4835 Sirona Drive, Suite 400
Charlotte, NC 28273
844.233.5673

Applying Disinfectants For Large Surfaces using Covid-19 Approved Chlorine-based Liquid Solutions

M. Dovrat, O. Baharav, F. Habibulla, Q. Archer
Maxify Solutions, Inc.

Updated January 31, 2022

Abstract

Since it has recently been shown how SARS-CoV-2 (the cause of COVID-19) can stay viable and infectious on various surfaces for a period of days, there is a growing interest in using Power Breezer evaporative coolers as a means of disinfection against Covid-19. In this study, we show how the Power Breezer can be utilized as a means of depositing disinfectant products that meet the U.S. Environmental Protection Agency (EPA) criteria for use against SARS-CoV-2 (the cause of COVID-19). In particular, we demonstrate a method of creating the thin film of disinfecting solution required to disinfect surfaces.

Introduction

About the Power Breezer

The Power Breezer is an industrial-grade evaporative cooler capable of discharging 4–5 gal/hr of water mist. It throws clean water onto a high velocity rotating disk (the atomizer). Water is rotated and thrown (by centrifugal force) onto small walls on the disk's perimeter, which serves to break down the water into vapor or mist. This mist is added to a powerful air stream generated by a strong fan situated at the back of the atomizer. The mist evaporates in the air, serving to cool and humidify it. The mist is generally felt at a distance of up to 50 ft before it completely evaporates (depending on the ambient conditions). While the Power Breezer is a very effective evaporative cooler, it was not originally designed as a chemical sprayer or applicator. Nonetheless, the basic capability of dispersing mist (water vapor) at a high efficiency may be utilized in order to create a thin film of disinfecting solutions on surfaces exposed to the mist. This paper will demonstrate how to use the Power Breezer as a material deposition sprayer or applicator in order to create a thin wet film of disinfecting solution over a large area, which may be utilized in disinfecting surfaces. In addition, depending on the misting conditions, these surfaces may not even need to be in the direct line of sight of the Power Breezer in order that a wet film will be created on them.

Disinfectants for SARS-CoV-2

It has recently been shown that SARS-CoV-2 (the cause of COVID-19) may remain viable and infectious on surfaces for a period of days.[1] The list of disinfectants compiled by the EPA[2] mentions many commercially available products and materials that meet the EPA's criteria for use against SARS-CoV-2 for disinfecting surfaces by creating a wet-film over the surfaces for a time ranging between 1-10 min (per each manufacturer's instructions).

At this time (April 4, 2020), the EPA site [2] has 357 listed materials. Of these, 304 are in liquid form (either RTU - ready to use, or dilutable) suitable for use in the Power Breezer. Over 80% of these disinfectants can be classified into three main groups according to their main active ingredient - quaternary ammonium, sodium hypochlorite or other chlorine containing compounds, and hydrogen peroxide.

Since the outbreak of COVID-19, several materials have emerged with claims to be "registered by the EPA" or even the FDA, safe for use around people, "non-toxic", etc. One must be careful not to take these claims per se, as they may well be out of context. If the material is not on the EPA list for SARS-CoV-2, it cannot claim in high certainty that it will be effective. Claims stating that the active material of one material "appear on the list" are also out of context, since that said material has not met the sufficient level of proof required to be included on the list. Being safe for use around food products in certain concentrations does not mean safe to use on around people, and so forth.

Warnings and Disclaimers:

1. **Always read the label on the chemicals.** Despite what anybody may claim, most (if not all) of these chemicals are poisonous, harmful, and highly irritating to the skin, eyes, and respiratory system,[3] as well as may have other health related long-term effects.[4] That is not to say you should not use them. **Use as directed on the label or per specific SARS-CoV-2 instructions from the manufacturer,** and try to limit the human exposure to these chemicals to a minimum.
2. **NEVER mix chemicals!** The effect of mixing 2 chemicals is not "additive" (they won't disinfect faster or better) and may result in the release of highly toxic fumes and violent chemical reactions.
3. **These materials, even if in "ready to use" (RTU) form, may be corrosive to surfaces if exposed for a long period of time.** Dilute according to the instructions on the label or other instructions by the manufacturer in order to reach the concentration required against SARS-CoV-19. Higher concentrations may be harmful both to people and the disinfected

[1] "Aerosol and Surface Stability of SARS-CoV-2 as Compared ...." https://www.nejm.org/doi/full/10.1056/NEJMc2004973.
[2] "List N: Disinfectants for Use Against SARS-CoV-2 | Pesticide ...." https://www.epa.gov/pesticide-registration/list-n-disinfectants-use-against-sars-cov-2.
[3] "Chemical Disinfectants | Guidelines Library - CDC." https://www.cdc.gov/infectioncontrol/guidelines/disinfection/disinfection-methods/chemical.html.
[4] "Choosing safer products to clean and sanitize your home - EPA." https://www2.epa.gov/sites/production/files/2013-08/documents/fact_sheet_for_families_choosing_safer_products_to_clean_and_sanitize_your_home.pdf. Accessed 4 Apr. 2020.

surfaces. In any case, Power Breezer and our Distributors assume no liability to the effects these materials have on equipment, furnishings, machines or **people**.

4. **Do not mist directly on people, animals, open food, and plants. Remove all people and animals from the affected area before or immediately following the initiation of misting. Thoroughly ventilate the area after dispensing. Seal and mark the area where disinfection takes place and ensure no person is inside or walks into the area before it had been properly ventilated.** In case of accidental direct misting, follow the guidelines on the label, which in general may recommend removing contaminated clothing, washing the skin and eyes to avoid irritation, letting the affected person breathe fresh air, and seeking professional medical advice in case of a severe exposure.
5. **Do not spray alcohol with the Power Breezer.** The has the potential to be a very serious fire or explosive hazard. **Do not attempt this.**
6. **Do not spray** in the presence of exposed electrical wires or batteries. **Water and electricity - do not mix!**
7. **Be careful of slip hazards due to the water solution film on floors and equipment.**
8. **Buyer acknowledges that the seller has no expertise in disinfection of surfaces. Disinfection expertise and guidance is from the manufacturer of the disinfectant, the EPA and the CDC. Seller does not warranty or claim the use of Product on it's own is effective against COVID-19. Buyer acknowledges that the use of Product with disinfectants MUST follow the EPA and/or CDC guidelines and the EPA registered disinfectant's label direction for use in misting. Buyer acknowledges that all risks related to effectivity, efficacy or harm to people or equipment are borne by the buyer. Buyer further acknowledges that certain product parts have not been sufficiently tested for long use with the added disinfectants. These parts may be affected by use of disinfectants and consequently may not be covered by the Product's standard warranty.**

With regards to the Power Breezer system itself, after inspecting some of the materials on the EPA list, we can conclude with a high degree of certainty that the Power Breezer can withstand exposure to bleach, quaternary ammonium compounds, and hydrogen peroxide in the concentrations required to disinfect against SARS-CoV-2. However, please understand that extensive testing over a long exposure period was not performed. If the need arises, the pump, tubing and atomizer are readily available as replacements parts. In order to minimize the possibility of long-term damage to some of these components, run some fresh water through the system after the disinfection is done in order to remove the chemicals from the unit.

The use of Bleach

The U.S. Department of Health Center of Disease Control and Prevention (CDC) specifically recommends using diluted household bleach[5] in order to disinfect surfaces against COVID-19.[6] We, therefore, concentrate in this paper on using chlorine-based solutions, but the results shown will be equally applicable to other solutions as well.

Household bleach is composed of 2 main ingredients. The active ingredient in most household bleach is sodium hypochlorite (NaOCl, the sodium salt of hypochlorous acid HOCl) and a stabilizing agent is added (sodium hydroxide, NaOH) in order to slow down the decomposition of the active ingredient. The dilution ratio of household bleach mentioned in [4] for use as a disinfectant is approximately 1:50 ("5 tablespoons per gallon of water", or "4 teaspoons per quart", see the table below).[7]

Mixing Instruction	Resulting Dilution Ratio
5 tablespoons per gallon	5:256, or 1:51.2
4 teaspoons per quart	4:192 or 1:48

However, the active ingredient concentration is still rather vague, since the concentration of the active ingredient in household bleach solutions ranges from 3–8.25%. Reference [4] (from CDC) further reduces the range of active ingredients most abundant in US household bleach to 5.25–6.15%, resulting in an active ingredient concentration ranging in 1,005–1,255 PPM (parts per million[8]) in water. This concentration is consistent with similar instructions from the Australian Department of Health pertaining to disinfection principles for COVID-19, mentioning the concentration of 1000 PPM of hypochloric acid (the active ingredient in bleach).[9]

Experiment

In order to create a wet film over a large surface area, we have used a Power Breezer unit (2019 model and after), with a 1 HP fan motor (the standard, with 5 or 6 blades impellers).

We prepared a diluted bleach solution (1,000 PPM) and put it into the unit. We ran the Power Breezer in swing (oscillation) mode over a large concrete floor and measured the time it takes for a thin film of diluted bleach solution to form over the entire area of coverage. We also measured the size of the area where this wet film has formed.

---

[5] Bleach means a liquid solution where sodium hypochlorite is the main active ingredient typically available off the shelf.
[6] "Clean & Disinfect - CDC." 6 Mar. 2020, https://www.cdc.gov/coronavirus/2019-ncov/prepare/cleaning-disinfection.html.
[7] The standard sizes are 3 teaspoons per tablespoon, 64 tablespoons per quart, and 4 quarts per gallon. See "Volume Converter." https://www.unitconverters.net/volume-converter.html.
[8] 1,000 PPM is by definition 0.1%. 1,005–1,255 PPM are 0.1005% to 0.1255%
[9] "Environmental cleaning and disinfection principles ...." https://www.health.gov.au/sites/default/files/documents/2020/03/environmental-cleaning-and-disinfection-principles-for-covid-19.pdf.

The temperature at the time of the experiment was 54°F (12°C), and the relative humidity was 60%.

Results

A noticeable wet film appeared after 4 hours over a sector of 60° (the unit's swing angle) up to a distance of 60 ft away from the unit.

Discussion

As seen in the results, we have been able to show how to obtain a wet film of a diluted bleach disinfecting solution over a large surface area, for a period greater than 10–30 minutes (the recommendation for most of the materials appearing on the EPA list [2]).

Although the experiment was conducted using diluted bleach, the results may be equally applicable to the disinfectants with other active ingredients (quaternary ammonium, hydrogen peroxide, or both).

The recommendations for use are as follows:

Formula Preparation:

If there are no specific COVID-19 instructions on the manufacturers' labels, you may use the table below to prepare a diluted bleach solution with ~1,000–1,200 PPM active ingredients, according to the two outlined methods of use. Please use a volume measurement cup with the appropriate imperial units (fl oz, cups). Please fill water first (according to the volume specified) and add the specified volume of bleach to water.

Original Strength of Active Ingredient	Preparation of ~20 gallons of bleach disinfecting solution (5 hours of operation)		
	"bleach"	Water	Concentration
5%	7 cups	20 gallons	1,070 PPM
5.25%	7 cups	20 gallons	1,123 PPM
6.15%	6 cups	20 gallons	1,132 PPM
8.25%	4.5 cups	20 gallons	1,144 PPM
10%	3.5 cups	20 gallons	1,082 PPM

"Bleach" (sodium hypochlorite) is offered by many brands, not all registered with the EPA, and even in some pool chlorinating solutions (at the high concentrations). If you get a hold of a concentration which does not appear on the table, use these formulas:

To get a 1100 PPM solution for W gallons of water:

(The volume in fl oz. to add to W gallon of water) = 128 × W / [9.1 × (Concentration in percent) - 1]

For example, starting from a 3% solution:

128 / (9.1 x 3 - 1) = add 4.87 fl oz. to 1 gallon of water

And to get a 1,100 PPM solution for W gallons:

(The volume in cups to add to W gallons of water) = 16 × W / [9.1 × (concentration in percent) -1]

For example, starting from a 3% solution:

16*20 / (9.1 * 3 - 1) = add 12.2 cups to 20 gallons of water

Dispensing the Material:

1. Preparing the unit
    a. First, fill the Power Breezer with 8 gallons of water
    b. Add any commercial bleach solution to the water diluted per table above.

2. Disinfecting the area
    a. Use one Breezer per approximately 5,000 square feet
    b. Close all doors and windows
    c. Set the Power Breezer fan to maximum and ensure the misting valve is in the fully open position.
    d. The machine will mist for 2 hours after which the solution would run out and only the fan will keep running, the pump will go to idle mode (to reset the pump for a subsequent operation, power off the unit and turn it back on).
    e. Open windows and doors, as soon as the visible film evaporates 10–30 minutes later (depending on ambient conditions) people can return to the disinfected area.

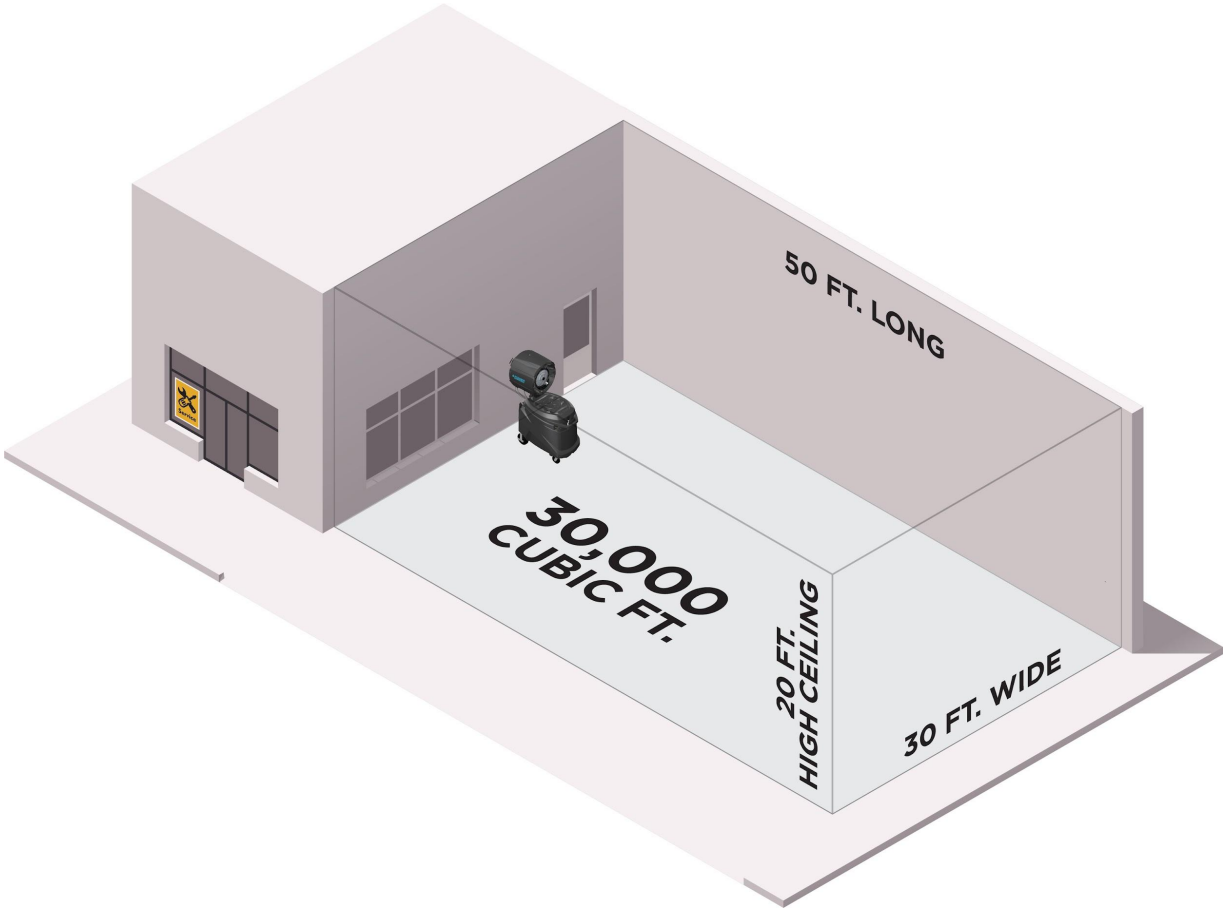
After Disinfecting:

After the disinfectant solution is finished, please refill the system with some pure water and allow it to work in order to remove any leftover chemicals from the Power Breezer internal parts (pump, tubes, and atomizer).

How Many Power Breezers Are Required to Disinfect a Large Space?

In order to answer this question, we resort to the psychrometric chart.[10] We know and remember that the evaporative cooling process is an isenthalpic process, so from the initial conditions in the room, we know what would happen if we keep adding humidity to the room with the Power Breezer: the air-vapor state would change along an isenthalpic line until we reach the dew point. In reality, we will not follow this line exactly, since the Power Breezer power (1,500 W) is also dissipating into the space, and the area is never hermetically closed to the surroundings so air may still be replaced with some outside air.

Example 1:

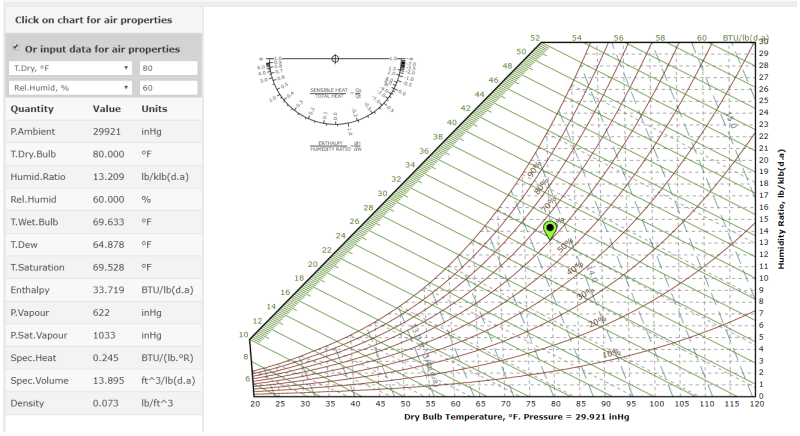


We are trying to disinfect a 50 x 30 ft room with a 20 ft high ceiling with a Power Breezer. That's 30,000 cubic ft. Let's assume that the temperature is 80℉, and the relative humidity is 60%.

From the psychrometric chart (or calculator), we see the following data:

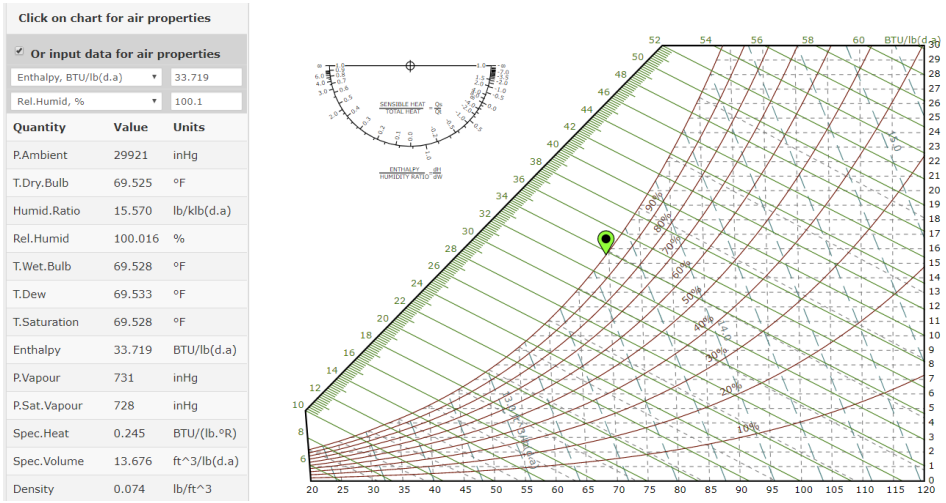
- The enthalpy is 33.72 BTU/lb (dry air).
- The humidity ratio is 13.209 lb water / 1,000 lb dry air
- The specific volume is 13.895 ft^3 / lb (dry air)

[10] "Free Online Interactive Psychrometric Chart - FlyCarpet." http://www.flycarpet.net/en/PsyOnline.

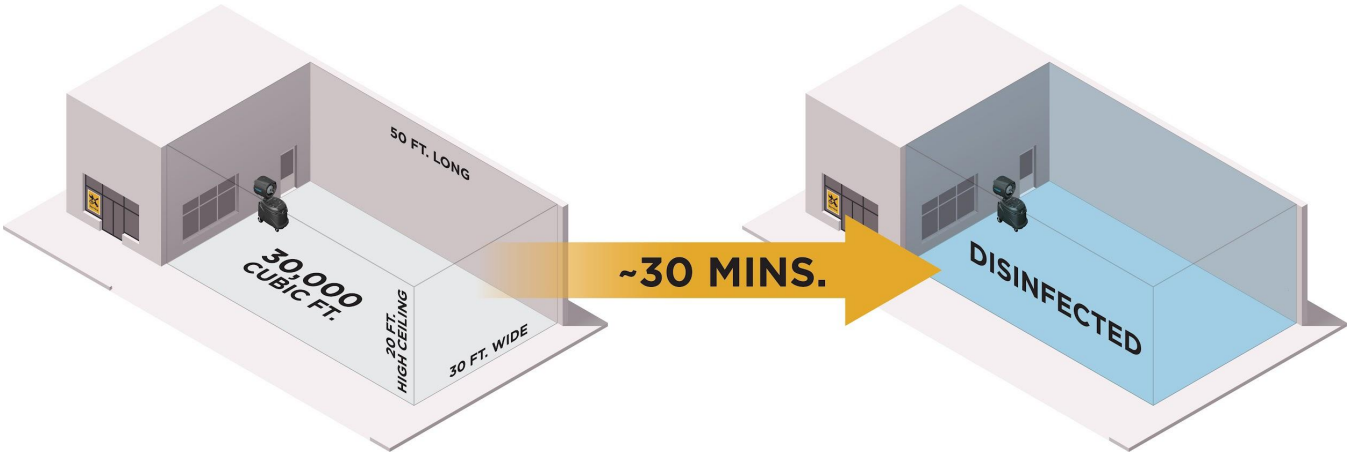


From the specific volume, we see that the air-vapor mixture in the room contains 2,159 lb dry air, and from the humidity ratio, we see that this amount of dry air carries 28.52 lb of water.

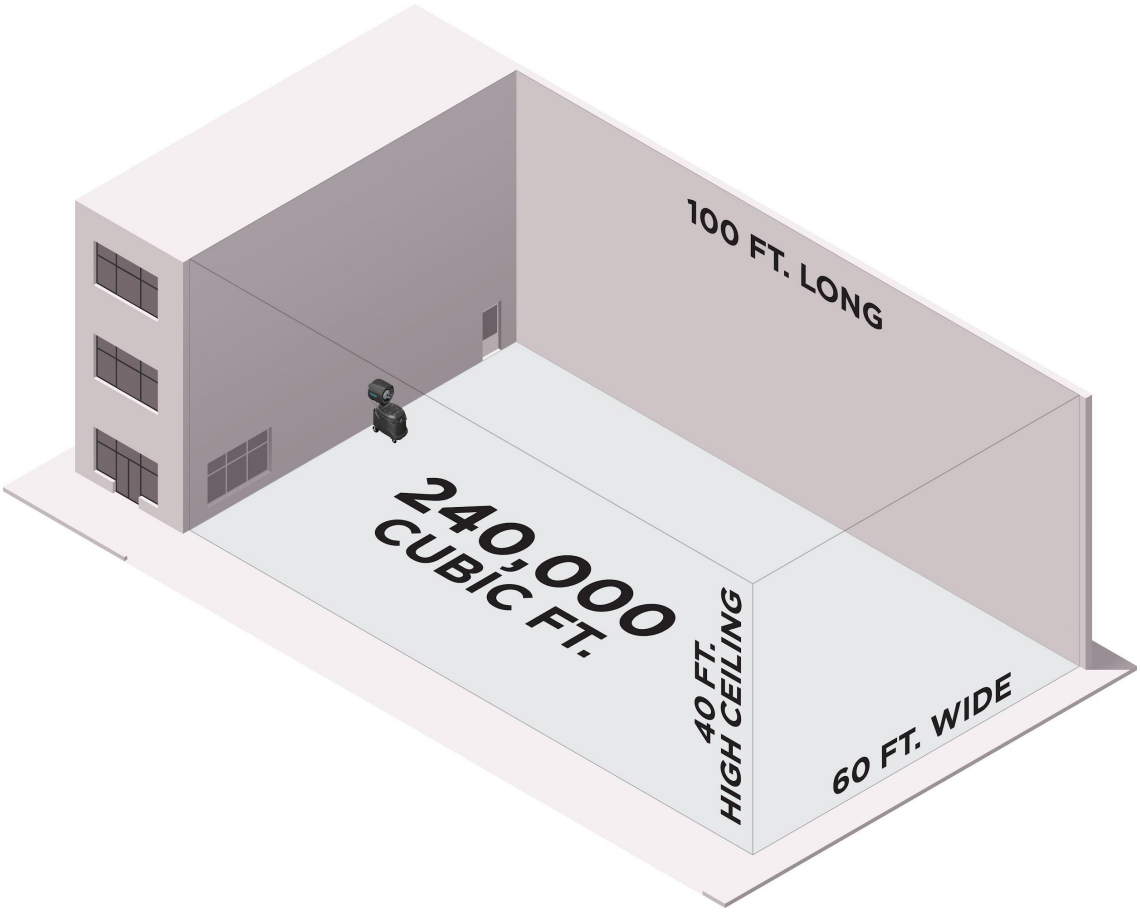
If we keep this enthalpy value (since the evaporative cooling process is isenthalpic) and calculate for 100% relative humidity, we see that the humidity ratio will be 15.57 lb water / 1,000 lb dry air. We need to add 5.1 lb of water to the existing air in order to reach this state.



If we now want to cover all of the walls, floor and ceiling of this room (totalling 6,200 sq ft) with a thin film of 10 microns (0.4 mil in Imperial units), we would need an additional 12.7 lb of water. We therefore need to disperse 18 lb of water, which are 2.2 gallons. This will take 30 minutes (at 4-5 gallons/hr).



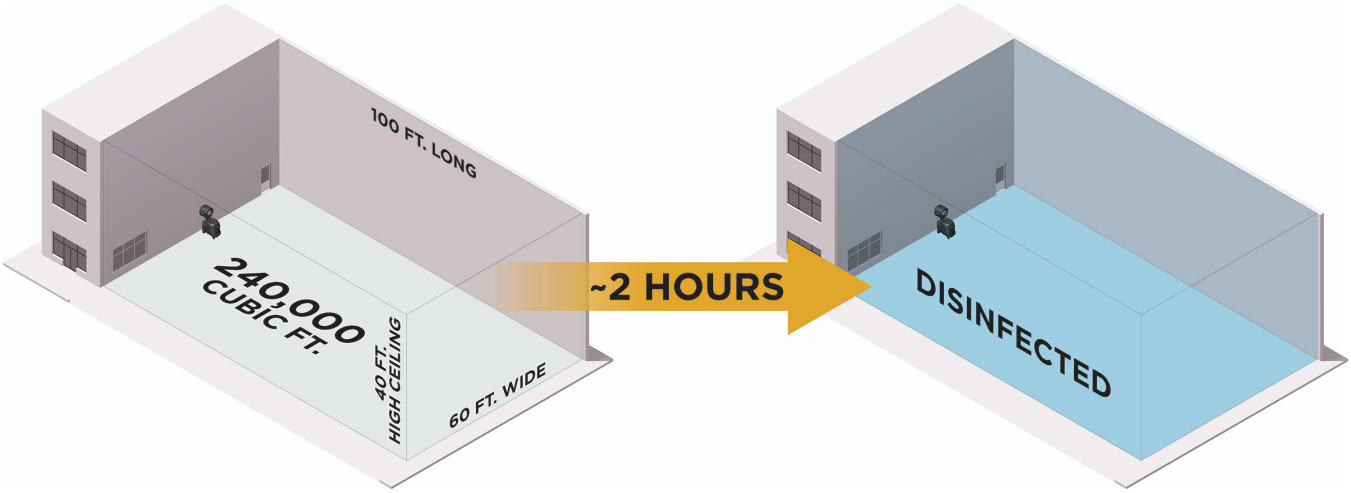
Example 2:



We are trying to disinfect a 100 x 60 ft room with a 40 ft ceiling. With the same conditions as in example 1 (80℉, 60% RH). The total volume of air is 240,000 cb ft, and the surface area of all of the walls is 24,800 sq ft.

Repeating the same calculations, the air is composed of 17,272 lb of dry air plus 228.15 lb of water (for 60% humidity). In order to saturate this volume 100% humidity, we will need the air to carry 269 lb of water, so we will need to add 40.8 lb of water.

In order to cover our 24,800 sq ft of walls and ceilings with a wet film of water (10 microns), we would need an additional 50.8 lb of water. We therefore need to disperse 91.6 lb of water, which are 11 gallons. This will take a little over 2 hours (at 4–5 gallons/hr).



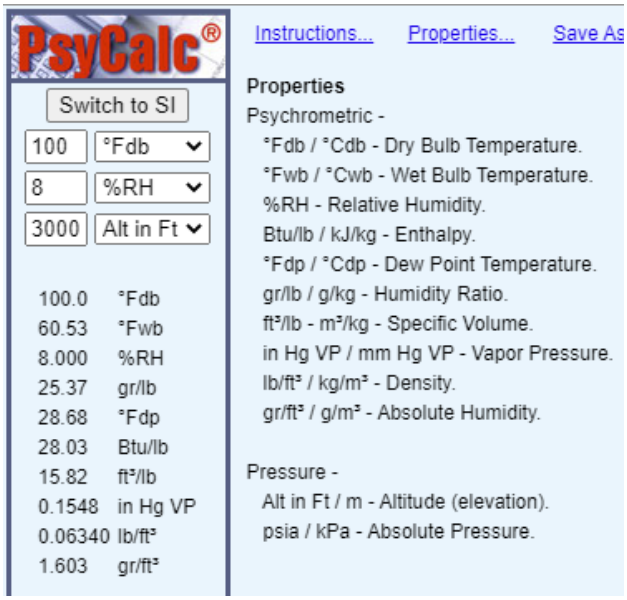
Example 3

We are trying to disinfect a field military tent which is 60 x 90 x 18 ft (9 ft height of the rectangular portion, and 9 ft of the triangular prism rooftop). Total 72,900 cb. ft. The surface area of all of the walls and ceiling is 14278 sq. ft.

We assume we are in a desert climate, with a temperature of 100℉ and a relative humidity of 8%. We also assume the elevation is 3000 ft. above sea level.

Using a psychrometric calculator,[11] we establish the following:

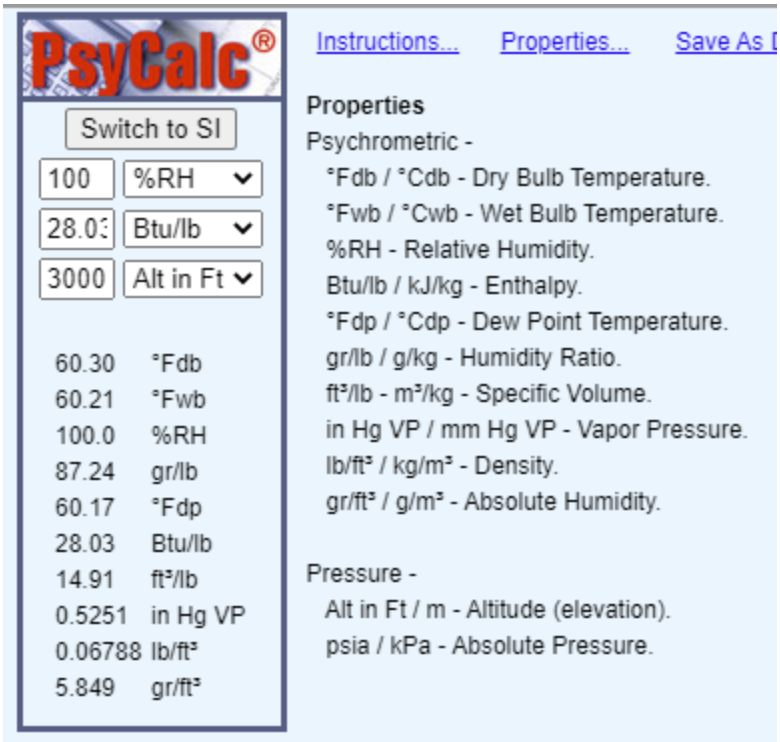
[11] http://www.uigi.com/WebPsycH.html



1. The enthalpy is 28.03 BTU/lb
2. The humidity ratio is or 25.37 grains / lb (water in dry air)
3. The specific volume is 15.82 cb.ft/lb (dry air).

Using the specific volume we calculate (total air volume / specific volume) that the tent holds 4608 lb dry air, and using the humidity ratio, we can tell (humidity ratio x dry air weight) that this amount of air holds 16.7 lb of water.

We keep the same enthalpy value (the evaporative cooling keeps the same enthalpy) and calculate the state for 100% humidity (complete air saturation).



We see the following:

1. The humidity ratio is now 87.24 gr / lb
2. The specific volume is 14.91 cb ft / lb

The tent air holds 4889 lb dry air with 60.94 lb of water in it (air is more dense now, some air must enter from the outside). Since we started with 16.7 lb of water, we need to add 44.2 lb. to saturate the air. We also want to cover the entire surface area with 4 mil (10 microns) of wet film. That adds 4.76 cb ft of water. The density of water at this temperature[12] is 62.363 lb/cb ft, 8.3367 lb/gal.

We combine the amount of water to saturate the air with the amount of water to cover the surface, and get 44.2 lb to add to the air, 296.8 lb to cover the surfaces, total 341 lb water, which are 40.9 gallons.

At 4 gallons/hr, it would take one unit to run for 10 hrs to achieve this.

Bear in mind that these calculations are done for “ideal” conditions. Several real-life phenomena may alter the actual result:

1. We assume that no significant amount of air can escape the tent during this time. Mixing with fresh (dry and hot) air would slow down the humidification process.
2. We assume that we are able to saturate the entire air volume. In real-life, hot air would tend to rise (or keep) to the ceiling, and cold air would fall to the floor. That would actually decrease the required time to cover the areas of interest (which are near the floor) with a wet film.
3. The tent is not completely insulating, and is exposed to sunlight. Both factors serve to heat the interior while disinfection is occurring.

[12] https://www.engineeringtoolbox.com/water-density-specific-weight-d_595.html

Conclusion

In conclusion, we have demonstrated how to create a film of chemical solution consistent with CDC recommendations for disinfecting surfaces against COVID-19 by using the Power Breezer for a period of a few hours in which the unit may be left unattended.

