NATIONAL PARK SERVICE
DEPARTMENT OF THE INTERIOR

Conserve O Gram

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Using A Psychrometer To Measure Relative Humidity

Monitoring and controlling relative humidity and temperature in areas where museum collections are stored and exhibited are essential to preventive conservation. Measuring temperature to determine relative humidity (RH) can be accomplished with a psychrometer, a relatively simple and reliable instrument when properly used. The psychrometer is used to make spot readings, to take readings in areas where there are no hygrothermographs or other monitoring devices, and to calibrate hygrothermographs and hygrometers. (See *Conserve O Gram* 3/2.)

There are two types of psychrometers: the sling psychrometer and the aspirating psychrometer. The sling psychrometer is a hand-operated device, while the aspirating psychrometer is usually battery powered, although wind-up models exist. These instruments are accurate to ±2% RH when properly maintained and operated by trained and practiced users.

The Sling Psychrometer

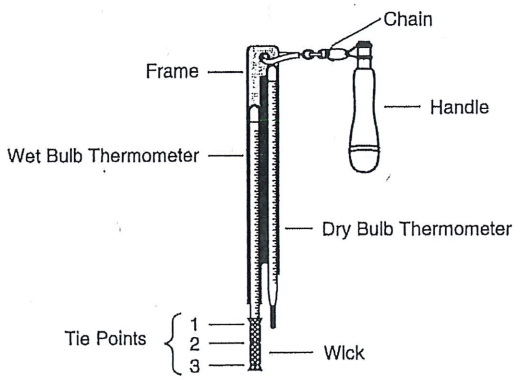
The advantages of this instrument are its simple design, low cost, and portability. The sling psychrometer is constructed of two thermometers secured to a frame. The frame either pivots on a handle or is attached to a handle by means of a chain. A cotton wick, which is wetted prior to use, covers the bulb of one of the thermometers. This thermometer is referred to as the *wet bulb*, while the other thermometer is termed the *dry bulb*. The dry bulb measures room temperature. The thermometers may be graduated in degrees Celsius or degrees Fahrenheit. By using a psychrometric chart or slide rule to compare the dry bulb (room temperature) reading to the wet bulb reading, the relative humidity is determined. Sling psychrometers are available in various sizes ranging from pocket-size models to larger units approximately a foot in length. The longer the thermometer, the smaller the increments, and the more accurate the reading.

The sling psychrometer, though simple and reliable, can be incorrectly used; however, with proper instruction and practice, the user can become adept at measuring relative humidity.

Using the Sling Psychrometer

- Prior to use, read both thermometers. When they are dry, they should register the same temperature. Otherwise, results may be inaccurate.
- Thoroughly saturate the wick on the wet bulb using distilled or deionized water only. Tap water may contain salts and other contaminants that could prevent uniform evaporation, thus interfering with an accurate reading.
- Some wick materials may contain sizing that interferes with proper wetting. It is advisable to wash a new wick in distilled water to remove the sizing before installing.
- Tie the wick securely with string or white sewing thread to the bulb while wet to allow it to conform to the bulb while drying. First, tie the wick onto the stem near the bottom of the thermometer; second, tie the wick at the top of the bulb; third, stretch the wick over the bulb and tie it firmly below the bulb.
- Avoid touching the wick with bare fingers. Oils and dirt that accumulate on the wick from handling or improper storage will result in erroneous readings. Change the wick when it becomes dirty.

- When using the psychrometer to calibrate another instrument, e.g., a hygrothermograph, take readings as close to the instrument as possible. Patches of sunlight and conditions away from the instrument may be different from nearby conditions.



- Ensure that there is sufficient space to swing the psychrometer safely.

- Droplets of water may fly off the wick as it is whirled. Use caution that the droplets do not land on surrounding museum objects.

- Because body heat and body moisture may affect the reading, hold the instrument at arm's length when swinging it.

- Whirl the instrument rapidly for at least one minute, but no more than three. The dry bulb thermometer simply reads the temperature of the surrounding air. However, as the wet bulb passes through the air, water evaporates from the wick causing the wet bulb thermometer to read a lower temperature than the dry bulb. This happens because evaporation has a cooling effect on the wet bulb thermometer. The temperature of the wet bulb thermometer will decrease as the instrument is swung until the moisture content of the wet wick reaches equilibrium with that of the surrounding air.

- Whirl the psychrometer until the wick achieves equilibrium with the surrounding air, otherwise the resulting wet bulb temperature will be too high and the relative humidity determination incorrect.

- Use caution that the psychrometer is not whirled too long. This will cause the wick to dry out and the wet bulb temperature to rise from its minimal reading, thus resulting in an erroneous relative humidity reading.

- As soon as the swinging is stopped, read the thermometers. Always read the wet bulb temperature first, since it will begin to rise once the instrument is stopped.

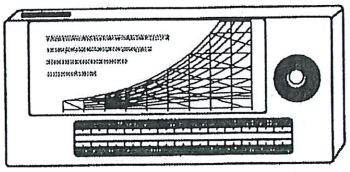
- The readings from the wet bulb and the dry bulb are then used to determine the relative humidity from a psychrometric chart or slide rule that is provided with the instrument. Readings taken from charts are generally more accurate than those from a slide rule because the slide rule introduces another interpretive factor. Some charts require that the wet bulb temperature first be subtracted from the dry bulb temperature. Other charts allow for direct comparison of the wet bulb and dry bulb temperatures. See NPS *Museum Handbook*, Part I (Rev 9/90), Chapter 4, for guidance on using the psychrometric chart. ***NOTE:*** Inaccurate RH measurements will result if calculations are not adjusted for changes in atmospheric pressure due to high altitude.[1]

- A minimum of three successive readings are advised to ensure accuracy. Inconsistent readings may indicate procedural error.

The Aspirating Psychrometer

The aspirating psychrometer is a mechanized unit, compact and easily transportable, that functions much like the sling psychrometer. The typical battery powered model will be discussed here. A fan inside the unit circulates a steady stream of air over the wet bulb. Advantages of the mechanized device are accuracy, less chance for procedural error, and usefulness in confined areas where there might not be space to whirl a sling psychrometer. Some models are equipped

with a lamp for illuminating the thermometers in dark areas. Body heat and moisture are less likely to affect the aspirating psychrometer.



Using the Aspirating Psychrometer

- The aspirating psychrometer is prepared for use in much the same way as the sling psychrometer. Thoroughly saturate the wick on the wet bulb with distilled or deionized water, in this case using a dropper. A small dropper bottle is often provided with the instrument.

- Refer to the sling psychrometer guidelines for how to handle, wash, and replace the wick.

- Take the reading as close to the instrument to be calibrated as possible. After the psychrometer is turned on, check the reading of the wet bulb after 30 seconds and then every 10-15 seconds as it descends. After 1½-2 minutes the wet bulb temperature should appear constant. Equilibrium has been achieved.

- Immediately turn off the psychrometer and take the readings from both thermometers, wet bulb first. Use caution that the psychrometer is not allowed to run too long, as this will cause the wick to dry out and the wet bulb temperature to rise from its minimal reading, resulting in an erroneous relative humidity reading.

- Determine the relative humidity by reading the chart or slide rule provided with the psychrometer.

- Although the aspirating psychrometer is recognized as the more accurate of the two types, a second reading is advisable, especially if the user is inexperienced with the instrument.

- Check the batteries in the unit periodically and replace them as needed. Weak batteries can affect fan speed and thus the accuracy of the reading. The batteries should be removed from the unit when it is not going to be used for a long period.

Further discussion on the relationship between temperature and relative humidity, and information on National Park Service standards and procedures for monitoring and controlling relative humidity, are available in the NPS *Museum Handbook*, Part I (Rev 9/90), Chapter 4; see the applicable appendix for a discussion of the effects of temperature and relative humidity on specific types of objects and materials found in museum collections. Guidelines for meeting NPS standards for temperature and relative humidity are found in Special Directive 80-1 (revised), "Guidance for Meeting NPS Preservation and Protection Standards for Museum Collections."

Note

1. Psychrometers and psychrometric charts are intended for use within a certain range of atmospheric pressure. High altitude, above 900 m (approx. 3,000 ft), will directly affect the accuracy of the RH reading unless a pressure correction formula is applied or a psychrometric chart or slide rule for the appropriate pressure is used. For further information see Ann Hitchcock and Gordon C. Jacoby, "Measurement of Relative Humidity in Museums at High Altitude," *Studies in Conservation* 25 (1980): pp. 78-86. (Copies are available to NPS sites from Curatorial Services Division, Harpers Ferry office.)

Reference

Thomson, Garry. *The Museum Environment.* 2d ed. London: Butterworth Publishers, 1986.

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Instructions for using the sling psychrometer
AOS 330
Prof. Petty

Sling psychrometers are the standard for accurately measuring ambient temperature and humidity. Every meteorologist should know how to use one correctly.

1. Inspect the cotton wick on the sling psychrometer and make sure that it is in good condition and firmly in contact with the thermometer bulb. A psychrometer with a yellowed or frayed wick will not give an accurate reading, and the wick should be replaced. Do not touch the wick with your fingers, because contaminants will affect the accuracy. Also, check for a separated mercury column.

2. Thoroughly saturate the wick with *distilled* water. If the water beads up and does not easily soak in, the wick should be replaced.

3. Face into the wind (if any) and begin swinging the psychrometer at a steady, comfortable pace (about 2 turns per second is good). *Be extremely careful that you don't strike the psychrometer on a nearby table, railing, or other obstruction!* Also, keep it far enough from your body that you don't pick up your own body heat.

4. After about 1 minute, stop and check the wet-bulb temperature, quickly reading it to the nearest 1/10 degree (if you stop too long, the temperature will start to change). Then continue swinging the psychrometer for another minute or so. Check the wet-bulb temperature again and see whether it has changed from your previous reading. If it has, continue swinging for another minute and check again. Repeat as necessary. Your goal is to get the *lowest possible reading* out of the wet bulb thermometer (assuming that it started out near the dry air temperature).

Important note: make sure that the wick does not become too dry. If it does, you will need to add another drop or two of distilled water and start over.

5. *Carefully but quickly* read and record the final wet bulb and dry bulb temperatures to the nearest 0.1 degree, interpolating between tick marks as necessary.

6. Use whatever method is available (psychrometric computer, Skew-T diagram, or table) to compute the dewpoint and relative humidity.

Important Tips: *Most beginners do not take accurate psychrometer readings because of the following common mistakes:* (1) not ventilating the psychrometer long enough to reach equilibrium; (2) not getting the wick wet enough, or letting it dry out; (3) holding it too close to the body or taking too long to read the thermometers; (4) touching the bulb ends with the hands while reading; (5) not facing into the breeze. *Every one of these mistakes usually leads to a wet-bulb temperature reading that is too warm!* Compare your readings with the instructor's and see how close you are!

Instructions for using the psychrometric computer

If you are using the psychrometric computer (circular slide rule) to compute dewpoint and temperature from your dry-bulb and wet-bulb readings, follow this procedure.

1. If your readings are in degrees Celsius, you will have to convert them to Fahrenheit for this calculation. Use the formula

$$[^\circ F] = 32 + (9/5 \times [^\circ C])$$

2. Subtract the wet-bulb temperature T_w from the dry-bulb temperature T to get the *wet-bulb depression* D in degrees Fahrenheit.

3. Find the zero index on the outer ring of the movable disk and point it at the wet-bulb temperature on the outer-most scale.

4. Look clockwise from the zero until you find the wet-bulb depression D. Read the dewpoint temperature T_d from the outermost scale.

5. To compute the relative humidity, find 100% on the innermost scale and point it at the dry-bulb temperature T. Then follow the temperature scale counterclockwise until you find the dewpoint T_d. Read the corresponding relative humidity on the innermost scale.

6. If required, convert your dewpoint temperature back to Celsius using the following formula:

$$[^\circ C] = 5/9 \times ([^\circ F] - 32)$$

SLING PSYCHROMETER INSTRUCTION MANUAL

⇨ MATERIALS

Sling Psychrometer/Compact Whirling Hygrometer
Distilled Water
Plastic Eye Dropper or Pipette
Watch

⇨ HOW IS THE SLING PSYCHROMETER DIFFERENT FROM A REGULAR THERMOMETER?

Sling psychrometers are the simplest form of hygrometer, a tool that measures water vapor in the air. Psychrometers have two thermometers that measure different temperatures. The dry bulb thermometer measures the temperature of the surrounding air. The wet bulb thermometer measures the lowest temperature to which that air can be cooled solely by the evaporation of water. The evaporation from the wet bulb takes place quickly because the psychrometers are twirled in a circle through the air. The wet bulb temperature is almost always less than the dry bulb temperature.

One difficulty in measuring air temperature is that solar radiation (energy from the sun) and thermal radiation (energy transfer from or to warm or cool surfaces such as a hot street or cold night sky) affect thermometers. One way to help fix this problem is to move air rapidly over the thermometer. This is what we do when we twirl the sling psychrometer.

⇨ I'D LIKE TO OWN MY OWN SLING PSYCHROMETER. WHERE CAN I BUY ONE?

The sling psychrometers used by Citizen Scientists may be purchased from Forestry Suppliers (online at www.forestrysuppliers.com). As of March 2011, the product number was 89288.

These recommended sling psychrometers have been approved by GLOBE, the worldwide hands-on, primary and secondary school-based science and education program and may also be used in the classroom for calculating humidity.

⇨ HOW DO I STORE MY SLING PSYCHROMETER?

Please keep your sling psychrometer boxed when not in use. Wet bulb temperatures will err on the high side if the cloth wick covering the bulb is not kept clean.

⇨ WHAT'S THE BEST WAY TO WET THE WET BULB THERMOMETER'S WICK?

The most effective way of wetting the wick is using a plastic eyedropper or pipette. The sling's thermometers may also be dipped in water, but care must be taken to dry the dry bulb thermometer completely using a paper towel before slinging.

⇨ DOES USING DISTILLED WATER TO WET THE WET BULB MAKE A DIFFERENCE?

Yes. The water in our homes and schools is filled with minerals which may build up on the cloth wick over time. Our tests indicate that using tap water increases the variability of wet bulb temperature readings. Gallons of distilled water may be obtained for less than one dollar at a grocery store, Target or Wal-Mart. Do not refrigerate, heat, or chill the water. Always rewet the wet bulb thermometer's cloth wick between measurements.

⇨ HOW LONG DO I SLING THE PSYCHROMETER?

Please sling the psychrometer for at least 45 seconds. 60 seconds is best. If you sling the psychrometer for less than 45 seconds the wet bulb temperature may be on the high side. To be precise, always count the time with a watch. Please make sure that the psychrometer is held away from the body, and that its thermometers are whirling parallel to the ground.

⇨ WHICH BULB DO I READ FIRST?

Always read and record the wet bulb first, immediately after slinging. The wet bulb temperature immediately begins rising as evaporation is slowed and the bulb adjusts to the warmer air temperature.

⇨ I'M UNFAMILIAR WITH THE CELSIUS SCALE. SHOULD I CONVERT THE TEMPERATURES TO FAHRENHEIT?

Not necessarily. You may download a conversion chart so students may see the numbers in a scale they are more familiar with (Fahrenheit). Scientists use Celsius scale temperatures rather than the Fahrenheit scale we're familiar with. When reading temperatures, round to the nearest half degree. A magnifying lens may help reading the numbers on the scale.

⇨ WHY DOES THE WET BULB THERMOMETER REGISTER A LOWER TEMPERATURE THAN THE DRY BULB THERMOMETER?

The wet bulb registers a lower temperature because the evaporation of water from the wet muslin will take heat away from the bulb of the thermometer and cool it down.

⇨ DO I NEED TO MEASURE MORE THAN ONCE?

Yes. It's best to take at least four consecutive measurements per location when investigating temperatures. If too little data is recorded, errors may not be seen. Measurements may be taken one after the other, or waiting one to five minutes between. You'll also achieve a more accurate average.

⇨ WHY MEASURE MULTIPLE LOCATIONS?

Measuring locations with different microclimates helps your students to understand the many factors that must be taken into account when reporting temperatures and investigating climate change. Microclimates are small areas that have a different climate than the area around them. They exist because of natural and human-made differences in the physical environment. It also raises the question, can our actions (construction, planting) influence the temperatures around us?

⇨ IT'S STORMING OUTSIDE. IS IT SAFE TO MEASURE?

Use your judgment when determining the appropriate conditions to venture out. Cloudiness, wind, and light precipitation are acceptable variables when noted in your students' observations. Use a sturdy umbrella to shield the psychrometer from any water or ice (and make sure the dry bulb thermometer stays dry). Please, do not attempt measurements in severe weather. Your safety and the safety of your class are important.

Sling psychrometers do not function well in temperatures below freezing. The relationship between evaporation and temperature is more complicated below freezing than above freezing, so the instrument is not as practical. Please do not measure on days where the predicted low temperature is below 23 degrees Fahrenheit (-5 degrees Celsius).

Project manual created by Felicia Savage with the support and assistance of BES Scientists and Maryland Science Center educators. January, 2010