The Effect of Wind Velocity on the Cooling Rate of Water

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Abstract

The effect of wind velocity on the cooling rate of water was investigated by blowing air horizontally over the surface of water contained in a plastic water-bottle cap. The time taken for the temperature to fall to the average of the surrounding and initial temperatures was recorded at different values of wind velocity. It was observed that on increasing the wind velocity, the time taken to achieve average temperature not only decreased but also remained the same after a certain point.

***Keywords*:** cooling rate, wind velocity, evaporation

I. INTRODUCTION

There are several opinions on scientific forums and websites regarding the cooling of a hot liquid by blowing over it.[1] Most of them assume that constant blowing leads to continuous cooling.[2] To the author's knowledge, no data has been published in this field. The aim of this investigation is to provide experimental evidence and a possible explanation as to how cooling might occur when air is blown over a liquid (water).

First, we define "time constant" (τ) as the time taken by a hot body to reach the average of the ambient and initial temperature

$$T(\tau) = \frac{T_0 + T_S}{2} \qquad (1)$$

where T_s is the ambient temperature and T_0 is the initial temperature of the body. By varying the wind velocity, we observe a change in time constant, which in turn allows us to deduce a meaningful relationship between the cooling rate of water and wind velocity.

II. METHODS

Air was blown through a steel pipe at a constant speed by connecting it to a vacuum cleaner in blower-mode. To vary the wind velocity over the surface of the water in a bottle cap, the distance of the cap from the mouth of the steel pipe was changed.

Next, water was heated to a temperature of 55.0 ± 0.1ºC and 27.6 grams of this water was poured into a dry bottle cap of inner radius 5.20 ± 0.01 cm and height $2.30 \pm$

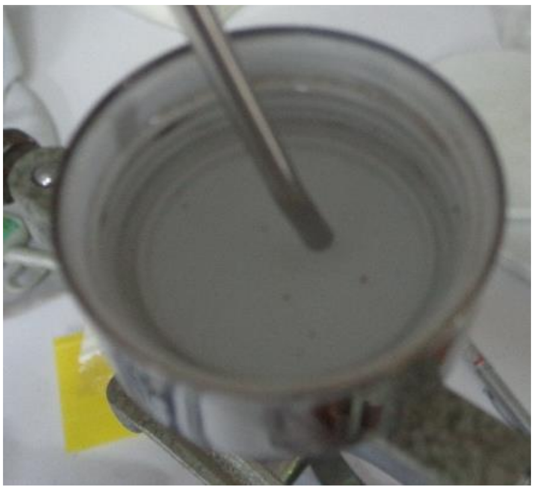

Figure 1. Hot water in the bottle cap with the temperature probe.

0.01 cm. The bottle cap containing the hot water (with a temperature probe dipped in the hot water, as shown in figure 1) was placed at the distances where the value of wind velocity was previously measured. The readings were recorded beginning when the temperature of the water fell to 50.0 ± 0.1^{o}C and continued until the temperature cooled to below 39.0 ± 0.1^{o}C.

The value of the time constant was determined for different distances (wind velocities) by noting the time taken for the water to reach the average value (39°C) of the initial temperature (50°C) and the surrounding temperature (28°C). So for instance, when the wind velocity was equal to 5.8 ms^{-1}, the time constant for a particular trial was measured to be 3.89 minutes, as shown in figure 2.

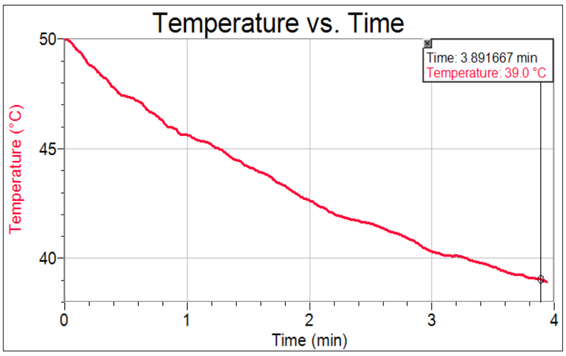

Figure 2. Cooling curve when the wind speed was 5.8 ms^{-1}.

III. RESULTS AND DISCUSSION

When selected trials of Temperature vs. Time for different wind speeds are plotted on the same graph for comparison (figure 3), we observe that the rate of cooling (slope of Temperature vs. time graph) becomes the same at higher wind speeds.

This suggests that the cooling rate levels out at some value of wind velocity. In order to approximately determine this value of wind velocity, a graph of the

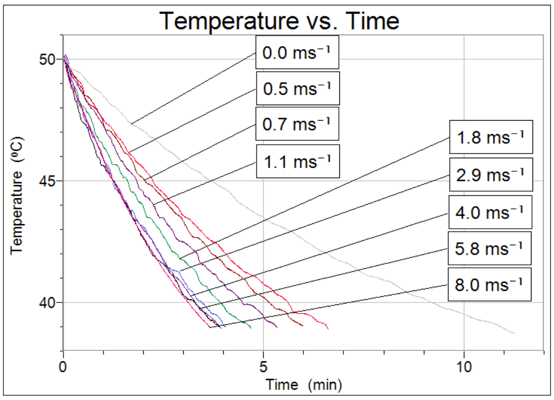

Figure 3. Family of cooling curves for different values of wind velocity.

mean values of time constant and their respective wind speed was plotted.

From figure 4 it can be inferred that the time constant and therefore the cooling rate levels out when the wind velocity reaches a value of about 4 ms^{-1}.

A possible explanation could be as follows: The air molecules rushing from the source collide with the evaporated water molecules that escape the surface of the hot water contained in the cap. So, each time the water molecules accumulate above the cap, they are, in essence, being "swept" away by these air molecules. This process, therefore, might result in the fall of the partial vapor pressure (the pressure of a vapor in equilibrium with its non-vapor phases) above the cap, allowing water molecules to move from a

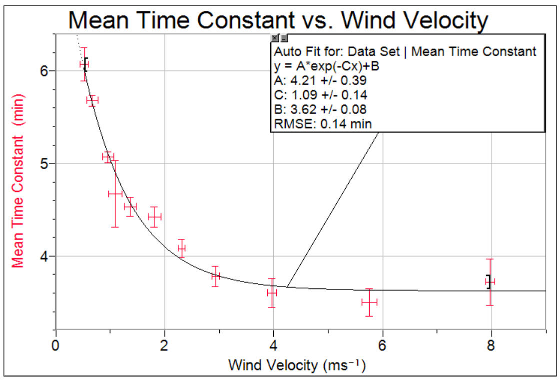

Figure 4. Wind speeds greater than about 4 ms^{-1} have no further effect on the mean time constant.

region of high pressure (on the surface of water) to a region of low pressure (above the cap). However, when the speed of the air molecules is sufficiently high, the space above the water surface will be "swept" almost immediately, and any further increase in wind velocity will not have any effect on the time constant (and hence on the cooling rate).

Further research into the effect of wind temperature and streamlined airflow on the cooling rate of water could be done. The same experiment could also be replicated for solids and other liquids to check whether the mean time constant levels out for these materials. To test the validity of our hypothesis, the loss of water mass by evaporation could be measured as a function of time (evaporation rate) for different wind speeds. If the evaporation rate is found to level out when wind speed reaches 4 ms^{-1} then that would confirm the role of evaporation in the cooling process.

IV. CONCLUSION

The time taken for water at an initial temperature of 50^oC to cool to the average value of its initial temperature and that of its surroundings, decreases with increasing wind speed while approaching a minimum value when the wind speed reaches 4 ms^{-1}. For wind speeds greater than 4 ms^{-1}, there is no further decrease in the time constant.

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