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Comparison Study of Bio-Growth in Commercial AHU's Using Copper Heat Exchangers and Components

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ABSTRACT

The growth of molds and other bio-organisms on heat exchangers in commercial air handling units (AHU's) can reduce air flow thereby affecting the efficiency of the HVAC system and potentially affecting air quality, as well. This growth is especially prevalent on the moist surfaces of cooling coils. The use of ultraviolet germicidal irradiation (UVGI) to control bio-growth on heat exchange coils in commercial AHU's has become a common practice with documented positive results. Although the use of UVGI is effective on those surfaces that receive sufficient doses of radiation, concerns about surfaces outside of the radiation field plus concerns about energy costs and maintenance issues related to UVGI equipment has led to a search for new methods and materials that are more effective and less costly in reducing bio-fouling of heat exchange coils over the life of an AHU.

The antimicrobial properties of copper are well documented (Weaver et al, 2010). After rigorous testing under approved protocols, over 500 copper alloys were registered by the US Environment Protection Agency (EPA) as antimicrobial agents for touch surfaces. For copper alloys used in HVAC applications, the EPA granted a "Treated Article Exemption" registration allowing registered manufacturers of copper HVAC components to make product protection claims of suppressed growth of bacteria, mold and mildew that can reduce system efficiency, and cause product deterioration and foul odors. The study presented in this paper was designed to observe a side-by-side comparison of copper alloy heat exchangers to conventional copper-tube/aluminum-fin heat exchangers.

At a school in New Jersey, one of 7 rooftop AHU's was fitted with hydronic and chilled water heat exchangers fabricated from all copper tubes and copper fins. The copper heat exchangers included copper brackets and drip pans. This AHU with copper coils and components was compared to 2 equally sized AHU's with copper tubes, aluminum fins, aluminum brackets and aluminum drip pans. One of the aluminum-fin AHU's was equipped with UVGI and one was not. Bio-growth sampling involved swabs from the surfaces of fins on both the supply-side and discharge-side

of the coils. Swabs were also taken on the surfaces of drip pans. Data points covered a full heating and cooling season.

The data in this paper shows that all-copper coils revealed dramatically less bio-growth than coils with aluminum fins and aluminum bracketry, including the AHU equipped with UVGI. These data support continued studies that quantify the economic impact of all-copper heat exchangers and total cost of ownership (TCO) related to AHU's without UVGI.

1. INTRODUCTION

This study was designed to explore the anti-microbial properties of copper alloys and their effectiveness in the prevention of bio-growth on commercial cooling and heating coils, including coil support structures such as brackets and drain pans. The antimicrobial properties of copper are well documented (Weaver et al, 2010) with more than 500 copper alloys registered with the US Environmental Protection Agency (EPA) as antimicrobial agents for touch surfaces. The EPA granted a "Treated Article Exemption" registration for copper alloys used in HVAC applications. The Treated Article Exemption allows registered manufacturers of copper HVAC components to make product protection claims of suppressed growth of bacteria, mold and mildew that can reduce system efficiency, accelerate product deterioration and cause foul odors.

Current state-of-the-art rooftop air handling units typically include coils made from copper tubes and aluminum fins. Ultraviolet germicidal irradiation (UVGI) is commonly used to control bio-growth and prevent fouling of the coils. Concerns about surfaces outside of the radiation field plus concerns about energy costs and maintenance issues related to UVGI equipment has led to a search for better methods and materials.

This study was designed to compare the current state-of-the-art copper-tube/aluminum-fin coils to coils made entirely of copper alloy. The subject building chosen for this study had to be large enough to allow a side-by-side comparison of similar AHU's equipped with both conventional coils plus coils protected with UVGI and all-copper coils.

2. SUBJECT BUILDING AND BACKGROUND

The building chosen for this study is a school located in New Jersey. The climate includes distinct cooling and heating seasons. The school was built in 1989 and has approximately 107,000 square feet. In 2005, this school underwent a complete HVAC system renovation.

The school classroom and hallway spaces are substantially conditioned through the use of seven (7) large rooftop units, all from the same manufacturer. Each rooftop unit contains a hot water coil and a chilled water coil. Although the heating and cooling coils run independently, the conditioned air passes through both coils. The units draw both return air from the conditioned space as well as outside air. The air runs through pre-filters and then passes through HEPA filtration prior to passing through the heating & cooling coils before discharge into the ductwork mains for distribution throughout the school. The units also contains UV lights for bacteria disinfection. The pre-filters are changed quarterly and the HEPA filters annually. The HVAC system is substantially controlled by requiring 55 degree F (12.8 degrees C) discharge air from the rooftop units, thus ensuring sufficient heat to the space during the heating season and sufficient dehumidification & cooling during the cooling season.

3. METHODOLOGY

A primary goal of this study was to generate sufficient data to support a valid comparison between conventional copper-tube/aluminum-fin HVAC coils to coils made entirely of copper. Understanding the effect of UVGI on bio-growth as compared to the inherent antimicrobial properties of copper, was a key desired outcome.

3.1 Work Plan

1. All rooftop air handling units (AHU's) in the study retained the use of pre-filters rated MERV 8.
2. Of the seven (7) existing AHU's, the following equally sized units were chosen for this study to be equipped as described:
    a. AHU #4: UV lights, no HEPA filters and existing copper tube/aluminum fins coils.
    b. AHU #5: No UV lights, no HEPA filters and new copper tube/copper fin coils.
    c. AHU #6: No UV lights, no HEPA filters and existing copper tube/aluminum fin coils.
3. All three (3) subject air handling units were cleaned, received pre-filter changes, controls were re-commissioned and units re-balanced to establish a "baseline" for the study.
4. Controls included the following data points:
    a. Air flow-rate (return, fresh & discharge / supply)
    b. Temperature (return, fresh & discharge / supply)
    c. Relative humidity
    d. Outside air temperature and relatively humidity
    e. Cooling coil fluid flow-rate
    f. Coil temperature (entrance / exit)
    g. Fan operation
5. During the study, samples of air were taken as well as samples from the surfaces of the heating & cooling coils. Sampling locations were determined prior to the start of the study. Coil samples included vertical surfaces as well as low lying crevice surfaces. Coil samples were tested for fungal and bacterial colonies. Air samples were tested for fungal structures only.
6. Detailed species analyses were not in the scope of this study

4. COPPER COOLING AND HEATING COILS

Copper-fin/copper-tube heating and cooling coils replaced the existing, conventional coils in AHU #5. The all-copper coils included copper brackets and pans, and were fabricated to the specifications in Table 1.

Table 1: Cooling and Heating Coil Specifications

COOLING COIL	HEATING COIL
Type: Fluid Coil	Type: Fluid Coil
Size: 52.5 inches x 78 inches (1333.5 mm x 1981.2 mm)	Size: 52.5 inches x 78 inches (1333.5 mm x 1981.2 mm)
Tubes OD: 0.5 inches (12.7 mm)	Tubes OD: 0.5 inches (12.7 mm)
Tube Wall: 0.016 inches (0.406 mm)	Tube Wall: 0.016 inches (0.406 mm)
Rows of Tubes: 10 rows	Rows of Tubes: 1 row
Fins: 0.006" thick (0.152 mm) copper	Fins: 0.006" thick (0.152 mm) copper
Headers: 3.125 inches OD (79.4 mm OD) Standard Type "L" Copper	Headers: 1.625 inches OD (41.3 mm OD) Standard Type "L" Copper
Weight: 1,789 lbs. (811.5 kg)	Weight: 160 lbs. (72.6 kg)

Photos of the copper heating and cooling coils can be seen in Figures 1 and 2.

Figure 1: Copper heating coil, as delivered on site.

Figure 2: Copper cooling coil, as delivered on site.

5. BIO-GROWTH DATA

5.1 Coil Samples

Test Procedure:
Swab samples were taken from three (3) distinct AHU's; AHU #4, AHU #5 and AHU #6. (See section 3.1.2 for description of AHU differences.) Samples were taken from both heating coils and cooling coils, including the upstream or supply-side of the coil and the downstream or discharge-side of the coil. Sampling locations focused on vertical surfaces and low lying crevice surfaces. Each sample was tested for fungi and bacteria using the culture method (P027).

No appreciable bio-growth was recorded on any of the heating coils. Therefore, heating coil fungal and bacterial data has been omitted from the data tables below.

Results are reported in concentrations of colony-forming units (CFU) per square inch (645 mm^2). The following data tables show fungal and bacterial data from the initial baseline date followed by three (3) additional dates covering a full cooling season and heating season. Note that detailed species analyses were not in the scope of this study.

Table 2: Coil Bio-Growth Data for AHU #4, Cooling Coil (Copper Tubes, Aluminum Fins, Functioning UVGI)
Fungal and Bacterial Concentrations in Colony-Forming Unis (CFU) per Inch^2 (per 645 mm^2)

Sample Location - AHU #4 Cooling Coil	Baseline April 22, 2015 Fungal Conc. CFU/inch^2	Baseline April 22, 2015 Bacterial Conc. CFU/inch^2	June 22, 2015 Fungal Conc. CFU/inch^2	June 22, 2015 Bacterial Conc. CFU/inch^2	Oct. 7, 2015 Fungal Conc. CU/inch^2	Oct. 7, 2015 Bacterial Conc. CFU/inch^2	June 17, 2016 Fungal Conc. CFU/inch^2	June 17, 2016 Bacterial Conc. CFU/inch^2
Fin #1, up stream	<100	<100	100	100	200	200	500	200
Fin #2, up stream	<100	<100	100	100	100	600	100	<100
Horizontal flat, up stream	400	<100	1,700	100	4,400	200	37,000	300
Fin #1, down stream			<100	<100	<100	<100	<100	300
Fin #2, down stream			100	300	<100	<100	100	<100
Horizontal flat, down stream			3,000	90,000	300	220,000	12,000	200

Table 3: Coil Bio-Growth Data for AHU #5, Cooling Coil (All Copper Components, No UVGI)
Fungal and Bacterial Concentrations in Colony-Forming Unis (CFU) per Inch^2 (per 645 mm^2)

Sample Location - AHU #5 Cooling Coil	Baseline April 22, 2015 Fungal Conc. CFU/inch^2	Baseline April 22, 2015 Bacterial Conc. CFU/inch^2	June 22, 2015 Fungal Conc. CFU/inch^2	June 22, 2015 Bacterial Conc. CFU/inch^2	Oct. 7, 2015 Fungal Conc. CFU/inch^2	Oct. 7, 2015 Bacterial Conc. CFU/inch^2	June 17, 2016 Fungal Conc. CFU/inch^2	June 17, 2016 Bacterial Conc. CFU/inch^2
Fin #1, up steam	<100	<100	<100	<100	<100	<100	100	<100
Fin #2, up stream	<100	<100	<100	<100	100	100	<100	<100
Horizontal flat, up stream	<100	100	200	<100	<100	100	100	<100
Fin #1, down stream			<100	100	<100	<100	100	100
Fin #2, down stream			<100	<100	100	<100	100	<100
Horizontal flat, down stream			1,400	600	200	100	<100	100

Table 4: Coil Bio-Growth Data for AHU #6, Cooling Coil (Copper Tubes, Aluminum Fins, Disabled UVGI) Fungal and Bacterial Concentrations in Colony-Forming Unis (CFU) per Inch^2 (per 645 mm^2)

Sample Location AHU #6 Cooling Coil	Baseline April 22, 2015 Fungal Conc. CFU/inch^2	Baseline April 22, 2015 Bacterial Conc. CFU/inch^2	June 22, 2015 Fungal Conc. CFU/inch^2	June 22, 2015 Bacterial Conc. CFU/inch^2	Oct. 7, 2015 Fungal Conc. CFU/inch^2	Oct. 7, 2015 Bacterial Conc. CFU/inch^2	June 17, 2016 Fungal Conc. CFU/inch^2	June 17, 2016 Bacterial Conc. CFU/inch^2
Fin #1, up stream	‹100	‹100	‹100	‹100	100	‹100	800	‹100
Fin #2, up stream	‹100	‹100	‹100	‹100	100	‹100	‹100	‹100
Horizontal flat, up stream	100	100	72,000	›5,000,000	›5,000,000	›5,000,000	12,000	420,000
Fin #1, down stream			‹100	‹100	200	‹100	500	300
Fin #2, down stream			‹100	‹100	100	‹100	20,000	100
Horizontal flat, down stream			33,000	40,000	8,500	950,000	4,000	300

5.2 Air Samples

Test Procedure:
"Air-O-Cell" samples were taken from three (3) separate locations representing indoor air. Air-O-Cell samples were also taken at locations representing outdoor air, return air and discharge air at the three (3) subject AHU's; AHU #4, AHU #5 and AHU #6. (See section 3.1.2 for description of AHU differences.) Using microscopic method (P001), the Air-O-Cell samples were analyzed for total fungal structures by optical microscopy.

Results are reported as total fungal structures per cubic meter (35.3 ft^3) by optical microscopy.

Table 5: Air Sample Data - Total Fungal Structures per m^3 (35.3 ft^3) by Optical Microscopy

Sample Location	Baseline April 22, 2015 Fungal Structures per m^3	June 22, 2015 Fungal Structures per m^3	Oct. 7, 2015 Fungal Structures per m^3	June 17, 2016 Fungal Structures per m^3
Room C Storage	53	110	160	110
Room D111	53	160	320	160
Room C200	380	1,800	320	160
AHU #4 Outdoor Air	1,700	8,800	2,500	6,600
AHU #4 Discharge Air	640	2100	520	790
AHU #4 Return Air	160	590	590	210
AHU #5 Outdoor Air	2,700	11,000	5,100	220
AHU #5 Discharge Air	850	1,400	420	270
AHU #5 Return Air	160	2,300	220	270
AHU #6 Outdoor Air	3,200	7,700	3,500	11,000
AHU #6 Discharge Air	530	1,400	1,400	1,100
AHU #6 Return Air	370	530	470	7,900

6. EFFECT OF COPPER ON BIO-GROWTH

A critical comparison can be made between AHU #4 representing the current state-of-the-art including UVGI and AHU #5 representing a potential replacement using copper components without UVGI.

6.1 Fungal Growth

Considering fungal data from April to October covering a full cooling season, this data shows copper coils without UVGI were more effective at combating bio-growth than conventional coils utilizing UVGI (see Figure 3).

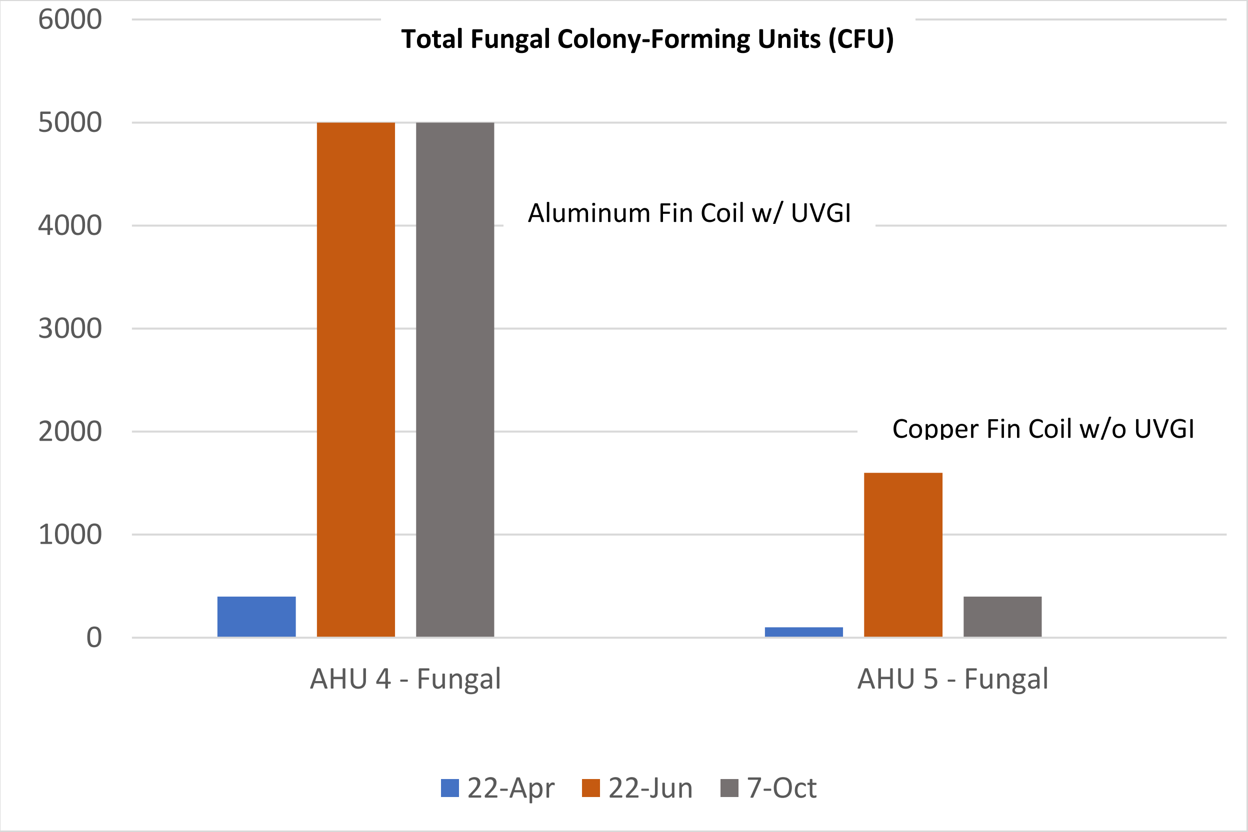

Figure 3: Comparison of fungal growth on conventional cooling coil with UVGI (AHU #4) to all-copper cooling coil without UVGI (AHU #5).

6.2 Bacterial Growth

Again focusing on data through a full cooling season from April to October, data showed significantly lower bacterial colonies in the fin pack of the all-copper cooling coil and dramatically lower bacterial colonies on the flat surfaces.

Bacterial data from the discharge-side of the pan was especially lob-sided in favor of copper. Differences of 90,000 CFU vs. 600 CFU were recorded in June and by October the difference had growth to 220,000 vs. 100. This is possibly due to the minimal amount of UV light that is able to penetrate through the aluminum fin pack to irradiate this surface.

7. CONCLUSIONS

7.1 Copper Cooling and Heating Coils

This study indicates that due to the inherent antimicrobial properties of copper, cooling and heating coils made from copper will control bio-growth without the use of additional agents such as UVGI. The potential benefits of coils made entirely from copper alloys include:

- Reduced energy consumption because anti-fouling properties of copper coils help maximize airflow.
- Reduced energy consumption due to UVGI equipment is not required.
- Reduced maintenance for coil cleaning.
- No maintenance for UVGI equipment.

7.2 Air Samples

Although the discharge air from the all-copper coils typically had lower fungal levels, no conclusions could be drawn from air sample data due to variations in the quality of the outside air. However, these samples did confirm that the air entering the building from the HVAC system was safe and dramatically cleaner than the outside air.

7.3 Additional Research

These results support further research on energy efficiency losses due to coil fouling and reduced airflows, as well as potential improvements in "total cost of ownership" (TCO) from all-copper coils.

Additionally, a project that includes detailed species analyses and studies the effect of all-copper coils on indoor air quality may uncover and quantity benefits of copper HVAC materials that are not fully understood at this time.

REFERENCES

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