Understanding critical measurement parameters in vaporized hydrogen peroxide bio-decontamination

Sanna Lehtinen

Abstract

This article discusses the importance of the relationships between temperature and relative humidity in vaporized hydrogen peroxide applications and introduces a new parameter: relative saturation. Relative humidity (RH) is a critical parameter in H_2O_2 vapor applications whether with a dry or wet method of bio-decontamination. Relative humidity is, of course, relative to temperature, so that is the second important parameter. The higher the temperature, the more H_2O_2 ppm can be added to the air mixture before condensation occurs. However, the addition of hydrogen peroxide vapor to the air mixture also has a great impact on the point at which condensation occurs.

Relative saturation is a new measured parameter that indicates the point at which the combined water vapor and hydrogen peroxide vapor will start to condense. When the air mixture contains vaporized H_2O_2, relative humidity can never reach 100%, making it nearly impossible to know exactly when condensation will occur. The greater the temperature, the greater the allowable relative humidity. On the other hand, the higher the H_2O_2 concentration, the lower is maximum achievable RH. It is proposed that relative saturation is a critical parameter in bio-decontamination processes because it accurately represents the point at which condensation can be expected to occur.

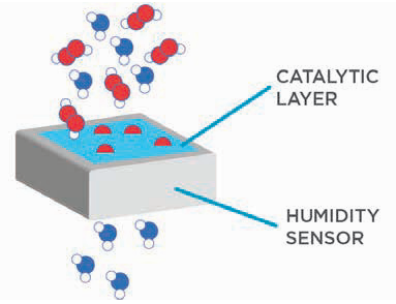

Figure 1: Diagrammatic representation of a humidity sensor with a catalytic layer

Introduction

Because vaporized hydrogen peroxide leaves no residue and is efficient for bio-decontamination in room temperature, it is used widely in applications such as isolators, transfer hatches and in different facilities that require reliable decontamination.

The relationships between temperature, relative humidity and relative saturation

Effective killing of microorganisms can be achieved with different humidity and H_2O_2 ppm levels. Some manufacturers of bio-decontamination chambers or isolators prefer subvisible condensation, whereas others prefer dry bio-decontamination processes where humidity is maintained far from condensation. However, dripping condensation should be avoided due to potentially negative effects on aeration time, materials and uniform decontamination efficiency. Therefore, it's crucial to measure humidity during vaporized hydrogen peroxide bio-decontamination cycles. However, water (H_2O) and hydrogen peroxide (H_2O_2) have a very similar molecular structure. Therefore they both affect the humidity of the air.

Relative humidity by its definition indicates the humidity of the air caused only by water vapor. Therefore, humidity sensors used in vaporized hydrogen peroxide applications typically use a catalytic layer over a normal humidity sensor. The catalytic layer catalyzes the hydrogen peroxide so that the humidity sensor measures only water vapor as shown diagrammatically in Figure 1. The measured relative humidity indicates the humidity of the air caused only by water vapor. When measuring H_2O_2 in a vapor state, relative saturation

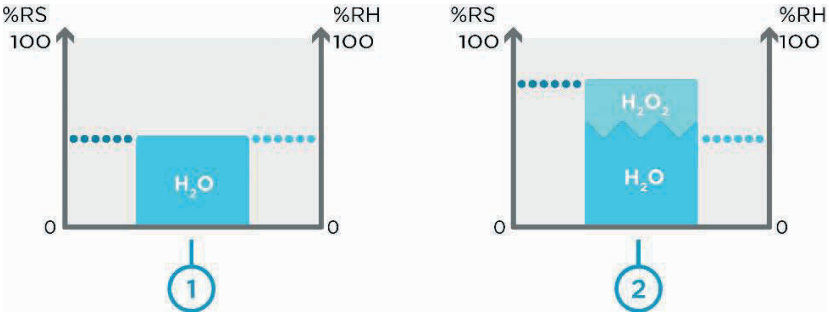

Figure 2: Space 1 without H_2O_2 vapor and space 2 with H_2O_2 Vapor

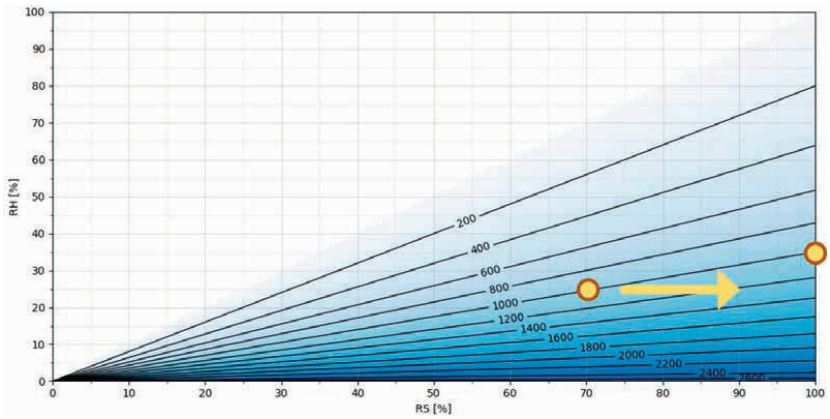

Figure 3: H_2O_2 ppm as a function of RS/RH at T = 25 °C

is the parameter that indicates the amount of humidity in the air caused by both hydrogen peroxide and water vapor. The air mixture starts to condense when the relative saturation reaches 100 %RS. Relative saturation is the only parameter that indicates when the air mixture with the water vapor and hydrogen peroxide vapor starts to condense. Therefore, it is essential to follow the relative saturation value during the bio-decontamination process.

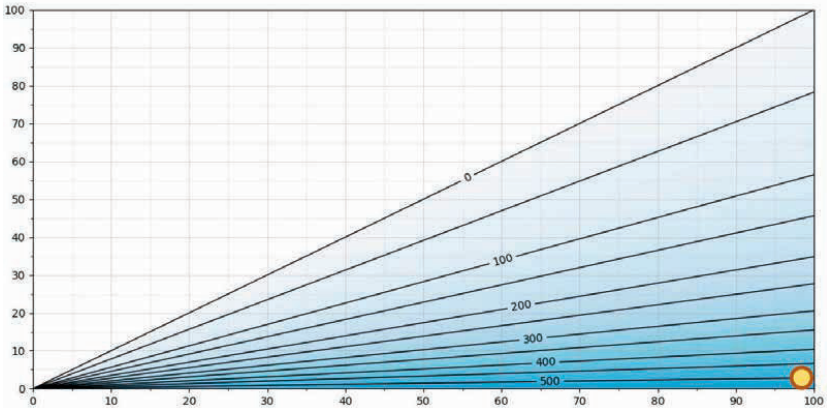

Figure 4: H_2O_2 ppm as a function of RS/RH at T = 5 °C

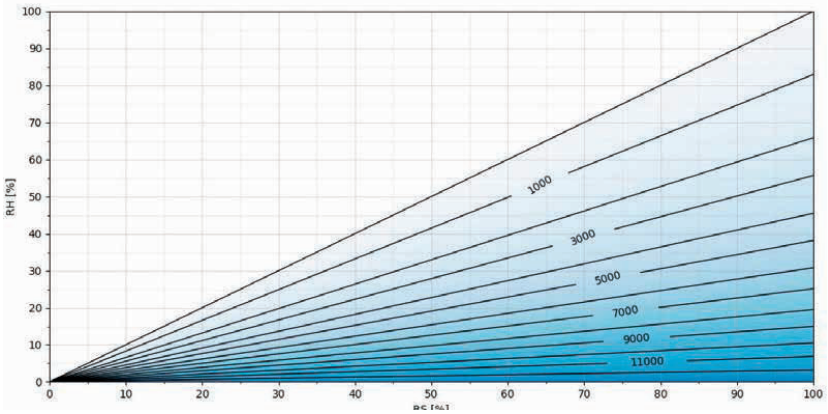

Figure 5: H_2O_2 ppm as a function of RS/RH at T = 50 °C

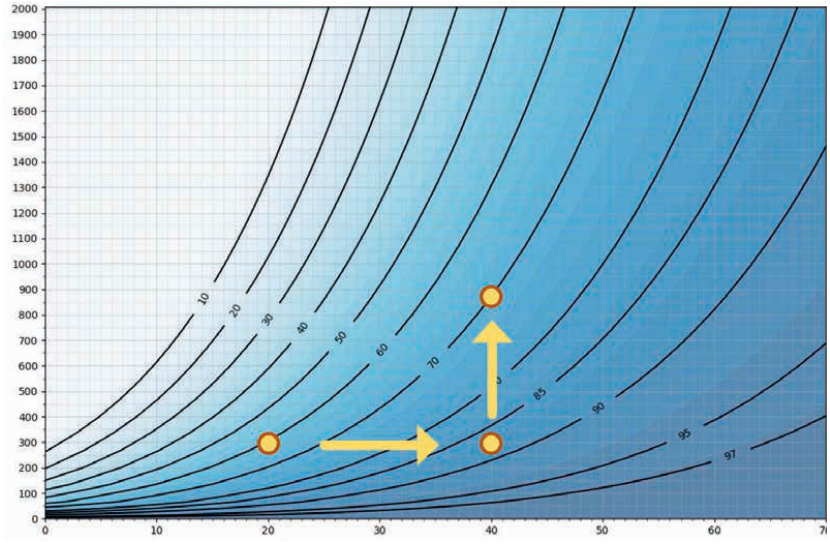

Figure 6: The x axis = temperature, y axis = ppm concentration

Rule: The higher the H_2O_2 ppm, the lower the maximum achievable RH and the greater the difference between RH and RS.

Figure 2 shows two different spaces: space 1 without H_2O_2 vapor and space 2 with H_2O_2 vapor. When H_2O_2 vapor is not present, relative saturation equals relative humidity. This can be seen in space 1. Within space 2, we have the same volume of air with H_2O_2 vapor introduced. Now, relative saturation is higher than relative humidity.

Figure 3 shows you H_2O_2 ppm as a function of relative saturation and relative humidity at 25 °C. Relative saturation is on the x axis and relative humidity is on the y axis. Darker shading shows higher ppm of H_2O_2. As you can see, the more hydrogen peroxide in the air mixture, the greater the difference between relative saturation and relative humidity values. For example, at 25 °C and 1000 ppm hydrogen peroxide, the humidity level 25%RH is equivalent to 70%RS. When this gas mixture with 1000 ppm hydrogen peroxide starts to condense (relative saturation being 100%), relative humidity is 35%.

Temperature affects how much hydrogen peroxide can be in the air before condensation (relative saturation equals 100 %RS). Thus, the graph on Figure 3 changes when temperature changes.

Figure 4 shows same graph at 5 °C. The maximum H_2O_2 ppm level at 5 °C is slightly above 500 ppm. As an example, at 5 °C, 500 ppm hydrogen peroxide and Relative Saturation 100 %RS, the relative humidity is approximately 2 %RH. As the relative saturation is 100 %RS, the air mixture will condense. The difference between %RS and %RH at this temperature is enormous: 100 %RS vs. 2 %RH. Measuring %RH in this particular case is of no real value.

The higher the temperature, the more H_2O_2 ppm can be added to the air mixture before condensation, as seen in Figures 5 and 6. In Figure 5, at a temperature of 50 degrees Celsius, an H_2O_2 concentration of >12000 ppm can be achieved.

Each point in Figure 6 represents a condensation point, I.E. relative saturation is 100 %RS. Temperature is on the x axis and H_2O_2 ppm is on the y axis. The curves show the maximum relative humidity. As an example, at 20 °C and 300 ppm hydrogen peroxide, 60%RH is equivalent to 100%RS. If we increase air temperature to 40 °C with an H_2O_2 concentration at 300 ppm, relative humidity will be 87% and

relative saturation will be 100%. Condensation occurs at a relative humidity of <100% because of the relationship between air temperature and H_2O_2 concentration. Therefore the higher the temperature, the higher the maximum RH%. If we increase the hydrogen peroxide level from 300 ppm to 900 ppm at 40 °C, then the maximum achievable relative humidity decreases from 87 %RH to 70 %RH. The higher the ppm concentration, the lower the maximum %RH.

These figures illustrate why it is insufficient to look only at relative humidity in bio-decontamination processes that use vaporized hydrogen peroxide. Air that is infused with H_2O_2 will condense at <100% relative humidity, depending on the temperature of the air and the concentration of hydrogen peroxide. When the air mixture contains vaporized H_2O_2, relative humidity can never reach 100% making it nearly impossible to accurately estimate when condensation will occur. The greater the temperature, the greater the allowable relative humidity. On the other hand, the higher the H_2O_2 concentration, the lower is maximum achievable RH.

When performing bio-decontamination with vaporized hydrogen peroxide, relative saturation is the only parameter that accurately represents the true saturation level; that is, the point at which you can expect condensation to occur.

To learn more, please visit: www.vaisala.com/biodecontamination or contact Vaisala at www.vaisala.com.

Sanna Lehtinen is a Product Manager at Vaisala. She has worked as an electronics designer and with life science product management in leading international high tech companies for 20 years. At Vaisala, Sanna ensures product quality and road mapping, gathers industry insight, develops leading products for demanding customer needs and produces relevant customer-facing material. Sanna holds an MSc in Biomedical Engineering from Tampere University of Technology and an MSc in Economics from Helsinki School of Economics.