water, the powerful Cl- ions attack the aluminum oxide coating, tearing it from the surface and exposing new aluminum metal.
- As soon as this aluminum metal corrodes into aluminum oxide, it too is stripped from the surface by the Cl- ions.
- The natural protection that aluminum gets from its oxide coating is lost.
  - This is the reason that aluminum cars and equipment will often corrode badly if they are used in or near the sea.

Corrosion Basics - Copper

- Copper metal also corrodes in this way, but forms a bright green coating of oxide (copper sulfate), which protects the copper from further corrosion.
  - This is why the Statue of Liberty in New York is still looking as good as the day it was erected in 1886. Had it been made out of Iron it would have rusted away by now.

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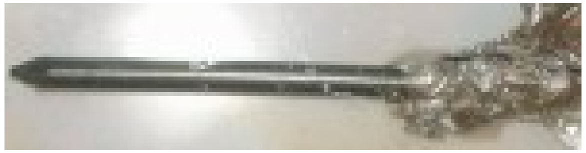
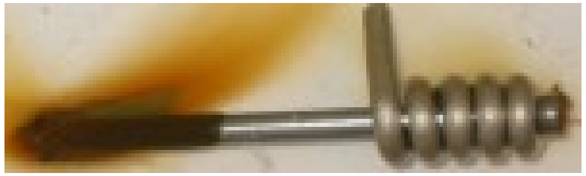
Corrosion Basics – Galvanic

- When two different metals are joined together in water, the same metals behave differently.
  - When the iron nail is attached to aluminum it does not rust at all, but when it is attached to copper it rusts very badly. But the nails are identical. Why does this happen?



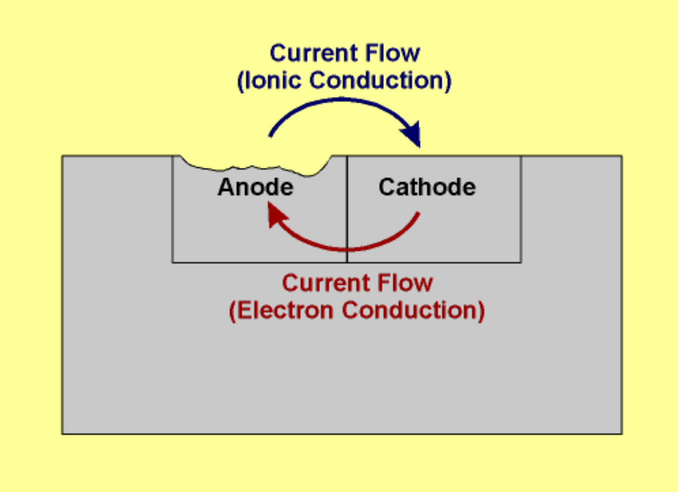


Corrosion Basics - Galvanic

- So we can confidently predict that if aluminum and copper were joined together in the solution, the aluminum would corrode, and the copper would be protected.

Corrosion Basics - Conclusion

- For corrosion to occur, the following must be present:
  - An anode.
  - A cathode.
  - A conducting environment for ionic movement (electrolyte).
  - An electrical connection between the anode and cathode for the flow of electron current.



Corrosion Basics – Prevention

- If any of the previous components is missing or disabled, the electrochemical corrosion process will be stopped. Clearly, these elements are thus fundamentally important for corrosion control.
- Prevention Options:

1. ***Cathodic Protection:*** Sacrificial protection of the underlying substrate, a galvanic effect (for example, steel protection by zinc).
2. ***Barrier:*** limiting the access of chemical species involved in the corrosion reaction, notably oxygen in the cathodic reaction.
3. ***Barrier:*** maintaining a high electrical resistance at the substrate interface, restricting the access of ionic species

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Generic Coil Coatings

- For the past 25 years various Coil Coatings have been used on HVAC units to prevent corrosion.
- These traditional Coil Coatings serve as thick barriers in an attempt to block salt ions that accelerate the corrosion process of aluminum and copper.

Generic Coil Coatings

- Within the past 8 years a clear, cross link cured siloxane coating, which is installed in ultra-thin, micron film thicknesses was introduced into the market.

- How does this new and patented technology differ from the more traditional paints and coatings previously available and how can the HVAC/R design engineer, as well as the owner and operator of the asset, make the most informed decision concerning the preservation of the HVAC asset by means of a protective coating?

Coil Coating Technologies

1. CROSS LINK CURED
2. COALESCING CURED
3. SOLVENT EVAPORATION CURED
4. OXIDATION OR CONVERSION CURED
5. CATALYZED CURED

Cross-Link Cured

- EPOXY
  - Polyamide
  - Polyester
  - Amine Adduct
  - Acrylic
  - Coal Tar
- URETHANE
  - Acrylic Aliphatic
  - Polyester Aliphatic
  - Moisture Cured

Cross-Link Cured Epoxy

- Most Common Applications:
  - Industrial maintenance facilities
  - Tanks, floors or equipment.
- Properties:
  - High gloss or semi-gloss films
  - Excellent chemical, abrasion and water resistance
  - Excellent Adhesion to ferrous metals
  - Moderate to Good Adhesion to non-ferrous metals
  - Very poor UV Resistance
    - Will Chalk and turn Yellow
  - Extremely hard and tight, when first cured
  - Moderate to Good heat resistance

Cross-Link Cured

- These are composed of multiple component materials that must be mixed before use.
  - Like Chemical Velcro – Hooks and Loops (molecule) type film forming.

- The typical full curing of these films will occur in about 7 to 10 days at ambient temperatures between 70^0 and 80^0 F. (Faster at higher temperatures; slower at lower temperatures)

- They are typically low temperature sensitive and will generally not cure at temperatures much below 50^0 F.

Coalescing Cured Polymers

- LATEX
  - Acrylic
  - Vinyl
  - Polyvinyl Acetate
  - Acrylic / Vinyl blends
  - Other blended Polymers

Coalescing Cured Polymers

- Most Common Applications:

  - Architectural Finishes
  - Light Commercial or Industrial

- Properties:
  - High gloss to matte flat finish
  - Moderate chemical, abrasion and water resistant
  - Poor adhesion to non-ferrous metals
  - Good UV Resistance
  - Poor heat resistance

Coalescing Cured Polymers

- The coalescing curing mechanism, simply stated, is a “melting” process of the polymer molecules into each other in order to create a continuous film.
- These coatings can be formulated with many co-solvents, which help promote the coalescing cure film formation, as well as solvents that help with freeze/thaw stability, pigment acceptance and flow and leveling properties.
- These coatings are generally water thinned.

Coalescing Cured Polymers

- Latex polymers will dry to touch in about 30 minutes, but take about 8 to 10 days to reach full cure;
- This group will typically not cure at temperatures below 45^0 F.
- Co-solvents take several days to evacuate out of a freshly installed film; long after the coating has dried to touch.
- Most polymers exhibit poor wet adhesion properties.

Solvent Evaporation Cured

- Generally not associated with HVAC/R protection.
  - Chlorinated Rubber
  - Solution Acrylics
  - Shellac
  - Many Lacquer Products

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Solvent Evaporation Cured

- Most Common Applications:
  - Architectural to Light Industrial.

- Properties:
  - High gloss to low sheen finishes
  - Average Chemical Resistance
  - Poor Adhesion over non-ferrous metals
  - Limited to Good UV Resistance
  - The formed films are typically very brittle.
  - They are always solvent sensitive.
    - Even if these films have cured for years, reintroducing many solvents onto the film can cause the coating to become resoluble, reverting back to a liquid state.

Solvent Evaporation Cured

- This broad group of coatings cures by solvent evacuation. Simply stated, when the carrying solvents in the coating evaporate out of the film, they are fully cured.
- The carrying solvents are generally low flash point, fast evaporating solvents such as xylene, toluene, MEK, MIBK, naphtha derivatives, glycol ethers, alcohol, etc;
- Many times the carrying solvents can be blends of the above listed solvents, or others not listed. These are typically very fast curing products, because once the solvent is gone, they are cured.

Solvent Evaporation Cured

- These coatings cure fairly rapidly, once the solvent evaporates, the film is cured.
- They can cure at temperatures down to 35^0 F

Oxidation or Conversion Cured

- Linseed Oil Based Paints
- Soya Alkyd Based Paints
- Alkyd / Urethane Blends
- Phenolics
- Epoxy Esters
- Silicone Alkyds
- Acrylic / Alkyd Blends

Oxidation or Conversion Cured

- Most Common Applications:
  - Architectural to Light Industrial

- Properties:
  - High gloss to matte flat
  - Moderate to Good Chemical Resistance
  - Good adhesion on ferrous metals
  - Poor adhesion on non-ferrous metals
  - Poor to Good UV Resistance
  - Abysmal Mold & Mildew Resistance
  - The formed films become brittle with age

Oxidation or Conversion Cured

- This is a very broad group of oil-based products.
  - The oils can be extractions from soybeans, flax, fish or petroleum bi-products.
- The extracted oils are then processed & reacted with acid rosins to produce any number of desired molecule chains, which exhibit different properties.
- When formulated into a finished product, these oil chains are further reacted by the introduction of oxygen and any number of other metallic salt driers or catalysts in order to dry and cure the film.

Oxidation or Conversion Cured

- These coatings will reach 95% of full cure in about 14 days and then will continue to harden until they eventually just crack and crumble apart.

- They truly never stop curing. The older the film becomes, the more brittle it becomes.

Catalyzed Siloxane Coating

- Inorganic Siloxane

Catalyzed Siloxane Coating

- Most Common Applications
  - HVAC/R Aluminum and/or Copper Coils
  - Non-Ferrous Metals & Stainless Steel
  - Concrete, Concrete Pavers, Decorative Stone
  - Hard Tile & Grout or Terrazzo
- Properties:
  - Gloss finish
  - Excellent Chemical & Water Resistance
  - Excellent Adhesion to Non-ferrous Metals
  - Excellent Mold & Mildew Resistance
  - Excellent UV Resistance
  - Excellent Anti-Graffiti Resistance

Catalyzed Siloxane Coating

- These are inorganic film formers that adhere by both London Force and Covalent Bond methods to bare non-ferrous metal surfaces.
- The dry film formation is between 5 to 8 microns, which is sufficient to provide an effective barrier against corrosion causing ions, but will not act as an insulator.
- In contrast to more porous paints, the cross-link cured siloxane film reduces resistance of both air and liquid laminar flow.
- The ultra-thin deposit enables the film to have negligible impact on heat transfer efficiencies.

Catalyzed Siloxane Coating

- Curing time for water resistance is 2 to 4 hours at ambient temperatures between 70^0 F and 90^0 F.

- The fully cured film exhibits a slight positive charge, which is very hydrophobic and oliophobic, thereby providing the surface a natural repelling action.

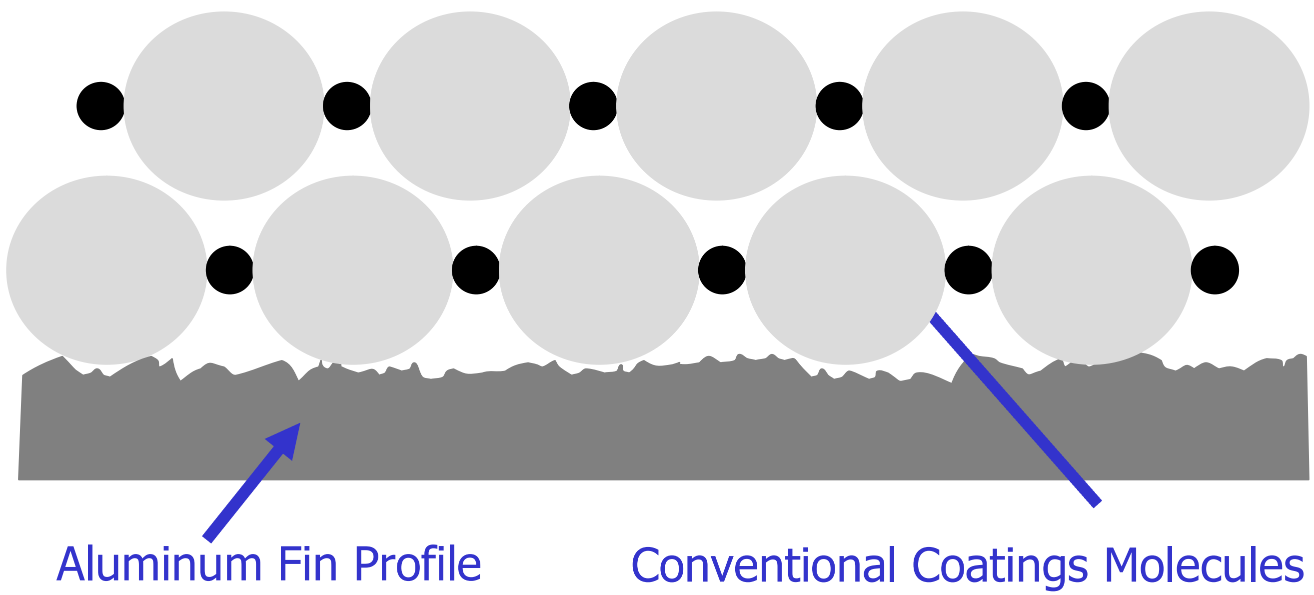
- The inorganic characteristic of the cured siloxane film provides no food source for mold and mildew.

Adhesion

- Gaining & Maintaining Adhesion Depends On:
  - Surface Profile
    - Surface needs to have an acceptable profile (anchor pattern) for film molecule size to grab onto and maintain bond.
  - Substrate Preparation
    - Substrate must be free from dirt, grease, salts and contaminants.

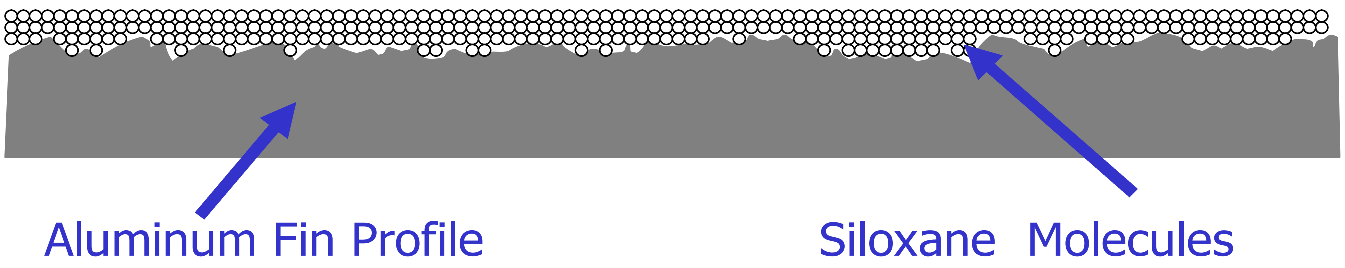
Adhesion

Surface Profile – Conventional Coatings



Adhesion

Surface Profile - Siloxane



Energy Consumption

- Energy Consumption is based on:
  - Airflow through coil
  - Coating heat transfer capabilities
  - Coating thickness acting;

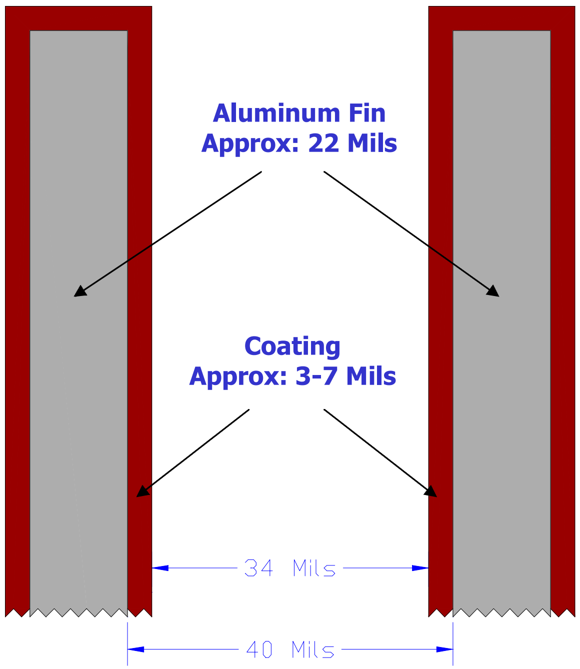
    As an insulator

    As an air flow disruptor

Energy Consumption

Conventional Coatings

- Airflow passage is reduced by approximately 15-35% (higher when more FPI).
  - Pressure drop across the coil increases.
  - Hydrodynamic drag increases.
  - Higher fan power consumption.
  - Reduced air flow through the coil increases refrigerant pressure.
  - Heat Transfer is reduced.



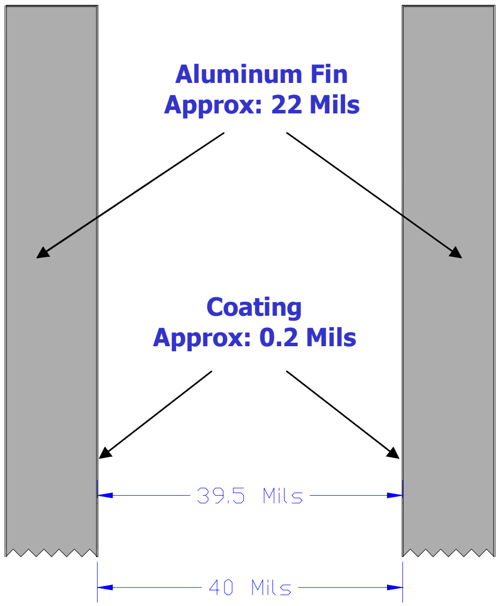
Coil on illustration is 16 FPI

Energy Consumption

Siloxane Coating

- Airflow passage is not reduced.
  - Pressure drop across the coil decreases.
  - Aerodynamic drag is reduced by 25%.
  - Lower fan power consumption.
  - Heat Transfer is enhanced.

Coil on illustration is 16FPI



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Comparative Table

		Cross Link Epoxies	Coalescing Polymers	Solvent Evaporation	Oxidation Phenolic	Siloxane Reacted
Dry Film Thickness	Microns	35 - 50	25 - 40	25 - 50	30 - 50	3 - 5
Heat Transfer	Insulator	Poor	Poor	Poor	Poor	Good
Adhesion (aluminum)	ASTM D3359	Good	Poor	Poor	Poor	Excellent
UV Resistance	ASTM G53	Poor	Good	Poor	Poor	Excellent
Heat Resistance	Fahrenheit	350 - 400	200 - 250	150 - 200	300 - 350	600 – 800
Mold/Mildew Growth	ASTM G-21	Yes (2-3)	Yes (1-2)	Yes (2-3)	Yes (3-4)	No Growth
Product Installation	Method	Spray/Dip	Spray/Dip	Spray	Spray/Dip	Spray
Installation Means	By Spray	Shop	Shop/Field	Shop	Shop	Shop/Field
Coil Penetration	By Spray	2 – 4 rows	2 – 4 rows	2 – 4 rows	2 – 4 rows	8 rows
Coil Penetration	By Dip	12 rows	8 rows	n/a	6 rows	n/a
Salt Spray - Hours	ASTM B117	3,000 +	2,000	1,000	3,000	6,000 +