COLMAC COIL
Manufacturing Inc.

Technical Bulletin

By Bruce I. Nelson, P.E., President

Evaporator Coils for Food Processing

Introduction

The control of pathogens in food processing facilities plays an important part in ensuring the safety of our food supply. Among other requirements, the USDA mandates that equipment is carefully cleaned to remove soil and then sanitized to disinfect surfaces. Often these two processes involve chemicals which, if not selected and applied properly, have the potential to corrode and damage the metal surfaces of evaporator coils. This technical bulletin discusses sources of corrosion, corrosion resistance of various metals used in evaporator coils, and makes recommendations regarding the selection of coil construction and accompanying cleaning and sanitizing chemicals appropriate for the operating environment.

Evaporator Construction

Industrial evaporator coils can be manufactured by Colmac Coil with a number of different tube and fin materials to match the requirements of the working fluid (refrigerant), the operating environment, and the project's first cost requirements.

Tube Materials:

- Aluminum (3003)
- Copper (not suitable for ammonia)
- Stainless Steel (304L, 316L)
- Carbon Steel – Hot Dip Galvanized after fabricating

Fin Materials:

- Aluminum (1100, 8006, AlMg2.5)
- Epoxy Coated Aluminum
- Copper
- Anti-Microbial Alloy
- Stainless Steel (304L, 316L)
- Carbon Steel – Hot Dip Galvanized after fabricating

Available Combinations (Tube/Fin):

- Aluminum / Aluminum
- Stainless Steel / Aluminum
- Stainless Steel / Epoxy Coated Aluminum
- Copper / Aluminum
- Copper / Epoxy Coated Aluminum
- Copper / Copper
- Stainless Steel / Anti-Microbial
- Stainless Steel / Stainless Steel
- Carbon Steel / Carbon Steel - Hot Dip Galvanized after fabricating

In general, the listings above show materials and combinations in order of increasing first cost with aluminum being the lowest cost material. Aluminum is also the lightest metal of those listed and is more thermally conductive than any of the metals shown except copper.

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Corrosion

Evaporator coils being used in food freezing systems or processing rooms can come into contact with food, food additives, and food seasonings. All foodstuffs are acidic to varying degrees. Common types of acids in food include:

- Acetic Acid (fruits and berries, as well as vinegar)
- Citric Acid (citrus fruits)
- Fatty Acids (fats and oils)
- Lactic Acid (sour milk products, sourdough bread making)

When onions are sliced they release sulfur-laden gases which when they oxidize and combine with water to form sulfuric acid – this is what causes the stinging sensation in your eyes. Onions also contain phosphoric acid. The pickling of vegetables with vinegar (acetic acid) can also produce an operating environment that is quite acidic.

Food additives and seasonings, along with various chemicals that are applied to foods to manage discoloration, shelf life, etc., are too numerous to mention here but can alone or in combination create corrosion conditions. It is important to identify and understand the chemistry of these additives and seasonings and factor them into the coil material selection process. One of the most common seasonings used for flavoring as well as preservation of food is sodium chloride. It will be seen below that certain metals, while they have good corrosion resistance over a wide range of pH conditions, exhibit pitting corrosion in the presence of chloride ions.

Corrosive conditions can also result from the fumigation of rooms with gases for disinfection. Sulfur dioxide is commonly used in grape storage facilities to kill molds and fungi. The sulfur dioxide gas combines with water to form sulfurous acid which is highly corrosive to steel. Chlorine dioxide is another gas used on equipment and in rooms to disinfect and sterilize surfaces. If not applied correctly, severe damage to stainless steel surfaces can result (this has been witnessed by the author).

In general, aluminum, copper, and stainless steel all exhibit good corrosion resistance to mildly acidic conditions while galvanized steel will quickly corrode when exposed to the same conditions.

Cleaning and Sanitizing

The cleaning process is defined as the removal of organic soil (fats and oils) and/or inorganic soil (mineral scale or stains). The sanitizing process is defined as treating cleaned surfaces to effectively kill or remove pathogens. The USDA requires that these two processes be done separately.

Cleaning and sanitizing chemicals used in the food processing industry fall into four general categories:

1. Acidic
2. Strongly Alkaline
3. Mildly Alkaline
4. Chlorine Based

There are many manufacturers of cleaning and sanitizing chemicals, each manufacturer having its own array of complex and proprietary formulations designed for specific foodstuffs and processes. It is not the intent of this article to give even a cursory list of manufacturers and their products, but instead to describe in general terms the effects of categories of chemicals and their pH on various metals used in evaporator coils.

The effect of these cleaning and sanitizing chemicals on the metal surfaces of coils will be determined by a number of factors:

- Concentration of the solution
- Proper and complete application
- Correct sitting/soaking time
- Correct temperature
- Complete and thorough rinsing with clean water after cleaning and sanitizing

Corrosion Resistance of Metals

Aluminum

Aluminum is a lightweight, strong, thermally conductive metal which can be alloyed with a number of different elements to produce variations in strength, ductility, weldability, and so on. It is in wide use in automobile, aircraft, and shipbuilding industries, it is used as a building material, for beverage containers, baseball bats, and so on. Because of its lightweight, high thermal conductivity, strength, and corrosion resistance, it is used extensively in heat exchangers of many kinds. It is compatible with all refrigerants including ammonia, in fact anhydrous ammonia naturally passivates aluminum surfaces.

Aluminum fins severely corroded by application of highly alkaline (pH > 9.0) cleaning chemicals.

In the presence of air, aluminum oxide forms very quickly to protect the surface of the metal. This oxide layer is very stable and tenacious and is very resistant to corrosion when 4.0 < pH < 9.0. However, aluminum oxide dissolves and the surface of the metal will corrode quickly, seen as pitting and metal loss, when exposed to strong alkaline cleaners (pH > 9.0) such as sodium hydroxide (caustic soda). The oxide layer is also attacked by highly acidic (pH < 4.0) cleaners and chlorine-based sanitizing chemicals.

Stainless Steel (304L, 316L)

Stainless steel is widely used in the food processing industry because of its high tensile strength and corrosion resistance. The chromium in stainless steel forms a very dense passive film layer which is generally very stable over a wide pH range. The oxide resists corrosion by strong alkaline cleaners such as sodium hydroxide (caustic soda) and in the presence of most acids.

While stainless steel has a reputation for being practically indestructible and able to handle any corrosive environment, the passive layer on stainless steel can be attacked by certain chemical species. The chloride ion Cl- is the most common of these and is found in everyday materials such as salt and bleach. The halogen salts, primarily chlorides such as sodium chloride, penetrate the passive oxide layer and can result in pitting and/or stress corrosion cracking. Exposure to sodium hypochlorite (chlorine bleach), or hydrochloric acid solutions, in high enough concentrations will result in pitting and/or stress corrosion cracking. It is interesting to note that this susceptibility of stainless steel to chlorides is practically speaking independent of pH.

Copper

The oxide layer on copper surfaces forms quickly in the presence of air and is very stable over a wide pH range. The color of the oxide layer ranges from brown to green and is referred to as “patina”. Copper is cathodic to most metals (steel, stainless steel, aluminum, and zinc) and so galvanic corrosion typically proceeds very slowly.

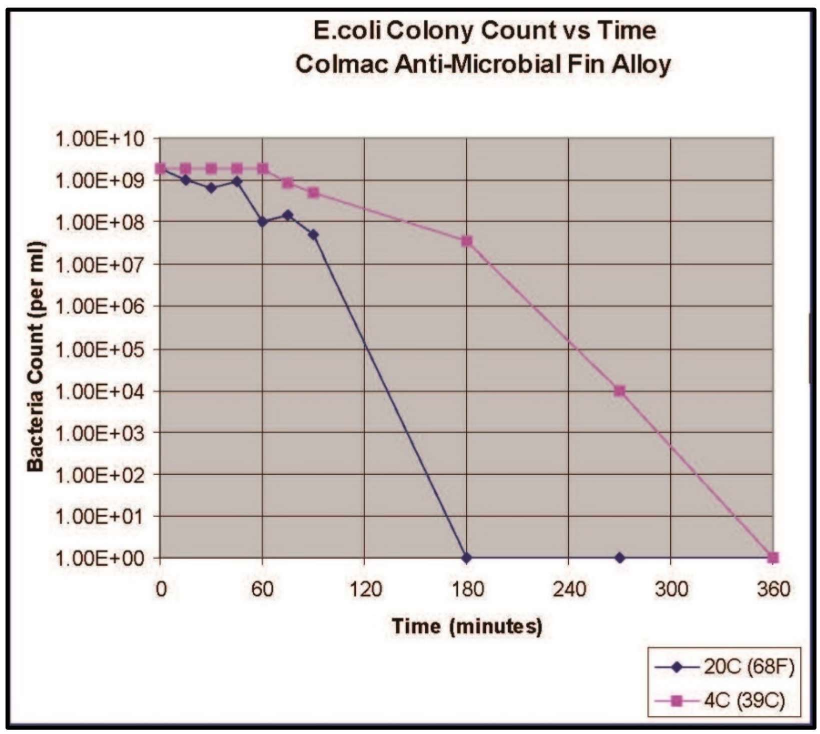
Stress corrosion cracking appears quickly when copper is exposed to ammonia and aqua-ammonia. This obviously makes the metal unsuitable for use in piping, heat exchanger tubing, and other components in direct contact with ammonia.

Most copper tubing is joined by brazing with silver-bearing alloys. While the copper is resistant to acidic environments, the components of the brazing alloy – specifically phosphorus – may not be. For example, in low pH environments such as grape storage where sulfur dioxide is used in fumigation, or in citrus ripening rooms, it is important to specify that only phosphorus-free brazing alloys be used for joining copper tubes in coils.

Anti-Microbial Fin Alloy

This proprietary metal alloy, when used to make fins, exhibits corrosion resistance similar to stainless steel but with conductivity and thermal performance similar to aluminum. This special alloy also displays active anti-microbial behavior. It has been shown by testing that colony counts of cultured e-coli bacteria placed on the surface of this fin material approach zero after only 2-3 hours. *Pathogens cannot exist on the surface of this fin material.*

Anti-microbial fins are available as an option with stainless steel tubes on any Colmac Coil evaporator coil or air cooler.



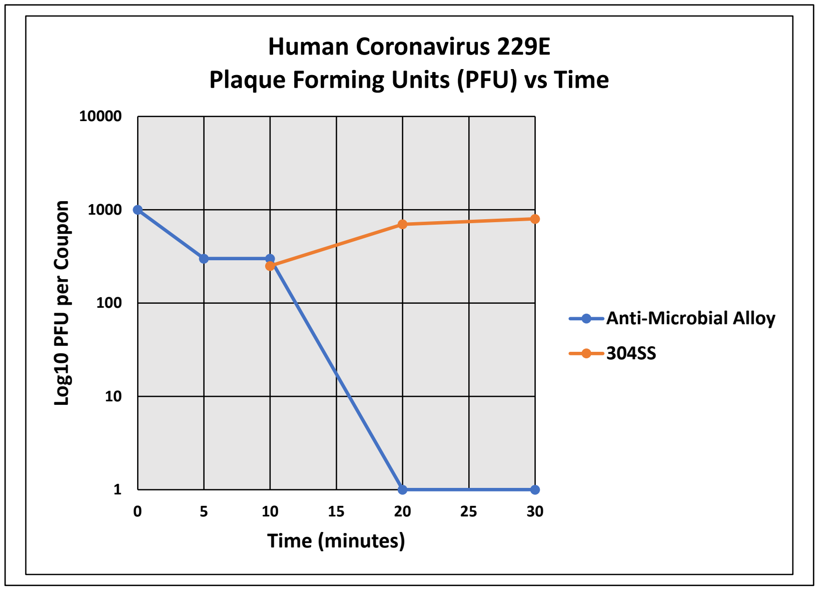
Colmac Anti-Microbial fin alloy actively kills pathogens

Human Coronavirus

Newly emerging zoonotic viral pathogens (viruses found in wild animals which transfer to humans), such as the novel coronavirus COVID-19, pose a significant global health risk. Most of these are RNA viruses which are transmitted through the mucal or respiratory route and manifest as respiratory disease such as pneumonia. The World Health Organization (WHO) has estimated there are 450 million cases of pneumonia per year resulting in 4 million deaths, with approximately 200 million of these starting with viral infections.

In 2003, the coronavirus SARS which emerged in Guangdong Province in China and infected over 8,000 people was believed to have originated in bats and palm civet cats transferred to humans. In 2012 the coronavirus Middle East Respiratory Syndrome (MERS) appeared in the Arabian Peninsula and was thought to have been transferred from bats and possibly camels to humans. This virus was found to have a very low infectious dose which suggests that transmission of very few virus particles person-to-person or contact with contaminated surfaces may be an infection risk. Most recently COVID-19, also a coronavirus thought to have been transferred from bats and possibly pangolins to humans originated in Hunan Province in China. The spread of this highly contagious coronavirus has resulted in a global pandemic which is ongoing as of this writing (2020).

Research performed at the University of Southampton (UK) in 2015 showed that samples of the human coronavirus HuCoV-229E, which is associated with a wide range of respiratory disease from mild colds to severe pneumonia in immune-compromised people, were very quickly inactivated (killed) when placed in contact with the same alloy used in Colmac Anti-Microbial fins. It is known that coronaviruses persist in an infectious state on common surfaces such as stainless steel, glass, and plastics for several days, however, the metal alloy used in Colmac Anti-Microbial fins releases copper ions which then generate reactive oxygen species (ROS) which quickly inactivate the coronavirus. This process results in fragmentation of the viral genome, ensuring that inactivation of the virus is irreversible. It was shown that samples of the coronavirus placed in contact with the Anti-Microbial fin alloy were completely inactivated in less than 30 minutes. This latest research has shown that both bacterial and viral pathogens are quickly killed when placed in contact with Colmac Anti-Microbial fins.



Anti-Microbial Fin Alloy also inactivates Human Coronavirus

Source: "Human Coronavirus 229E Remains Infectious on Common Touch Surface Materials" Warnes et al (2015)

Anti-microbial fins are available as an option with stainless steel tubes on any Colmac Coil evaporator coil or air cooler.

Galvanized Steel

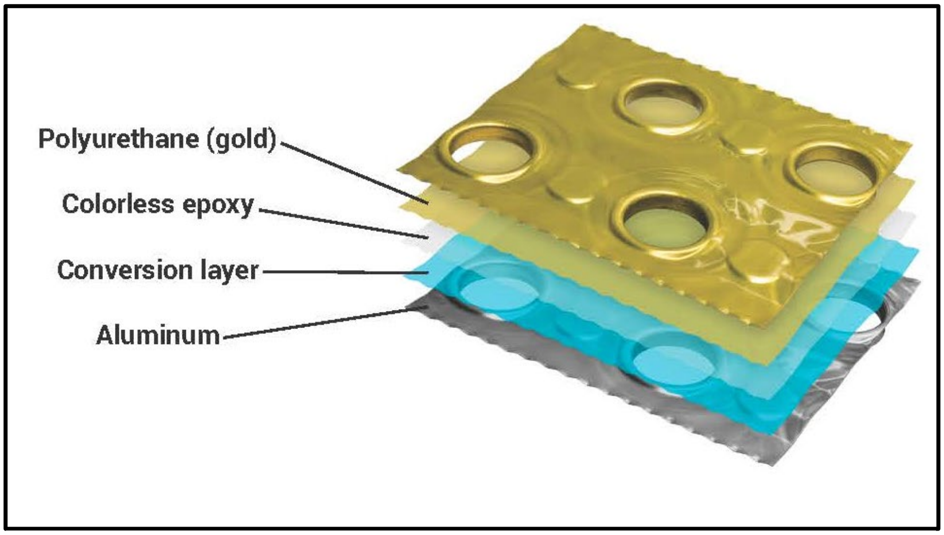
In the past industrial ammonia evaporators were traditionally made by hot dip galvanizing (application of molten zinc) carbon steel tubes and fins after fabrication. The zinc oxide layer forms quickly in air on coil surfaces and is stable with the range 7.0 < pH < 12.0.

Galvanized steel construction corrodes very quickly when exposed to acidic solutions, even mildly acidic, such as sodium hypochlorite. Consequently, this type of construction is very difficult to sanitize and so has fallen out of favor in recent years with the increased focus on controlling pathogens.

However, because of the corrosion resistance of galvanized steel to highly alkaline cleaners such as sodium hydroxide (caustic soda) this type of coil construction is still popular in some meat processing facilities where heavy accumulations of fat and oils must be removed during cleaning.

Epoxy Coated Aluminum

Colmac Coil offers fins made from epoxy coated aluminum fin stock as an option on all evaporator coils and air coolers.



Colmac Epoxy Coated Aluminum fin stock coating system

The coated fin material offers the following benefits:

- Over 300% more resistant to corrosion than bare aluminum fins.
- High thermal conductivity with negligible impact on heat transfer.
- Flexible - will not peal crack or chip.
- Highly resistant to abrasion.
- Coating does not support growth of micro-organisms.

The coating system (EPPU) consists of the base aluminum alloy prepared with a chemical conversion layer coated with a colorless epoxy layer and a final polyurethane top coating.

Testing of the coating has shown the following results.

- Heat Resistance: 200 deg C/5 min
- Solvent Resistance: Trichlorethlene (85 deg C/5 min), Perchlorethylene (120 deg C/30 min)
- Salt Spray Test (ASTM B117): >1,000 h
- Kesternich Test (ISO 3231): > 15 cycles
- Humidity Test (DIN 50017): No degradation, no corrosion
- UV Resistance (ASTM G154): OK

Cleaning and Sanitizing Chemicals

Two general groups of cleaning chemicals, alkaline and acidic, are used to remove soil from coil surfaces. Alkaline cleaners are effective at removing fats and grease while acidic cleaners are used to remove minerals and scale.

When cleaning coil surfaces these cleaners are usually supplied in a foaming format which causes the chemicals to adhere and 'stick' to vertical surfaces to keep the chemicals in contact longer.

Amount and concentration of the cleaning chemicals used is important along with the temperature of the solution. Longer soaking time requires lower concentration of the chemical. Warmer water/solution temperatures also require lower concentration of the chemical. Rinsing with clean water is critical after cleaning and sanitizing to avoid accumulation and high concentrations of the chemical collecting in crevices and initiating corrosion sites. Even though chemicals are applied in the correct concentration with pH in the acceptable range, neglecting to rinse thoroughly after cleaning and sanitizing can result in increased concentrations of chemicals in crevices as coil surfaces dry out resulting in crevice corrosion. Proper rinsing is critical!

Sodium hypochlorite (chlorine bleach) is widely used as a sanitizing chemical and is effective at killing pathogens on metal surfaces. Unfortunately, high concentrations of sodium hypochlorite will cause pitting corrosion on stainless steel surfaces. Also, if the pH of the sodium hypochlorite solution is allowed to fall below 4.0 then aluminum oxide will begin to dissolve and aluminum surfaces will corrode. Therefore, sodium hypochlorite is not recommended for use on any Colmac Coil evaporator coil.

Fortunately, there are numerous cleaning and sanitizing chemicals available which are compatible with the various types of evaporator coil construction listed above. A few are listed below according to the metal surface being cleaned and sanitized. WARNING: The supplier of the cleaning and sanitizing chemicals to be used must be consulted and their application guidelines carefully followed regarding chemicals and procedures used for a given type of coil construction. It is the responsibility of the chemical supplier and end user to correctly select and apply cleaning and sanitizing chemicals to avoid damage to coil surfaces due to corrosion.

Recommended Cleaners and Sanitizers

1. Aluminum or Stainless-Steel Tubes with Plain or Epoxy Coated Aluminum Fins
    a. Cleaning
        i. Organic Soil (Fats and Grease)
            1. Use a foaming mildly alkaline cleaner with pH < 9.0
            2. Example: ZEP FS Strike Three (Potassium Hydroxide based)
        ii. Mineral Soil (Minerals and Scale)
            1. Use a foaming mildly acidic cleaner with pH > 4.0
            2. Example: ZEP Formula 7961 (Phosphoric Acid based)
    b. Sanitizing
        i. Spray-on application
            1. Use Peracetic Acid or Quaternary Ammonia with pH > 4.0
            2. Example: ZEP FS Amine A, FS Amine Z
            3. Note: DO NOT use Sodium Hypochlorite-based (Chlorine Bleach) sanitizing chemicals on stainless steel or aluminum surfaces.

2. Stainless Steel Tubes with Stainless Steel or Anti-Microbial Fins
    a. Cleaning
        i. Organic Soil (Fats and Grease)
            1. Use a foaming alkaline cleaner with pH < 12.0
            2. Example: ZEP FS Strike Three (Potassium Hydroxide based) or Sodium Hydroxide (Caustic Soda)
        ii. Mineral Soil (Minerals and Scale)
            1. Use a foaming mildly acidic cleaner with pH > 4.0
            2. Example: ZEP Formula 7961 (Phosphoric Acid based)

b. Sanitizing

i. Spray-on application
   1. Use Quaternary Ammonia with pH > 4.0
   2. Example: ZEP FS Amine Z
   3. Note: DO NOT use Sodium Hypochlorite-based (Chlorine Bleach) cleaning or sanitizing chemicals on stainless steel or anti-microbial alloy surfaces.

3. Galvanized Steel
   a. Cleaning
      i. Organic Soil (Fats and Grease)
         1. Use a foaming alkaline cleaner with pH < 12.0
         2. Example: ZEP FS Strike Three (Potassium Hydroxide based) or Sodium Hydroxide (Caustic Soda)
      ii. Mineral Soil (Minerals and Scale)
         1. Very difficult to remove from galvanized steel surfaces
         2. DO NOT use Acidic cleaning chemicals!
   b. Sanitizing
      i. Very difficult to sanitize galvanized steel surfaces
      ii. DO NOT use Acidic sanitizing chemicals!

Conclusion

Evaporator coils used in OEM freezing equipment and in air coolers installed in food processing facilities very often come into contact with food, food additives, and food seasonings, some of which can be quite corrosive to certain metals. Coils are also regularly exposed to harsh cleaning and sanitizing chemicals used to control pathogens, which can also result in corrosive conditions. Selecting the proper materials for coil construction suitable for the operating environment has been the subject of this article. It is particularly important to understand the effect of cleaning and sanitizing chemicals on metal surfaces, and to work closely with chemical suppliers to properly select and apply these chemicals. Following the guidelines presented above will help prevent damage to evaporator coils due to corrosion while successfully controlling pathogens.

For more information contact Colmac Coil Manufacturing, Inc.
www.colmaccoil.com | P: 800.845.6778 or 509.684.2595
PO Box 571 | Colville WA. 99114-0571