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# EXPERIMENTAL MEASUREMENT OF WET-BULB TEMPERATURE

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## Abstract

The wet-bulb temperature is an important psychrometric property and accurate measurements are essential for testing and rating of various types of Heating Ventilating Air Conditioning and Refrigeration (HVACR) equipment. The goal of the research project is to develop guidelines for measurement of wet bulb temperature and comparing with thermodynamic wet bulb temperature. Wet Bulb Temperature needs to measure which is as much as equal to thermodynamic wet bulb temperature. For measurement of wet bulb temperature an aspirated psychrometer and globe thermometer is designed and developed. The research will provide the basis for improvements in ASHRAE Standard 41.6-1994, Standard Method for Measurement of Moist Air Properties. The outcomes are the precautions to be taken during the measurement and providing guidelines which are used to avoid error in measurement of wet bulb temperature.

## 1. Introduction

The thermodynamic wet-bulb temperature T*, is a unique property of a given moist air sample that depends only on the initial properties of the moist air W1, h1 and p. It is also an imaginary property that only hypothetically exists at the end of an ideal adiabatic saturation process [1]. For any state of moist air, there a thermodynamic wet-bulb temperature T* exists that exactly equals the saturated temperature of the moist air at the end of the ideal adiabatic saturation process at constant pressure [1]. If moist air at humidity ratio w1, enthalpy h1, an initial temperature T1, and pressure p

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flows over a water surface of infinite length in a well-insulated chamber, as shown in below Figure (1) liquid water will evaporate into water vapor and will disperse in the air. The humidity ratio of the moist air will gradually increase until the air can absorb no more moisture. As there is no heat transfer between this insulated chamber and the surroundings, the latent heat required for the evaporation of water will come from the sensible heat released by the moist air [1].

### 1.1 Measurement of Wet Bulb Temperature:

When unsaturated moist air flows over the wet bulb of thermometer, liquid water on the surface of cotton wick evaporates and as a result, the temperature drops this depressed temperature is called wet bulb temperature [1]. The true or actual wet bulb temperature is balance between heat and mass transfer with including radiation from surrounding atmosphere. To measure actual wet bulb temperature with aspirated psychrometer, a moist air stream is drawn across a temperature sensor that is kept wetted by a moist cotton sock [3]. As the sock evaporates, resulting into sensor cooling. The cooling of sensor below ambient dry bulb temperature leads to convective heat gain from the air stream to thermometer sensor. The achieved temperature at equilibrium condition that obtained when energy loss by evaporation balances the energy gained by convection [3].

### 1.2 Why does thermometer bulb measures lower in wet bulb Thermometer than Dry Bulb Thermometer:

Muslin cloth around bulb of thermometer takes water by capillary action [1]. Unsaturated Moist air when passes on this cloth water vapour from cloth goes to moist air by mass transfer, but for going water from cloth to moist air it must be turned to vapour from liquid water. Latent heat required for turning liquid water to Vapour is taken from wet cloth hence its temperature drops down. Thermometer bulb measures temperature of wick and hence mercury drops down [1,2].

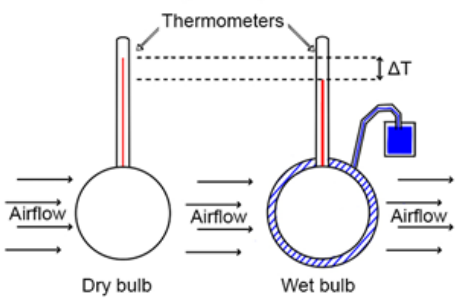


**Figure 1:** Difference between dry bulb and wet bulb temperature

As temperature in Wet Bulb thermometer drops ΔT will develop. At initially mass transfer is

maximum and heat transfer is minimum, but as temperature difference ΔT is developed leads to minimum mass transfer and heat transfer is maximum which is seen as ΔT in above Figure. Moist air at higher temperature will start sensibly heating the wick. More the drop more is sensible heating Mass transfer is trying to lower the temperature, mass transfer is directly proportional to difference between saturation pressure at water temperature and partial pressure of water vapour in air heat transfer is trying to increase the temperature, when both forces match mercury stabilizes That is the wet bulb temperature [1,2,3].

### 1.3 Factors affecting on wet bulb temperature measurement process:

The following are the important factors as thermal state, wind speed over bulb of wet bulb thermometer, radiations with surrounding, Wet Bulb Diameter, Mean Radiant Temperature, Emissivity of wet muslin cloth, least count and accuracy of using sensor to measure temperature and response of sensor to small change in temperature.

## 2. Literature Review

A psychrometer is used to measure dry bulb temperature and wet bulb temperature. Both temperatures are used further to determine relative humidity of moist air. Sling Psychrometer and Aspiration Psychrometer are two psychrometer are used to measure dry and wet bulb temperature. An aspiration psychrometer containing a small battery driven fan to produce air velocity over wet bulb thermometer and minimum 6 m/s air velocity is required to maintain to get accurate wet bulb temperature. Muslin cloth is used to wet wick of wet bulb thermometer [1]. In the research paper a experiment is carried out of analysis and validation of Psychometric apparatus. By measuring wet bulb temperature by different sensors, a wet bulb temperature is calculated, which resulting into difference in wet bulb temperature of each different sensors, mercury-in-glass thermometer, PT100, AD592, K-thermocouple etc. Wet bulb Temperature is considered vital to function of air speed over wet bulb temperature and tested for 1.25 to 5.00 m/s and results shows that tested range does not lead to any major change in wet bulb temperature hence there is need to increase and minimum at least 6 m/s air velocity needed to maintain to get accurate results of wet bulb temperature Due to change in wet bulb temperature there is significant change in relative humidity of 2-3 % [2]. The true wet bulb temperature (The Thermodynamic Wet Bulb Temperature) is different compared to actual wet bulb temperature. In this research paper carried out an analysis to find out which are different factors on wet bulb temperature. The measured wet bulb temperature is affected by many factors such as thermal state, location of where we are measuring wet bulb temperature, wind speed or air velocity over sensor wet bulb thermometer and radiations with surrounding. From the experiment it is found that due to shielding the measured wet bulb temperature is always less than adiabatic saturation temperature. Wet bulb thermometer sensor is of very small, the temperature obtained is equal to adiabatic saturated temperature at low velocity of air usually about 6 m/s. From experiment it is recommended that wet bulb sensor is required to

be in range of 6-12 mm diameter [3,4]. In this research paper effect of variability of wet bulb temperature on thermal performance of cross ow cooling towers evaluated. The small even changes in wet bulb temperature will lead to changes of evaporation losses [5]. During controlling drying process through relationship between wood moisture content and wet bulb temperature, it is required to maintain a wet bulb temperature within proper limits [6]. In this research paper, wet bulb temperature is calculated by developing explicit formula and wet bulb temperature is calculated from relative humidity and air temperature. It is found that at higher that at higher dry bulb temperature and low relative humidity the wet bulb temperature errors are much more [7]. Measure of dry bulb and wet bulb temperature is very important and they are affecting on uncertainty of relative humidity measurement. By changing wind velocity ranging from 1 m/s to 5 m/s a difference is seen in reading value and actual value. By using different equation, a actual value are calculated. As velocity is more than 5 m/s, the measurement of wet bulb temperature is close to actual value of wet bulb temperature [8]. A new direct equation is developed for calculating wet bulb temperature directly from dry bulb temperature and relative humidity. Due to error analysis, it recovered that normalized error are present and they are less than 55 %. Hence it is needed to be protect maximum variation is up to 0.55 ºC obtained through rough data. The errors are valid for temperature range of 3 ºC to 100 ºC and relative humidity is required between 7% to 97%. It gives us sense that errors are present even in direct calculation of wet bulb temperature so experimentally required to get errors associated with wet bulb temperature [9]. In the research paper, the relative humidity is determined when measuring wet and dry bulb temperature. It is learned that aspiration psychrometer is device is used to measure dry and wet bulb temperature. Relative humidity errors are more sensitive to measurement error in case of wet bulb temperature thermometer or sensor. To maintain errors within of relative humidity below 2%, it is required that temperature measurement error required to within 0.2 ºC [10]. Wet bulb temperature is considered as function of pressure and evaluation and wet bulb temperature accuracy is within limit of 0.65 ºC. This errors in wet bulb temperature will increase if temperature is very high which is more than 40 ºC and very low and very high relative humidity from below 5% to above 80% [11-15]. In this research paper, a methodology developed for hybrid ground source heat pump based on wet bulb temperature. In propriety between, ground source heat pump and water-cooled chiller is determined based on wet bulb temperature. The optimization of wet bulb temperature is achieved with optimized total energy consumption. From this research paper we will get into usefulness and significance of wet bulb temperature. By utilizing wet bulb temperature strategy, we able to easily optimize different quantity including RH and DPT [16-20]. In this research paper, a methodology is developed to calculate relative humidity based on dry bulb temperature and wet bulb temperature. Relative humidity is calculated as function of dry bulb temperature and wet bulb temperature. The obtained results having a error of less than 4% of standard psychrometric calculation of relative humidity [21-26].

## 3. Materials and Methods

The aspiration psychrometer is used to determination of dry bulb and wet bulb temperature. The main measuring components of this instrument is two mercury-in-glass thermometers with having a measuring range of -10 ºC to + 50 ºC. By using dry and wet bulb temperature, relative humidity can be calculated. Two mercury-in-glass thermometers are measuring elements of aspiration psychrometer. Both thermometers are fitted in the same direction. A small tank of water is provided to wet muslin cloth. Muslin cloth of white colour is used to wet the wick of wet bulb thermometer. First thermometer measures this wet bulb temperature. Second thermometer is directly measuring temperature of air so it is kept dry, this temperature is dry bulb temperature. For suction of air a battery-operated fan is installed with 1800 rpm. The minimum air velocity is provided with 6 m/s over wet bulb temperature. The shielding is provided between sensors of dry and wet bulb in order heat transfer. All components are assembled in acrylic sheet cover body. A clear white acrylic sheet is provided over wet bulb sensor to understanding effect of radiations. A switch is provided to on /off fan. Sufficient space is given for putting muslin cloth over wet bulb sensors. By capillary action wetting of sensor of wet bulb thermometer is done. To wet sufficient wick, it takes more than 1 minute. In case of measurement of thermodynamic wet bulb temperature, a hard bound paper sheet is provided by using a stand at height to order to avoid direct effect of sunlight. Thermometer used to have very less least count of 0.1 ºC hence a small change in temperature is also easily sensed by both the thermometers.

## 4. Working Principle

Humidity measurement based on constant exchange of water vapour between water and air and surrounding atmosphere on other side whereby heat will be converted into latent heat of vaporization or vice-versa i.e latent heat will be converted into perceptible heat condensation [8,14]. A small tank is provided containing a water and muslin cloth is attached from tank of psychrometer up to wet bulb of wet bulb thermometer. One thermometer is continuously kept dried which is measuring dry bulb temperature. Due to capillary action, the water is wetting to surface of muslin cloth over bulb. It will take 1-2 minutes to circulate water and wet sufficiently muslin cloth. Fan switch makes it on, once fan started, it ready to give air velocity to bulb of wet bulb thermometer. After waiting for 5 to 7 minutes depends on shielding provided, the lowest temperature is getting in wet bulb thermometer is known as wet bulb temperature. Second thermometer which we are put as dry is measuring temperature of surrounding air, it is known as dry bulb temperature. To make accurate measurement of dry and wet bulb temperature a sufficient time must provide to stabilize heat and mass transfer. A shield sheet needs to be selected carefully because we are stopping only sun direct sunlight while remaining surrounding radiations are still present in both shield and with shield condition.

Working of aspiration psychrometer is easily understand by looking into actual image as seen below.


**Figure 2:** Aspiration Psychrometer

## 5. Results and Discussion

Due to the huge difference a shield is reduced to small size which cover bulb of wet bulb thermometer. By using this new shield again measurement is taken at closed room under tin roof in which there is not much difference is seen. The measurement is taken at different location and time and observation table is as seen in below observation tables. The obtained result and image of large shield as seen are as following.

**Table 1:** Under full sunlight

| Location | DBT (With Shielding) | Thermodynamic WBT | DBT (Without Shielding) | WBT |
|---|---|---|---|---|
| Time | °C | °C | °C | °C |
| 5.05 PM | 29.9 | 25.5 | 38.9 | 27.1 |

### 5.1 Time Vs. DBT and WBT (With and Without Shielding)

As seen in below graphs of Time Versus DBT and WBT by changing with shield and without shielding condition and comparing both graphs, it is seen in graph by applying shield both dry bulb and wet bulb temperature decreases with respect to time and after a minimum time interval of 5 minutes when heat and mass transfer is reached to equilibrium temperature a steady reading is obtained. While in second graph where measuring apparatus are directly exposed to radiations which is affecting on increase in both dry and wet bulb temperature and after 7 minutes a steady reading is obtained.

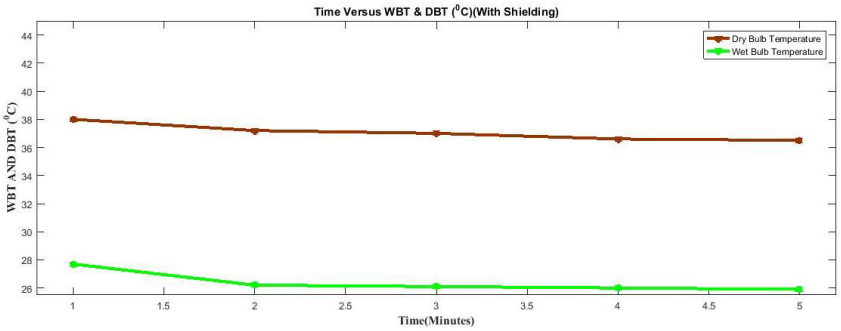


**Figure 3:** Time Versus DBT and WBT (with shielding)

## 6. Conclusions

After performing the experiments with the aspiration psychrometer with and without shield and globe thermometer it is found that actual wet bulb temperature and thermodynamic wet bulb temperature are different due to radiation effects. It is found that the aspiration psychrometer takes around 6 to 7 minutes for accurate measurement. It is found that small change in wet bulb temperature leads to a large change in corresponding humidity ratio, hence utmost care is required to get accurate wet bulb temperature. The muslin cloth shall have lesser emissivity for more accurate reading. A minimum 4-6 m/s suction air velocity is required to evaporate water vapour over bulb of thermometer. An appropriate wetting of bulb of wet bulb thermometer is to be done, if it is to much wetted then will get water temperature and if is less wetted then will get dry temperature. Aspiration psychrometer is more effective compared to sling psychrometer, which avoids a direct wet muslin cloth contact with bulb of dry bulb thermometer.

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