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## HOW A PSYCHROMETRIC CHART IS USED TO DETERMINE AIR PROPERTIES

James M. Beck<sup>1/</sup>

In seed drying air has two functions: (1) it supplies the heat that is necessary to evaporate moisture and (2) it is the vehicle for transporting moisture away from seed being dried and exhausting it into the atmosphere.

Under storage conditions seed attain a rather characteristic moisture content when subjected to given levels of air temperature and relative humidities. This equilibrium moisture content is directly related to the properties of the air surrounding the seed.

A knowledge of the terms used in psychrometrics and use of the psychrometric chart is essential for an understanding of the processes involved in seed drying and in analyzing individual requirements for controlled temperature and humidity seed storage.

### PSYCHROMETRIC CHART

The psychrometric chart is a device which simplifies the measurement of air properties and eliminates many time-consuming and tedious calculations which would otherwise be necessary. Different air-conditioning manufacturers have slightly different forms of this chart which may differ in the location of information. All, however, are basically the same in that any psychrometric chart is simply a graphic presentation of the conditions or properties of air, such as temperature, humidity, and dewpoint. (A psychrometric chart supplied by Log E, Dryomatic Division, Springfield, Virginia, is attached.)

### PSYCHROMETRIC TERMS

The essential terms which are most commonly thought of in connection with the psychrometric chart are: dry-bulb temperature; wet-bulb temperature; relative humidity; dewpoint; and grains of moisture.

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Dry-bulb Temperature is the temperature of the air as measured by an ordinary thermometer such as a household thermometer. (See Figure 1)

Wet-bulb Temperature is the temperature of the air as measured by an ordinary thermometer whose glass bulb is covered by a wet cloth or gauze. (See figure 2) The temperature is recorded after the thermometer has been moved rapidly in the air.

A wet-bulb thermometer is so called because the bulb of the thermometer is wet when a temperature reading is taken. This is accomplished by slipping a cloth "sock" on the bulb end of the thermometer and then dipping both into water. Except for the "sock", a wet-bulb thermometer is the same as a dry-bulb or ordinary thermometer. To measure wet-or dry-bulb temperatures, a sling psychrometer is used.

A sling psychrometer (See figure 3) has two thermometers mounted on a base plate. The one with the "sock" is the wet-bulb thermometer; the other is the dry-bulb. The wet-bulb extends below the dry-bulb. This is done purposely so that the "sock" can be dipped in water without wetting the dry-bulb thermometer.

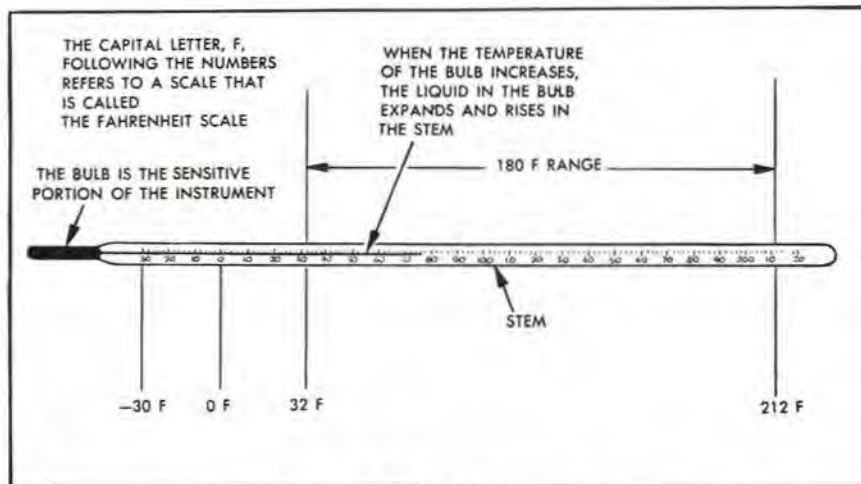
If the "sock" is wetted as described, and the two thermometers are moved quickly through the air until the water evaporates from the "sock" the thermometer with the dry-bulb will register the dry-bulb or ordinary temperature, and the thermometer with the wet sock on the bulb will register a wet-bulb temperature.

Although the air passing over the dry-bulb is the same temperature as the air passing over the wet-bulb, the temperature registered by the two thermometers is not the same. The dry-bulb always registers the actual air temperature, the wet-bulb registers a temperature that is lower than the dry bulb reading.

The key to the seemingly apparent discrepancy in temperature readings is the word "evaporation." As moisture evaporates from a surface, it removes heat from that surface.

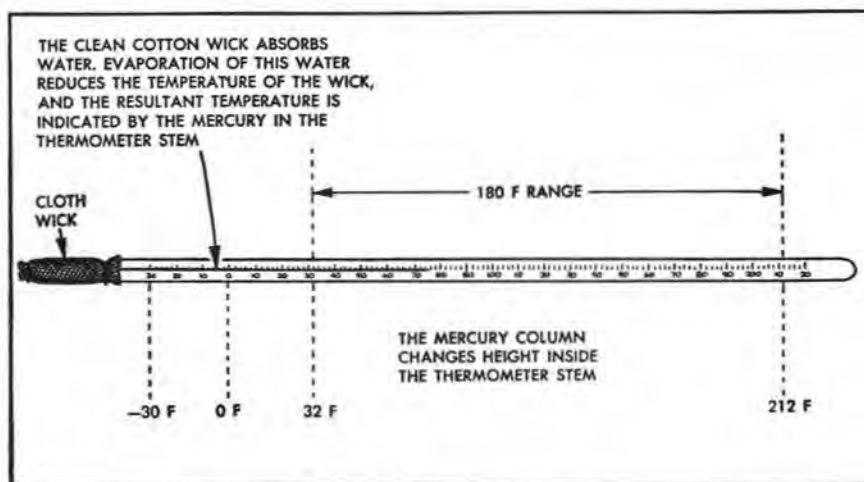
In this instance, moisture evaporates from the wet "sock" on the wet-bulb thermometer and consequently cools the surface of the thermometer bulb. This is primarily the reason for a lower wet-bulb thermometer reading.

The temperature spread between the dry-bulb and wet-bulb readings depends upon the amount of moisture in the air. If moisture content is high, evaporation at the "sock" on the wet-bulb takes place at a slower rate. If the moisture content of the air is low,



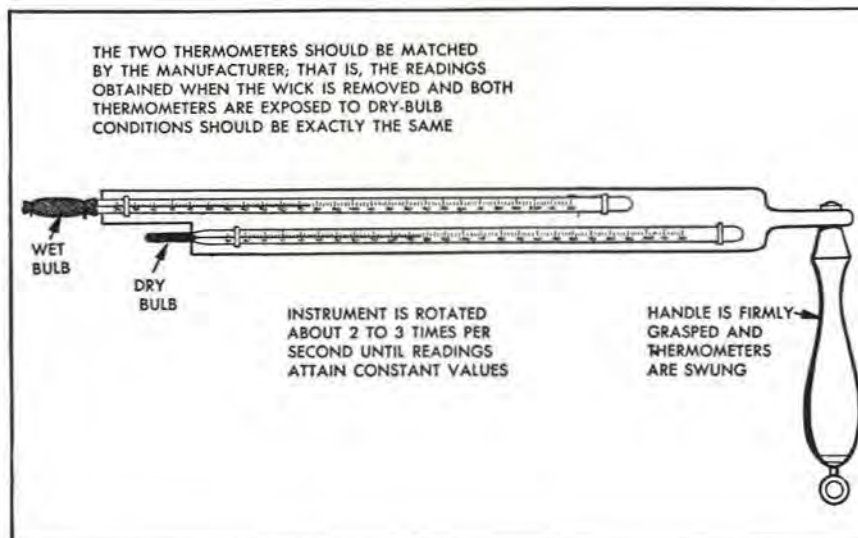
DRY-BULB THERMOMETER

Figure 1



WET-BULB THERMOMETER

Figure 2



SLING PSYCHROMETER

Figure 3

the air is dry and can readily absorb moisture. Therefore, evaporation at the "sock" takes place at a rapid pace and heat is removed in larger quantities. This makes the surface of the wet-bulb cool rapidly. As a result, the reading on the wet-bulb thermometer is lower than for air that has a high moisture content.

Dry air, or air that has low moisture content, therefore, has a low wet-bulb temperature; humid air, or air that has a high moisture content, has a high wet-bulb temperature. In fact, when the moisture content reaches 100% or 100% relative humidity, the wet-bulb temperature becomes the same as the dry-bulb temperature. This can be readily seen on the psychrometric chart. At this condition evaporation ceases because the air cannot absorb more moisture. Therefore, it is not possible to remove heat by evaporation from the "sock" on the wet-bulb, and the two thermometers register the same temperature.

Relative Humidity is the actual amount of moisture in the air compared to the total or maximum moisture the air can hold.

Grains of Moisture is the unit of measurement used to determine the amount of moisture in the air. 7000 grains equals 1 lb. of water.

Dewpoint Temperature is the temperature at which moisture condenses on a surface.

In relation to the Psychrometric Chart, these terms can quickly tell many things about the condition of the air, for example:

If the dry-bulb and wet-bulb temperatures are known, the relative humidity can be read from the chart.

If dry-bulb temperature and relative humidity are known, the wet-bulb temperature can be determined.

If wet-bulb temperature and relative humidity are known, the dry-bulb temperature can be found.

If wet-bulb and dry-bulb temperature are known, the dew-point can be found.

If wet-bulb temperature and relative humidity are known, dewpoint can be read from the chart.

If dry-bulb temperature and relative humidity are known, dewpoint can be found.

The grains of moisture in the air can be determined from any of the following combinations:

Dry-bulb temperature and relative humidity (rh)

Dry-bulb temperature and dewpoint

Wet-bulb temperature and relative humidity

Wet-bulb temperature and dewpoint

Dry-bulb and wet-bulb temperatures

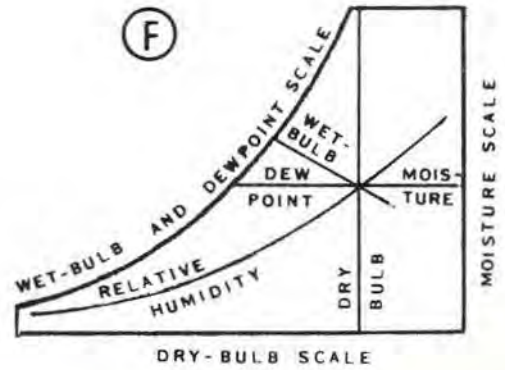
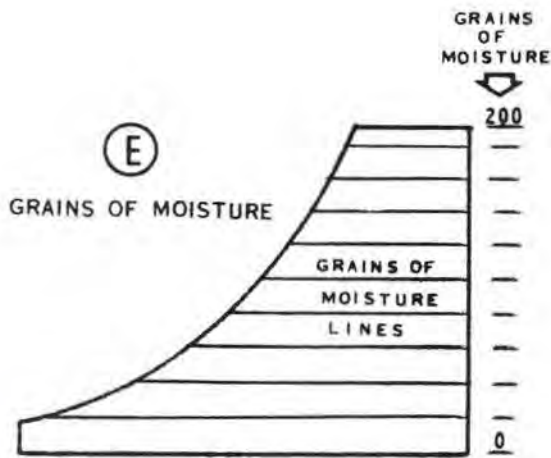
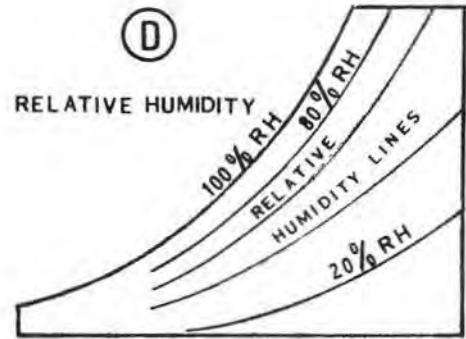
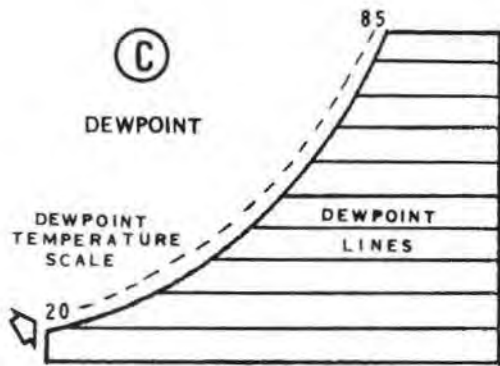
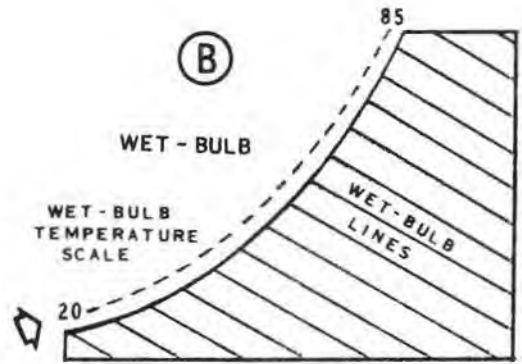
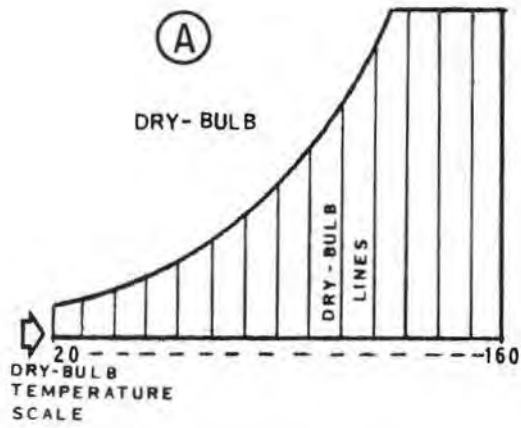
Dewpoint alone

#### IDENTIFICATION OF LINES AND SCALES ON THE CHART

Picture the chart as a shoe or boot with the toe on the left and the heel on the right. Refer to the skeleton psychrometric charts, A-F, to clarify the following:

- A. The dry-bulb temperature scale extends along the sole from toe to heel. The dry-bulb lines extend straight up from the sole... one for each degree of temperature.
- B. The wet-bulb scale extends along the instep from the toe to the top of the shoe. The wet-bulb lines extend diagonally downward to the sole and the back of the shoe...one for each degree of temperature.
- C. The condensation or dewpoint scale is the same as the wet-bulb scale. However, the dewpoint lines extend horizontally to the back of the shoe...one for each dewpoint temperature.
- D. The relative humidity lines are located along the side of the shoe and follow approximately the same curve as the instep. The instep line is actually the 100% relative humidity line.
- E. The grains of moisture scale follows along the back of the shoe from the heel to the top. The lines are the same as the dewpoint lines.
- F. All the properties of air at any given condition can be represented on a psychrometric chart by plotting a single point.

SKELETON PSYCHROMETRIC CHARTS



## RELATIONSHIP OF TERMS

A few examples will illustrate all of the foregoing relationships. Each example will directly relate to the psychrometric chart, therefore, the chart should be used to clarify the solution to each example. By using a sling psychrometer it is determined that the dry bulb temperature is 78°F. and the wet bulb temperature is 65°F.

Example 1: Dry-bulb, Wet-bulb--Relative Humidity

Given: Dry-bulb-78F.  
Wet-bulb-65F.

Find: Relative Humidity

Solution: (See skeleton chart No. 1)

1. Locate 78F. on dry-bulb scale at bottom of chart.
2. Draw a line straight up the 78F. line to the curved line at the instep.
3. Follow down the instep (wet-bulb scale) to 65F.
4. Draw a line diagonally along the 65F. wet-bulb line until it crosses the 78F. dry-bulb line.
5. Read 50% relative humidity at the intersection of the dry-and wet-bulb lines.

So, at 78F. dry-bulb and 65F. wet-bulb temperatures, the relative humidity is 50%. Relative humidity can be read at the intersection of the dry- and wet-bulb lines.

Example 2. Dry-bulb, Wet-blub--Dewpoint

Given: Dry-bulb-78F.  
Wet-bulb-65F.

Find: Dewpoint



Solution: (See skeleton chart No. 2)

1. Find the intersection of the 78F. dry-bulb line and the 65F. wet-bulb line.
2. Proceed horizontally to the instep line.
3. Read 58F. dewpoint temperature.

At 78F. dry-bulb and 65F. wet-bulb, the dewpoint temperature is 58F.

Example 3: Dry-bulb, Relative Humidity--Dewpoint

Given: Dry-bulb-78F.  
Relative Humidity 50%

Find: Dewpoint

Solution: (See skeleton chart No. 3)

1. Find the intersection of the 78F. dry-bulb and 50% r.h. lines.
2. Proceed horizontally to the instep line.
3. Read 58F. dewpoint temperature.

At 78F. dry-bulb and 50% r.h. the dewpoint temperature is 58F.

Example 4: Dry-bulb, Wet-bulb--Grains of Moisture

Given: Dry-bulb-78F.  
Wet-bulb-65F.

Find: Grains of Moisture

Solution: (See skeleton chart No. 4)

1. Find the intersection of the 78F. dry-bulb and 65F. wet-bulb lines.
2. Proceed horizontally along the grains of moisture line, to the back of the shoe.
3. Stop at the first column of numbers. This column is the grains-of-moisture scale. Read 72 grains.

At 78F. dry-bulb and 65F. wet-bulb, the moisture in the air is 72 grains.

This example shows how to find grains of moisture by using dry-bulb and wet-bulb temperature. Grains of moisture can also be found on the psychrometric chart by using other combinations of psychrometric properties. These combinations are listed below. Simply find the intersection of the lines listed here and then follow across the chart to the grains of moisture scale.

Dry-bulb and Relative humidity  
Dry-bulb and Dewpoint  
Wet-bulb and Relative humidity  
Wet-bulb and Dewpoint

#### Grains of Moisture Per pound of Dry Air or Per Cubic Foot of Air

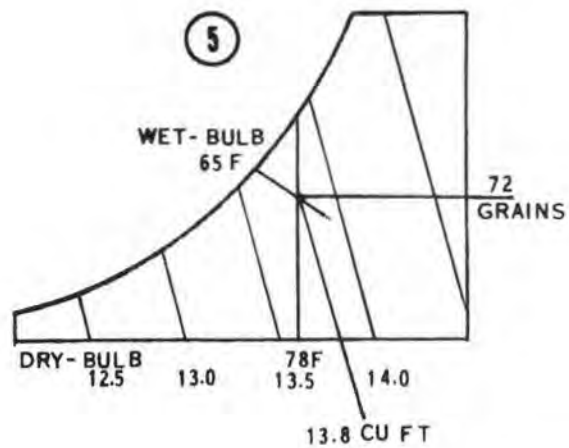
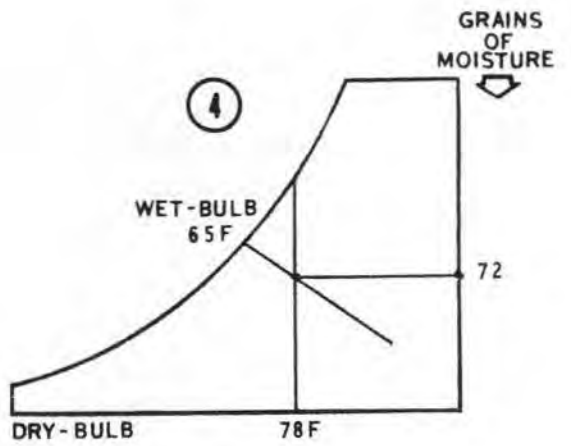
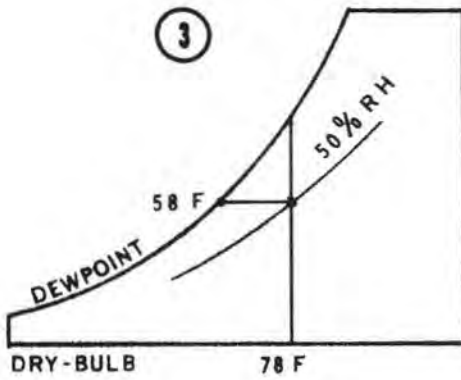
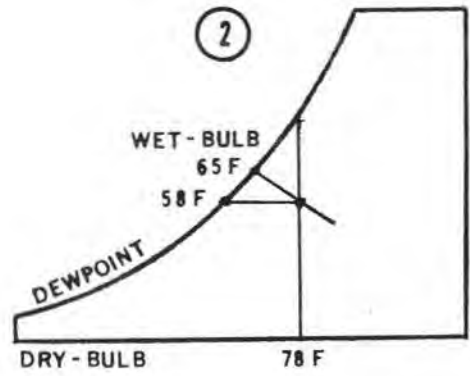
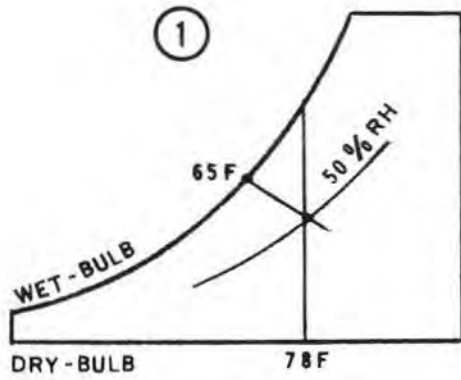
Notice at the top of the scale the words "grains of moisture per pound of dry air." This means that at 78F. dry-bulb and 65F. wet-bulb, the air holds 72 grains of moisture per pound.

Moisture can be measured per pound of air or per cubic foot of air. To find the moisture in a cubic foot of air, using the same conditions (78F. dry-bulb and 65F. wet-bulb), proceed as follows: (See skeleton chart No. 5)

1. Find the intersection of 78F. dry-bulb and 65F. wet-bulb.
2. Proceed horizontally along the grains of moisture line to the grains of moisture scale.
3. Read 72 grains.
4. Find the cubic foot scale along the sole of the shoe. The scale starts at 12.5 cubic feet and ends at 14.0 cubic feet. The cubic feet lines extend diagonally from the sole of the shoe to the instep.
5. Again locate the intersection of the 78F. dry-bulb and 65F. wet-bulb lines.
6. Draw a line parallel to the cubic foot line, from intersection located in Item 5, to the sole of the shoe. The line crosses the sole at a point that is over halfway between 13.5 and 14 on the cubic foot scale, say 13.8 cubic feet.

7. Divide 72 grains by 13.8 cubic feet.
8. Moisture in air =  $72 \div 13.8 = 5$  grains per cubic feet  
(approximately)

So, at 78F. dry-bulb and 65F. wet-bulb, the moisture in air can be read as 72 grains per pound, or, 5 grains per cubic foot.



## SUMMARY

1. Psychrometrics is the study of the properties of air.
2. The Psychrometric chart simplifies the measurement of air properties.
3. The chart is a picture or graphic presentation of air properties and air conditions.
4. Dry-bulb, wet-bulb, relative humidity, dewpoint and grains of moisture are common psychrometric terms.
5. If the value of any two of the psychrometric terms is known, the value of any other term can be found on the psychrometric chart.
6. The psychrometric chart is shaped like a boot. The sole is the dry-bulb temperature scale; the instep curve is the wet-bulb and dewpoint temperature scale; the humidity lines are approximately parallel to the instep curve, and following along the side of the shoe; the grains of moisture scale is along the back of the shoe.
7. The dry-bulb lines are in a vertical position on the chart; the wet-bulb lines are diagonal; the dewpoint and grains of moisture lines are horizontal.
8. A wet-bulb thermometer is so called because the bulb end of the thermometer is kept moist by a wet "sock" when the temperature reading is taken.
9. A wet-bulb thermometer registers a lower temperature than a dry-bulb thermometer except at 100% r.h.
10. The bulb surface of a wet-bulb thermometer is cooled by the effect of moisture evaporating from the wet "sock".
11. The wet-bulb temperature is higher in "wet" air than it is in "dry" air of the same temperature.
12. The amount of cooling that takes place at the bulb depends upon the amount of moisture in the air. At 100% r.h., cooling ceases because the air is saturated and can no longer absorb moisture from the wet "sock".