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Trane
ATTN: Gary Luepke
3600 Pammel Creek Rd.
La Crosse, WI 54601

Dear Mr. Gary Luepke:

RTI is pleased to submit this letter report to Trane on our project to test the efficacy of microorganism inactivation/collection by the Trane Catalytic Air Cleaning System (TCACS). The TCACS was provided to RTI by Trane and tested as supplied. The integrated fan was operated at its designated setpoint which produced a flow rate of approximately 420 sfpm face velocity as calculated by Trane.

The testing program detailed in this report is for the vegetative bacterium *Staphylococcus epidermidis*. *S. epidermidis* is a common gram-positive human shedding organism which is representative of vegetative bacteria. When aerosolized, *S. epidermidis* is spherical with a size range of 0.5 – 1.5 µm.

TEST METHOD

Chamber Air Cleaner Test

The test included a natural decay measurement and an air cleaner decay measurement at high relative humidity (RH)/lower temperature (approximately 75% RH and 65º F) conditions. The test also included a natural decay measurement and an air cleaner decay measurement at low RH/higher temperature (approximately 20% RH and 90º F) conditions. These measurements were performed after filling the chamber with challenge bioaerosol. The natural decay is defined as the decay of the test bioaerosol in the chamber with the air cleaner off. The air cleaner decay measurement is defined as the decay while the air cleaner is running.

The test method has been described in depth by Foarde et al. (1999). As an overview, the paper describes a test method to determine a Clean Air Delivery Rate (CADR) type measurement for a device when challenged with microbiological aerosols. The method is a modification of the Association of Home Appliance Manufacturers (AHAM) Standard AC-1, "Standard Method for Measuring Performance of Portable Household Electric Cord-Connected Room Aircleaner" which determines the CADR for three different particulate matter challenges (smoke, dust, and pollen). This extension of the AHAM method to microbial aerosols follows the tradition of the AHAM test of using realistic particle challenges and provides a means to compare and evaluate different brands of room air cleaning devices regarding characteristics significant to product use. This is a useful approach for evaluating a wide range of devices.

Test Chamber and Bioaerosol Sampling:
The Dynamic Microbiological Test Chamber (DMTC) was used for the air cleaner tests. The DMTC is a room-sized environmental chamber contained within the microbiological aerosol test facility, a nominally Class 1,000 cleanroom. The chamber is 2.44 x 2.44 x 3.05 m (18.16 m^3 or 640 ft^3). The walls and containment ceiling are 10-cm thick prefabricated panels with a stainless steel interior layer. The floor of the chamber was custom constructed of 12-gauge stainless steel with welded seams and insulation underneath between the support members. Floor seams were polished and the coved corners were sealed. The ceiling-mounted mixing fan consists of a two-blade aluminum casting 61 cm in diameter attached to a shaft extending 61 cm from the ceiling into the center of the chamber. To reduce the difficulty of decontaminating the interior features, no electrical outlets were installed inside the chamber. A finished 5 cm penetration in one wall allows extension cord access through rubber stoppers.

Temperature and humidity control were provided by a separate external air handler (AHU). The AHU also controls the steam humidifier which adds water to the chamber air while the HVAC system removes some water and controls the air temperature. Airflow through the system is monitored by an airflow station and controlled by a blower speed controller with the AHU. Air cleaning of the chamber is attained through the use of a HEPA (High Efficiency Particulate Air) filter installed on the discharge side of the AHU. It contains both an ASHRAE 30% prefilter and a HEPA filter.

Figure 1 shows an artist's rendition of the DMTC configured for air cleaner testing. The TCACS Unit was positioned near the center of the chamber and operated at the designated fan speed as per instructions from Trane. According to Trane, this results in a flow rate of approximately 166 CFM (for the nominal 420 sfpm face velocity through the unit).

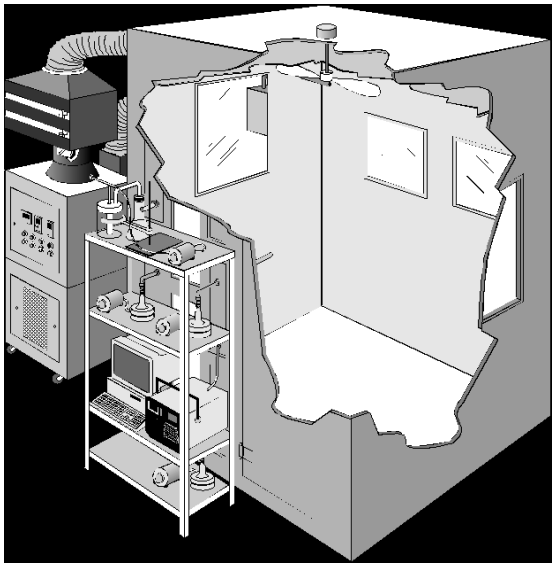

Figure 1 Artist's Rendition of the DMTC with sampling instrumentation.

The challenge bioaerosol suspension was aerosolized using a Collison modified MRE-type six-jet nebulizer (BGI, Waltham, MA) operated at 15 psi. The Collison nebulizer generates particles or droplets with an approximate mean diameter of 2 μm. The Collison generates droplets directly into the side of a cylindrical pre-chamber referred to as a drying tower. The drying tower, supplied with 2 CFM of dry HEPA-filtered air, was used as a mixing and drying space for the test aerosol. Its inlet to the DMTC was positioned near the middle of a wall that is adjacent to the dynamic chamber sampling wall.

Extractive sampling of the bioaerosols was accomplished using ports placed in sampling panels located in one wall of the chamber (see Figure 1). Three sampling ports were used to collect triplicate simultaneous samples. Port A was positioned near the center of the chamber wall, 1.52 m above the floor of the chamber and 1.0 m from the front wall. Port B was 1.52 m above the floor but was 0.25 m from the front wall of the chamber. The third port, C, was directly below

Port A, but 0.65 m above the floor of the chamber. Stainless steel 1.27 cm diameter piping extending 0.76 m into the middle of the chamber was used as sample lines. The dimensions of the sample lines were chosen to minimize particle losses during sampling.

Sampling of *S. epidermidis* was accomplished using one-stage Andersen viable bioaerosol samplers loaded with Petri dishes containing growth media. The one-stage Andersen sampler is a 400-hole multiple-jet impactor operating at 28 L/min. After sampling, the Petri dishes were removed from the sampler and incubated overnight at 37°C for *S. epidermidis*. CFUs (colony forming units) were then enumerated and their identity confirmed.

Test Protocol:
The test protocol for *S. epidermidis* was as follows:
1) Turn on the chamber AHU and circulating fan.
2) Allow the HEPA to clean the chamber air for at least 1 hour.
3) Turn off AHU and turn on the Collison nebulizer and run for 5 minutes with HEPA-filtered drying air flowing at 2 CFM. Turn off Collison nebulizer, and continue to allow the drying air to flow through the drying tower and into the chamber for another 8 minutes.
4) One minute prior to the start of collection for the "0 min" sample turn off the drying air, close the valve between the drying tower and the chamber to prevent backflow, and turn off the circulating fan in the chamber.
5) Switch on the TCACS at the start of collection for the "0 min" sample.
6) Collect triplicate bioaerosol measurements at appropriate intervals (usually 0, 4, 8 and 12 minutes, or 0, 5, 10 and 15 minutes).

One modification was used in the natural decay test for *S. epidermidis*:
1) Step 5 was omitted.

Calculations:
The performance of the air cleaner was evaluated by determining the Clean Air Rate (Microbial) or CARm, calculated as the CADR in the AHAM method. To calculate the CARm, the measured decay (k_e) and natural decay (k_n) rates are first calculated using the formula:

$$k = \frac{(\Sigma\, t * \ln C_t) - [(\Sigma\, t)(\Sigma \ln C_t)]/n}{(\Sigma\, t^2) - (\Sigma\, t)^2 / n} \qquad \text{Equation 1}$$

where:
C_t = concentration at time, t
n = number of data points used in the regression
k = decay constant ($time^{-1}$)
t = time (minutes)
Then the CAR(m) was calculated for each measured decay rate, using the formula:

$$CARm = V k_e - k_n \qquad \text{Equation 2}$$

where:

V = volume of the test chamber (ft^3)
k_e = measured decay rate (min^{-1})
k_n = average natural decay rate (min^{-1})for an organism.

RESULTS

Chamber Air Cleaner Test

The TCACS system as supplied incorporated a MERV 13 filter placed at the inlet of the device, a fan to draw air through the system at nominally 420 sfpm and a PCO media system used in conjunction with UVC lights. Testing was done at initial chamber conditions of 75% RH and 65º F (high RH and lower temperature) as well as at initial conditions of 20% RH and 90º F (low RH and higher temperature). The system was set up so that the device would be properly configured in advance and then turned on at the beginning of the test and no adjustments were made to the flow rate. The actual flow rate achieved during the test was recorded in the provided spreadsheet. A new MERV 13 filter was used for each test.

Figure 2 shows the decay curves for the *S. epidermidis* vegetative bacteria at conditions of the high RH and the lower temperature. The numbers of CFUs per cubic foot in the chamber are plotted on the y-axis with the time in minutes on the x-axis. The data points for each time represent average results from the three sampling locations. The error bars indicate the standard deviations calculated for the multiple samples comprising each average. The natural decay curve is labeled "device OFF", while the TCACS decay curve is labeled "device ON." The impact of the TCACS unit is readily visible in the graph. The decay rate with the device on is significantly and reproducibly higher than the decay rate with the device off over the time periods observed. The actual measured decay rate for the TCACS unit calculated according to the CARm method for each sampling location is shown in Table 1.

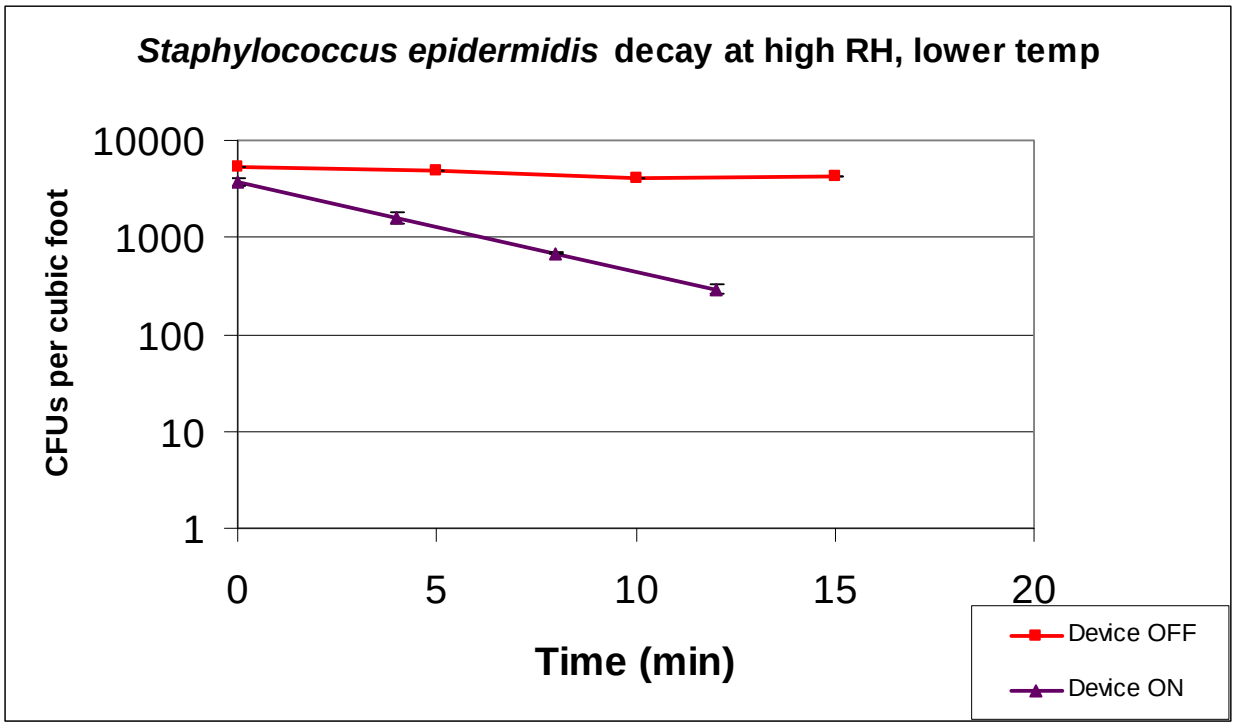

Figure 2. Decay curves for *Staphylococcus epidermidis* at high RH and lower temp

Figure 3 shows the decay curves and provides the same information for the *S. epidermidis* vegetative bacteria at the conditions of low RH and the higher temperature. The actual measured decay rate for the TCACS unit calculated according to the CARm method for each sampling location is shown in Table 2.

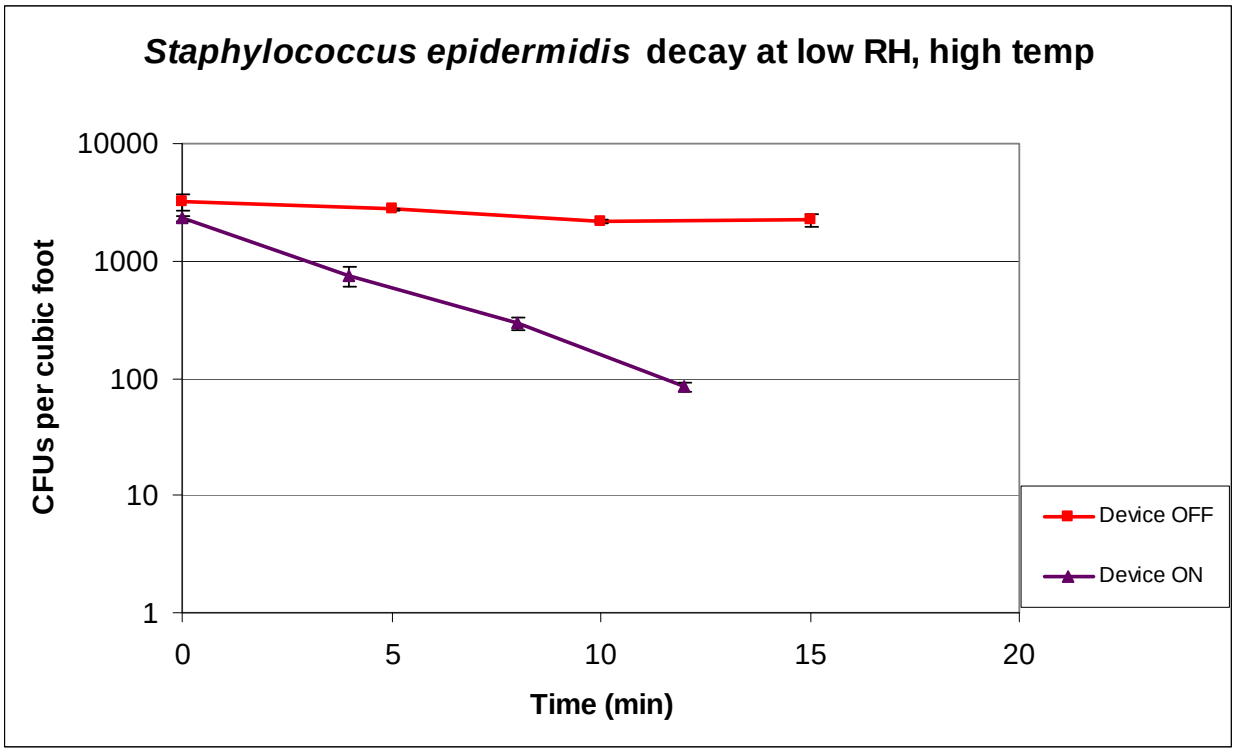

Figure 3. Decay curves for *Staphylococcus epidermidis* at low RH and high temp

Table 1. Decay rates measured for *S. epidermidis* at high RH and lower temp

Test Configuration	Chamber Position	Decay Rate
Natural Decay	knA	-0.01
	knB	-0.02
	knC	-0.02
Device on Decay	keA	-0.20
	keB	-0.22
	keC	-0.22

Table 2. Decay rates measured for *S. epidermidis* at low RH and higher temp

Test Configuration	Chamber Position	Decay Rate
Natural Decay	knA	-0.04
	knB	-0.02
	knC	-0.02
Device on Decay	keA	-0.27
	keB	-0.27
	keC	-0.28

Tables 3 and 4 present the average CARm results and standard deviations for the tests at the different temp and RH conditions. The CARm was calculated as shown in Eq. 2, and is a comparison of the two decay rates (natural and TCACS on decay) as a function of the volume of the test chamber (640 ft^3).

Table 3. CARm values for *S. epidermidis* calculated from mean decay rates for high RH and lower temp

Test Configuration	CARm (mean±SD)
Device on Decay	125±2

Table 4. CARm values for *S. epidermidis* calculated from mean decay rates for low RH and higher temp

Test Configuration	CARm (mean±SD)
Device on Decay	157±11

In the ideal case where the air cleaner provides a well-mixed chamber, the CARm is equivalent to the product of the air cleaner's flow rate and its inactivation/filtration efficiency for the challenge bioaerosol. In a chamber test, however, the test chamber is only "well-mixed" to the extent that the device itself provides this mixing by the air motions generated by its fan. Thus, the CARm combines the effects of efficiency of the air cleaner and the effectiveness of the air cleaner to draw the test chamber's air through it. Generally, the CARm should not exceed the air cleaner flow rate. The results show that the CARm value for the *S. epidermidis* challenge was indeed quite near the nominal TCACS air flow rate determined by Trane as 166 CFM. Thus, for the bacteria tested, the TCACS, with its combination of MERV 13 filter, UVC lights and PCO achieved near the maximum performance that could be expected from a device operating at the designated air flow.

Please let me know if you have any additional questions, and feel free to call me at 919-541-7349 or email me at mherman@rti.org.

Sincerely,

Michael L. Herman

Michael L. Herman
Microbiologist 2

cc: Karin Foarde
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