Energy Efficiency and Air Quality in Air Conditioning

Executive Summary

Introduction

Copper has had a long history in critical heat transfer components used in air-conditioning systems due to its unique combination of properties, including high-thermal conductivity, formability, corrosion resistance, ease of joining, infinite recyclability and, more recently, its antimicrobial effect.

Copper's antimicrobial property has been utilized for thousands of years through the use of copper vessels to maintain uncontaminated water stores. Pure copper and copper alloys have antimicrobial properties that kill microorganisms on contact and prevent the growth of bacteria and fungi. This effectiveness of copper has been proven in rigorous studies that led to EPA registration of 479 copper alloys as public health antimicrobial touch-surface products. Antimicrobial Copper® products are being developed for use in hospitals to address the serious problem of hospital-acquired infections.

The antimicrobial property of copper has also found utility in air-conditioning systems by eliminating biofilm formation and buildup on the heat-exchanger surfaces, thereby reducing the concentration of contaminants in the air.

Impact of airborne microbial contaminants

Airborne bacteria and fungi have the potential to adversely impact human health by causing infections, allergic responses or toxic effects. Therefore, microbial growth in heating ventilation and air-conditioning (HVAC) systems with the subsequent contamination of indoor air is of increasing concern. Pathogenic and toxin-producing bacteria and fungi thrive in dark, moist environments, and the conditions in HVAC systems would appear to be ideal for the growth and propagation of microbes. Microbes and the subsequent biofilms grow easily within heat exchangers. Intrinsic microbial biofilms on air-handling exchanger coils are associated with lowered heat transfer efficiencies and increased corrosion [1] as well as potential odor issues [2, 3]. Consequently, little or no growth of microorganisms on HVAC surfaces is optimally desired.

Microbial populations present in HVAC heat-exchanger systems can be substantial. Researchers have reported bacterial concentrations up to one million colony forming units (CFU) per square centimeter on air-handling cooling coils [4]. Other researchers have shown that the automobile and household air-conditioning units can discharge up to 2,500 CFU per cubic meter of bacteria and 1,000 CFU per cubic meter of fungi above ambient levels on initial startup [5]. The microbiological concentrations associated with the subsequent air stream 15 to 120 minutes after continuous use returned to background levels.

According to the United States Environmental Protection Agency (EPA), contaminated HVAC systems can serve as breeding grounds for bacteria and fungi, and a substantial reservoir for viruses and fungal and bacterial spores. Contaminants accumulate in HVAC systems on heat-exchanger coils and fins, in condensate drain pans, on air filters, and in air ducts. Indoor surfaces and building occupants can then be exposed to bio-aerosols from these sites [6].

Impact of copper components on microbial contamination and air quality in HVAC systems

A variety of commercial products on the market have been designed to reduce biofilms and subsequent odors and health concerns associated with air-conditioning systems. Some of these products have been tested under laboratory conditions and have demonstrated modest control of the growth of resident biofilms [7]. The inherent antimicrobial properties of copper and its alloys offer an alternative approach to control the growth and distribution of pathogens and allergens through HVAC systems [8, 9, 10, 11]. Uncoated copper surfaces are capable of killing bacteria, viruses and fungi in very short periods of time. Pathogenic bacteria die within 90 minutes at room temperatures and within a few hours as the temperature decreases [12, 13]. Similarly, fungi and some viruses are killed within hours of being exposed to metallic copper surfaces [11]. Conversely, microorganisms have been found to survive for a month or more on surfaces made from stainless steel or aluminum [11].

Several studies [14, 15, 16, 17] conducted through funding from ICA examined the growth of biofilms on heat-exchanger surfaces and its effects on air conditioner energy efficiency and long-term performance, as well as the effects on indoor air quality in buildings and in public transport buses. These comparative studies of all-copper and aluminum heat exchanger coils evaluated their ability to limit microbial growth, and the impact of this microbial growth on energy efficiency and air quality. The studies were conducted at Ft. Jackson, South Carolina (microbial growth and air quality), Shanghai Jiao Tong University (energy efficiency and performance), and the Shanghai Municipal Center for Disease Control & Prevention (bus cabin air quality). The goals of these studies were to evaluate whether or not inherent antimicrobial properties of metallic copper, when substituted for aluminum found in heat exchangers, might limit the colonization and growth of microbes on HVAC systems and, thereby, make an observable and quantifiable improvement in indoor air quality.

Most fungal species show a total die off within 24 hours of exposure to copper [11]. Aspergillus niger is the only fungus tested that shows no die off after significant periods of exposure to copper [11]. However, copper has been shown to inhibit the growth of A. niger spores and prevent A. niger from colonizing on a copper surface. Aluminum had no effect on A. niger [11]. Lab testing showed that biofilm building on aluminum heat exchanger coupons was three to four orders of magnitude greater than on copper heat exchangers The extent to which copper limited growth of bacteria was 99.9% and for fungi 99.74% of that observed on the control, aluminum-based heat exchangers [14]. Air conditioned by copper heat exchanger assemblies was found to have significantly lower airborne fungal concentrations when measured at the ambient breathing zone as well as adjacent to the discharge air vent, compared to aluminum assemblies, in both heating and cooling seasons [15].

Heat exchangers in public buses were tested, and it was found that aluminum coil surfaces had up to 10 times the fungi levels and 60 times the bacteria levels compared to copper coils [16]. The microbial level on the surface of the AC (air conditioner) coils with aluminum fins increased significantly along with the use of the system. Research showed the aluminum coil did not comply with local standards by the end of the testing period. Copper coils lowered the total number of bacteria in cabin air compared to aluminum coils, but the phenomena could not be shown unambiguously when monitoring the vent outlet air from the AC units.

In a long-term, laboratory-based performance test of all-copper coils versus copper tube/ aluminum fin coils, in normal thermal cycling and when not treated with mold, after 4,800 cycles (equivalent to four years of operating life) the copper coil had deteriorated to 94.2% of the original heat flow and the aluminum-fin coil had deteriorated to 90.1%. When both coils were treated with mold, the copper coils exhibited no mold growth and showed no performance deterioration from mold, whereas the mold-treated aluminum coils exhibited considerable mold growth of up to 60% of the frontal area and had a 19% reduction in heat flow rate. After 4,800 cycles and mold growth on 60% of the coil surface area, the capacity loss rate for the aluminum coils was 27%, which was 3.7 times greater than the loss for copper coils, 5.8% [17].

Conclusion

Copper alloys have antimicrobial properties that kill bacteria and mold on contact and prevent their growth. Copper's antimicrobial effectiveness has been proven in rigorous testing and, as a result, 479 copper alloys are now registered with EPA as public health antimicrobial touch-surface products. This registration allows copper components in HVAC systems to make product protection claims of suppressing the growth of bacteria and mold that reduce system efficiency and cause product deterioration or foul odors. Copper HVAC components can prevent the growth of bacteria and mold, resulting in longer coil life and higher operating efficiencies, and reduce airborne contaminants, resulting in improved indoor air quality.

References

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