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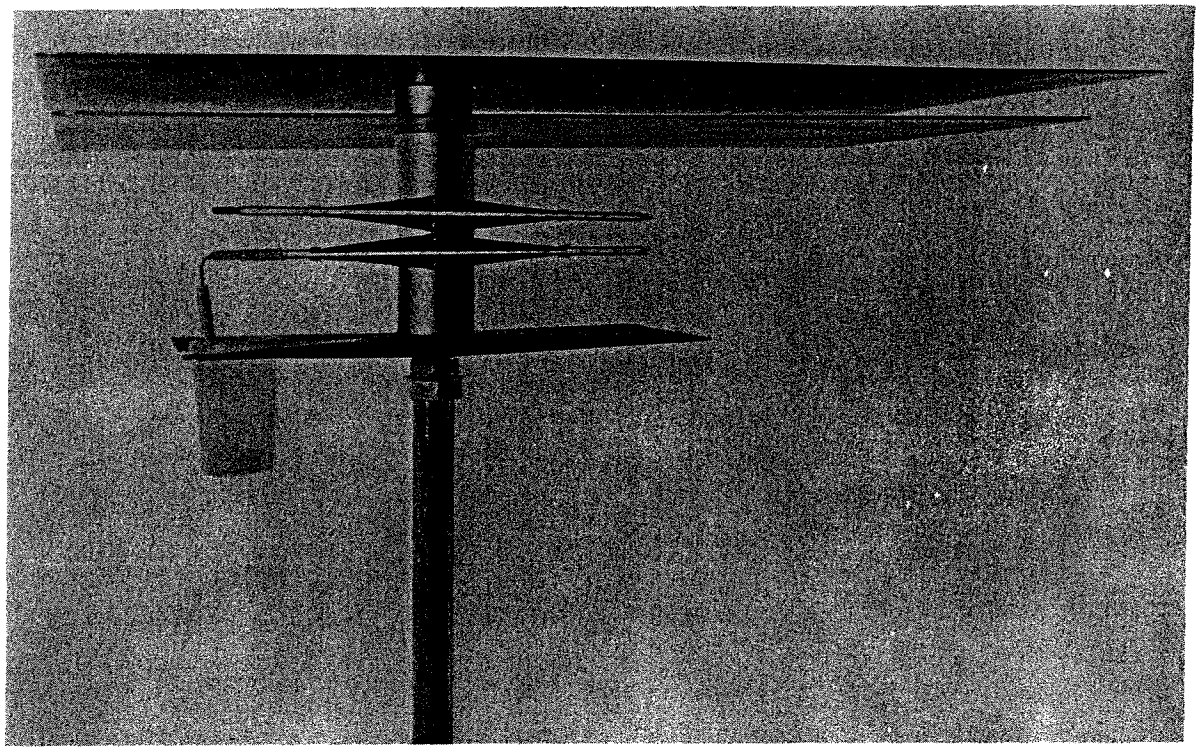

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Mortarboard Psychrometer

by Dee F. Taylor

Research has demonstrated that a high correlation exists between the moisture content of fine fuels and the moisture content of the ambient air. The mortarboard psychrometer was developed by the Southern Forest Fire Laboratory to provide a simple, accurate, yet inexpensive means of obtaining wet- and dry-bulb temperature readings to be used in estimating fine fuel moisture. It is one of the results of a series of studies conducted in conjunction with the development of the National Fire Danger Rating System.

A number of commercially available psychrometers were tested. All instruments produced accurate readings when carefully operated, but each had shortcomings for our planned use. They were either too expensive, too fragile, too hard to operate, or required ventilated shelters. These undesirable features led to the development and testing of the mortarboard psychrometer.

INSTRUMENT DESCRIPTION

The mortarboard (see page 5) consists of a radiation shield, a dry-bulb thermometer, a naturally ventilated wet-bulb thermometer, and supporting members.

Radiation Shield

The radiation shield consists of three pieces of polished aluminum. Two pieces are mounted above the thermometers to protect them from direct sun radiation. The third piece is mounted below the thermometers to reduce the effects of reradiation from the ground. The surface of each of the aluminum pieces facing the thermometers is painted flat black to reduce reflections.

The radiation shields are supported in a horizontal position and are free of vertical extensions that might interfere with normal air circulation around the thermometers.

Thermometers

Two laboratory-grade, yellow-backed thermometers are mounted horizontally between the upper and lower radiation shields. The thermometers are furnished in pairs and are not interchangeable. The lower, the wet-bulb thermometer, is identified by a black ring 3 inches from the bulb end. In operation, this bulb plus an inch of thermometer stem is covered by cotton' wicking. The upper, the dry-bulb thermometer, has no special marking but is graduated over a greater stem length than the wet-bulb thermometer.

Water Supply

Water must be supplied continuously to the lower thermometer. A water reservoir, a capped plastic cup, is held by the lower radiation shield directly below the wet-bulb thermometer. A plastic tube extends from near the bottom of the cup, through the cap, to 1 inch below the lower thermometer bulb. Water is carried from the cup to the wet bulb by a special wicking threaded through the plastic tube. The wicking extends from the cup, through the tube, over the thermometer bulb and up the thermometer stem for 1 inch. The lower inch of the stem is covered by the wick to minimize errors due to heat transfer along the stem.

Mortarboard Support

The support consists of l-inch electrical metallic tubing (EMT), spacers, couplings, and thermometer clips. Refer to drawings for exact parts placement. The support can be adjusted so that the thermometers are at the observer's eye level; it holds the radiation shields and the water reservoir in proper position, and permits the correct orientation of the complete device.

LOCATION, MOUNTING, AND ORIENTATION

Location

Mortarboards may be placed in the same locations that existing open-type fire danger stations occupy. They should be at least 6 feet from other instruments or shelters that are at or near the same height as a mortarboard. New stations should not be near bodies of water, swamps, extensive paved or dusty areas, irrigated lawns and gardens, nor less than 30 feet from any large

reflecting surface such as white-painted buildings. The main requirement is that the mortarboard be placed where there is free circulation of air from any direction past the thermometers. Be sure the instrument is plumb.

Mountina

A recommended method for mounting the mortarboard is to set a 5-foot section of $1\frac{1}{4}$-inch electrical metallic tubing (EMT) firmly 2 feet into the ground. The l-inch electrical metallic tubing (EMT) can be slipped into the larger conduit and held at the desired height with a 1 -inch compression coupling from which the lower nut has been removed. The positioning ridge or nub in the coupling must be filed down so that the coupling will slide freely on the l-inch EMT. This permits easy adjustment of thermometers to the eye level of the observer. If not at this height, the corners of the upper shield will be a safety hazard.

An optional method is to slide the support conduit over a l-inch 0. D. ground rod of bar stock permanently set in concrete. A notch and stud system for the ground-rod method (see page 6) will maintain the height and orientation of the installation.

Both methods will allow ready removal of the mortarboard for storage in off -season.

Orientation

The elongated portion of the upper shield must point south. This insures complete sun shading of both thermometers during midday for all mid-latitude locations. When the sun is low on the horizon, in early morning or late afternoon, direct sunlight may fall on one or both of the thermometers. Damage to the thermometers will not result but modified reading procedures, as explained in the section on Operation, are required.

OPERATION

A carefully fabricated mortarboard is nearly foolproof, but must still be located and read correctly. Since the thermometers are fixed rigidly, the observer must bring his eye directly in line with the top edge of the mercury column to avoid parallax and a false reading. The thermometers must reach

stability with the atmosphere before readings are made. The wick on the wet bulb must be saturated with water and the wet-bulb temperature must be the minimum producible by evaporating water from it.

Standard Readings

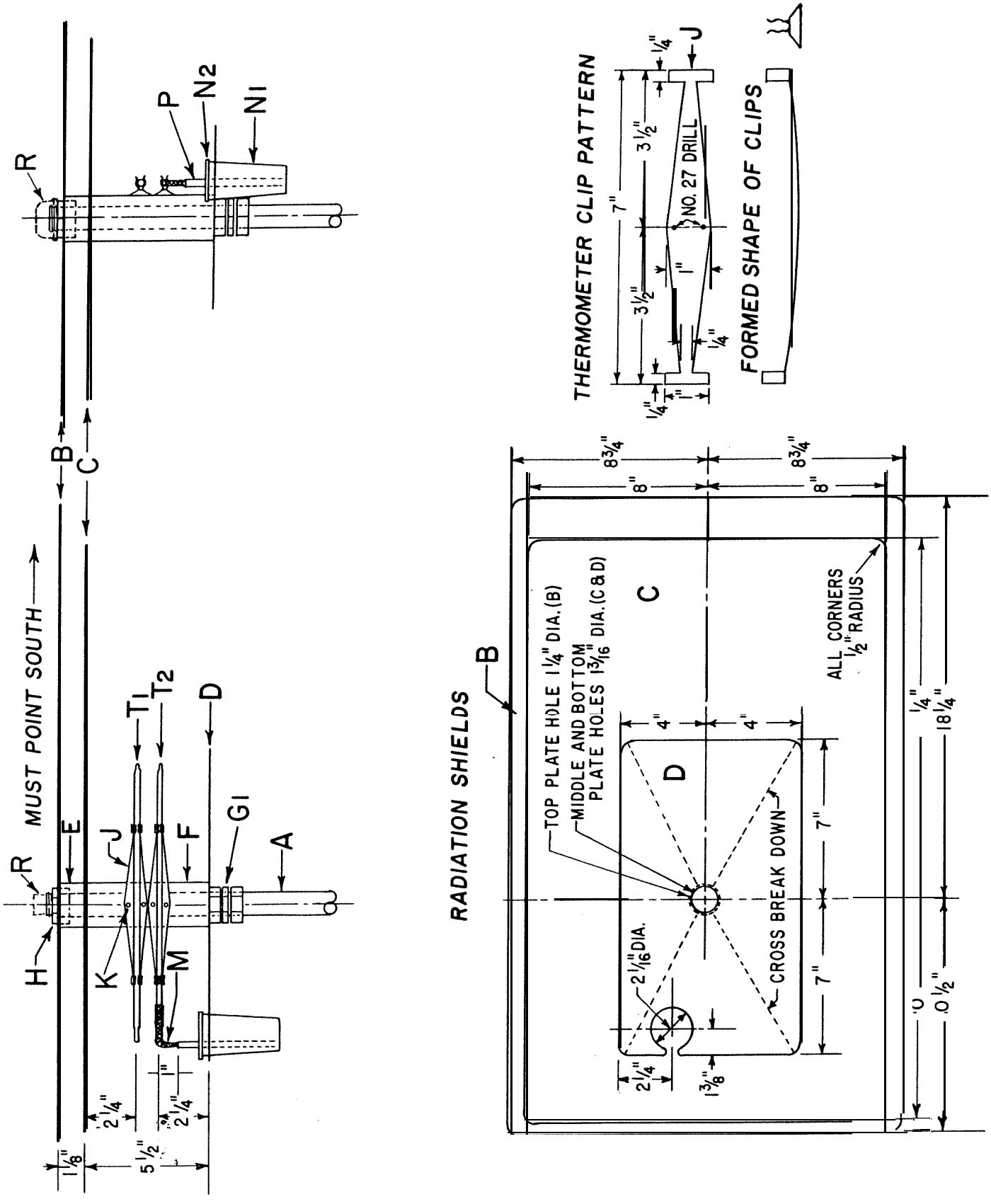
The temperature of the water evaporating from the wick will reach stability with the atmosphere if the wick remains saturated and there is sufficient airflow to keep the wick well ventilated. The operator must, during periods of near calm, fan or artificially ventilate the wet bulb to assure a correct reading. Fanning time will vary, but it probably should require only two or three minutes. The thermometer should be watched during fanning to find the lowest point. Only when a minimum wet-bulb temperature has been obtained should the companion dry-bulb temperature be read and readings recorded.

Early Morning or Late Afternoon Readings

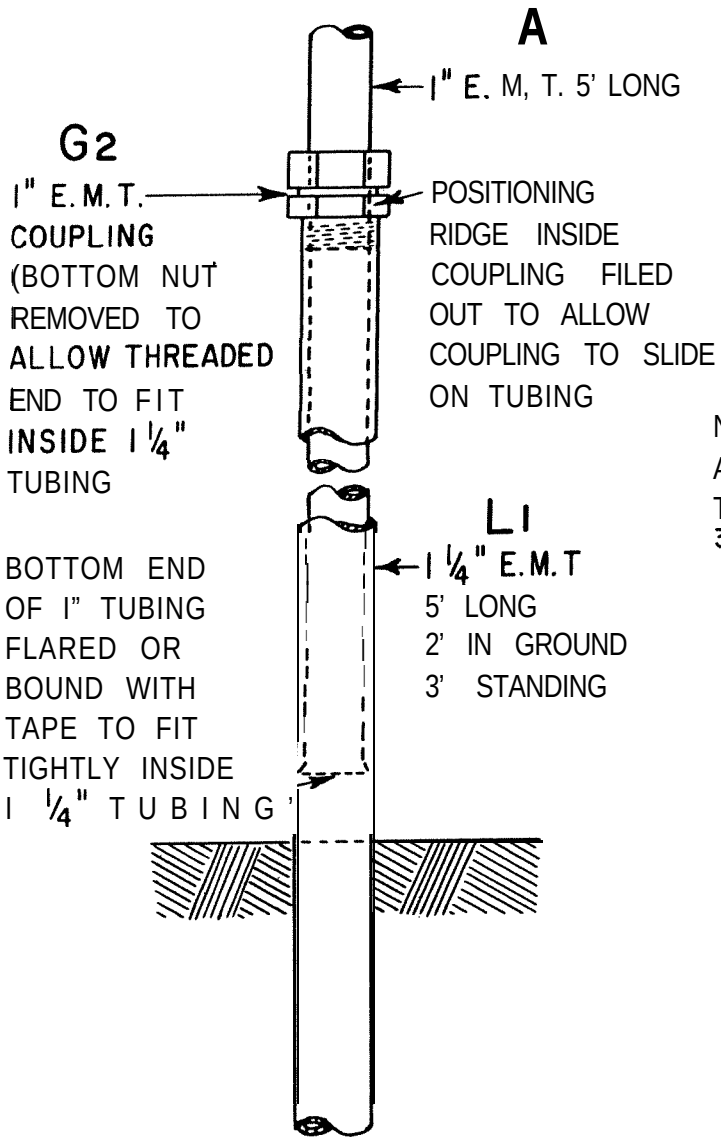
Temperature measurements will be inaccurate if direct sunlight is falling on the thermometers. If a reading is required during the period in early morning or late afternoon when sunlight is falling on one or both of the thermometers, a modified procedure must be followed. Shade must be provided for the thermometers with a minimum of disruption of the normal flow of air over the thermometers. A small curtain, such as a handkerchief or folded cardboard, hung from the upper shield to cast a shadow over both thermometers is effective. After the thermometers have been thus shaded, they must be allowed to stabilize for at least four minutes to regain equilibrium. The rest of the station readings can be taken during this time. After the thermometers have stabilized, continue the normal reading procedure.

Some observers may prefer to pivot the mortarboard in the ground tubing so that the thermometer bulbs are shaded from the sun by the spacer to which the thermometers are attached. As before, several minutes should elapse before temperature measurements are taken. Of course, the mortarboard should be returned to its proper north-south position as soon as the figures are recorded. A mark etched lengthwise on the upper and ground support tubing will make it easy to tell when the mortarboard is again correctly oriented.

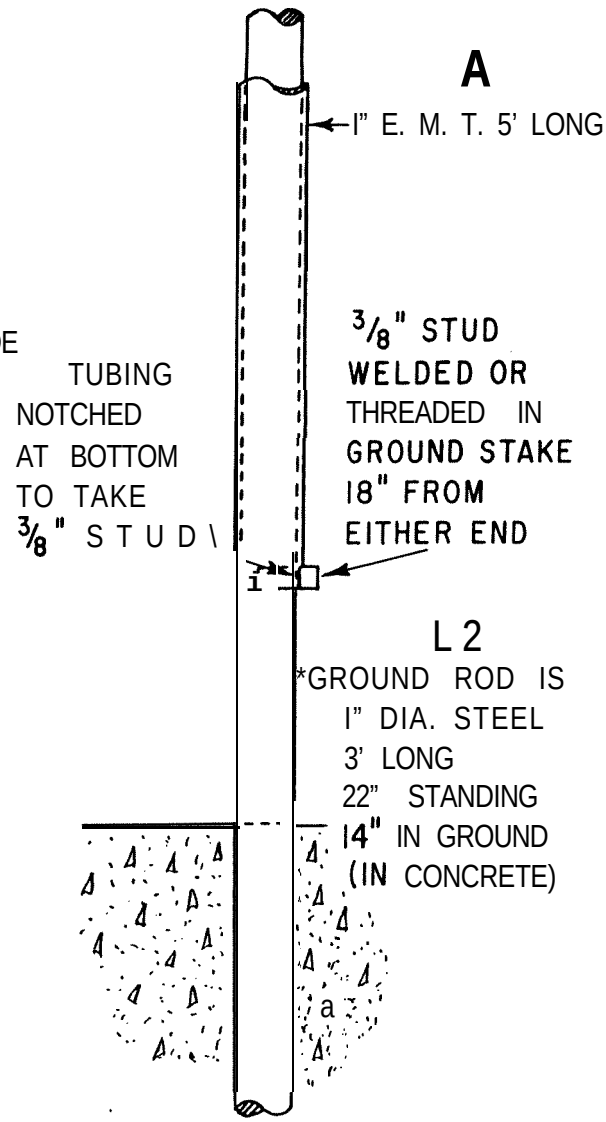
MORTARBOARD PSYCHROMETER



RECOMMENDED GROUNDSUPPORT

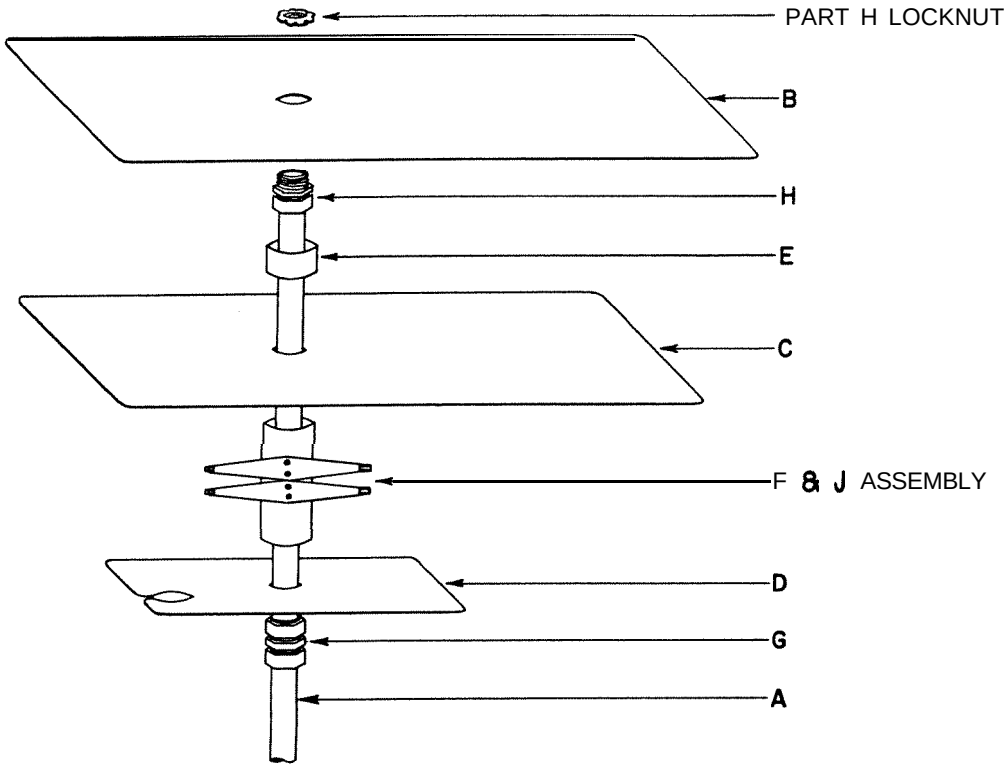


ALTERNATE GROUNDSUPPORT



INSTRUCTIONS FOR ASSEMBLING MORTARBOARD PSYCHROMETER

(Letters refer to parts as shown on drawings and in Bill of Materials.)



Assemble formed thermometer clips (J) on spacer (F) with the sheet metal screws (K) as shown on page 5.

Place support conduit (A) in vise and place component parts G, D, F, C, E, and H on conduit in this order, as shown in diagram above. Part H is compression type connector and is tightened securely at this point.

Now place part B over threaded end of part H and place locking nut on threads but just enough to start nut. THIS IS VERY IMPORTANT BECAUSE THE EXTRA THREAD SPACE ALLOWS FOR SQUEEZING ALL PARTS TOGETHER.

Push part G coupling hard against all parts and tighten by hand. Parts F and E will probably be off center at this point so use hammer handle and tap to approximate alignment.

Tighten part G permanently.

Tighten nut on part H. This is best accomplished by partially tightening nut with hammer and punch; then by turning part B, the nut and plate will both turn until nut of part H is tight.

Install the supporting member rigidly in the ground as shown on page 6.

Slip the coupling (partG2) up on the support conduit (part A); then lower the mortarboard assembly into the ground support member, adjusting the height of the thermometer to eye level by tightening part G2.

Orient instrument with overhang to south, thermometer clips facing west.

Assemble thermometers (T1 and T2), wick (M), and reservoir (N1), according to plan on page 5. The wet bulb (lower) thermometer (T2) has a black stripe 3" from the bulb. Coil extra wick in bottom of reservoir. Cut plastic tube (P) to expose 1" of wicking below the wet bulb.

Fill reservoir with distilled or clean rainwater, or mineral-free water.

BILL OF MATERIALS FOR MORTARBOARD PSYCHROMETER

(Letters refer to parts as shown on drawings. All parts are available from local supply sources, except as noted.)

Part	Description
	Support conduit
A	One 1" electrical metallic tubing (EMT) 5' long (thin-wall conduit)
	Radiation shields
B	One 28¾" x 17½" 11 or 12 gage sheet aluminum (.081" to .091")
C	One 26¼" x 16" 11 or 12 gage sheet aluminum (.081" to .091")
D	One 14" x 8" 20 gage (.0375") surface tempered aluminum, with *cross*-break down to prevent water beading
	Spacers, 2" I. D. aluminum pipe or tubing
E	One spacer, 1⅛" long
F	One spacer, 53" long
	Connectors and couplings
G1 and G2	Two 1" compression couplings for 1" EMT or thinwall conduit (One only required if alternate method (page 6) is used.)
H	One 1" compression connector for 1" EMT or thinwall conduit
	Thermometer clips
J	Two 20 gage half hard brass or 24 gage bright stainless steel (1" x 7") formed to shape shown in drawing
K	Four ¼" No. 6 sheet metal screws
	Ground supporting member
L1 or L2	One 1¼" EMT, 5' long One ⅜" x ¾" stove bolt

Part	Description
	Psychrometer wicking
M	One 28" long Source: Southern Forest Fire Laboratory will supply cooperators until further notice.
	Plastic water reservoir and cover
N1	One Tupperware spice shaker #102
N2	One Tupperware seal for 6 oz. tumbler #294-3 Source: 1/ Local Tupperware representative or Tupperware Company, Orlando, Florida.
	Tubing to protect wick
P	One polyethylene plastic tube 3/16" I. D., 5/16" O. D., 6" long
	Pipe cap
R	One 1" pipe cap (or a cork) for top of support conduit
	Thermometers
T1	One Dry Bulb Curtin #20650Y, -30° to 120° F. total immersion, yellow-backed laboratory thermometer
T2	One Wet Bulb Curtin #20658AY, -30° to 120° F. partial immersion, yellow-backed laboratory thermometer Source: 1/ W. H. Curtin Company, P. O. Box 118, Houston, Texas. Southern Forest Fire Laboratory will furnish matched pairs of thermometers at cost until further notice.
	Paint
	½ pint zinc chromate primer (undercoat for flat black) ½ pint flat black enamel

1/ Commercial products and sources are mentionedsolely for the convenience of Forest Service and cooperating personnel. This does not constitute an endorsement of such products by Forest Service or the Department of Agriculture to the exclusion of other equally acceptable products.

Readings During Freezing Weather

In sustained freezing weather the wick and the reservoir both freeze and the ice formed on the wick evaporates, leaving the wick completely dry. To obtain a correct reading, it is necessary to re-establish the evaporation from around the wet bulb. Cold water is applied to the wicking over the bulb. (This may be done with an eyedropper, a fine brush, or a feather.) Freezing will take place, releasing heat which should maintain the temperature near 32° F. during a short period. Avoid a thick coating of ice. If present, it must be removed by applying warm water. After complete freezing, the wet-bulb temperature will fall slowly to equilibrium. Allow 10 to 15 minutes, because the ice coat will insulate the mercury bulb and equilibrium with air will be established much more slowly than between a water-covered bulb and air. Fanning is most important in speeding up this process. Proceed with the readings as under normal conditions, remembering the wet-bulb temperature cannot be higher than the dry bulb and during freezing weather it is seldom the same as the dry bulb.

If a thin ice coating has not formed when the air temperature is below freezing, ice formation can be speeded up by touching the bulb with a bit of ice or cold metal.

Low Humidity Readings

Under conditions of prolonged low humidity (below 30 percent for more than a few hours) the wick tends to dry because the capillary action providing water to the bulb cannot keep up with the evaporation from the wick. Wetting the wick several minutes before taking a reading will correct this, but a slightly longer stabilization time may be required.

MAINTENANCE

The mortarboard was designed to be as maintenance-free as possible, but periodic inspections and cleaning will assure its trouble-free operation.

Water

The water used in the wet-bulb system should be as free of minerals as possible. Distilled water is best, but clean rainwater or refrigerator defrost water may be used as substitutes. Hard water should not be used because the

minerals will change the evaporating temperatures of the water and will deposit out on the wick, interfering with the normal capillary flow of the water to the wet bulb.

Wicking

The wick must fit snugly over the full length of the mercury bulb and extend a full inch up the thermometer stem to insure against heat conduction down the stem. Special wicking of known characteristics is furnished for this purpose. The wet-bulb wick requires weekly inspections for dirt and signs of mineral deposits. If these are present, change the wick. Excessive wick contamination will impede the flow of water to the wet bulb and finally cut if off completely. Under laboratory conditions, two weeks was found to be about the limit for proper operation even without signs of excessive deposits. A scum material may collect on the exposed wick which, though not visible, does cut the free flow of water.

The wick should be changed at least every two weeks. Wicking is furnished in 28-inch lengths; the excess wick is coiled in the bottom of the plastic water reservoir upon first installation. To change the wick, cut off the old wick halfway between the tube and bulb. Remove the old wicking from the bulb and discard. Pull up a length of fresh wicking and slip it over the mercury bulb and 1 inch up the stem. Be sure there are no sags in the wick between the end of the plastic tube and the end of the mercury bulb. It is essential not to dirty the wick when it is changed. The wicking slips easily over the bulb and stem if pushed by the thumbnails from the very tip of the mercury bulb.

Reservoir

The plastic cup reservoir and plastic tube will stand repeated freezes. The cap should fit tightly on the cup and the tubing should extend from the near bottom of the cup to 1 inch below the tip of the wet bulb. The cup and tube should be washed in clean water (no soap or detergent) whenever a fresh supply of wicking is added. A new supply is needed when that in use no longer reaches the bottom of the cup. Keep reservoir at least half full,

Thermometers

The thermometers are furnished in matched pairs and are not interchange able. If one is broken, or otherwise fails, request another set from the Southern Forest Fire Laboratory, Box 1421, Macon, Georgia. Return the old set in the shipping box.

The mercury column of a thermometer may separate either in shipping or occasionally in operation. This should be suspected if the two thermometers do not agree within $\frac{1}{2}$ degree when both are read as dry thermometers. Check this every time the wick is changed. If the mercury cannot be reunited by slight jars or shaking, as one would a fever thermometer, request a replacement pair. Also, refer to manufacturer's instructions on storage tubes.

The markings on thermometers will become obscured in time. They can be renewed by smearing a small amount of lamp black oil color on the stem. Immediately after application, rub excess off with a piece of hard finish paper. The lamp black can be obtained in small tubes from most paint or artist supply houses.

Paired thermometers are calibrated and stocked by the Southern Forest Fire Laboratory and will be issued to cooperators for $3.00 a set, together with wicking. Wicking will be supplied free of charge upon request. To provide for unbroken service, we suggest that extra sets of thermometers and wicking be maintained at cooperators' supply points and remote stations.

Electrical System

In areas where humidities below 30 percent are experienced frequently, it may be desirable to incorporate a small battery or A. C. powered fan to help insure adequate ventilation for the instrument, in lieu of manual fanning. More ventilation is required in the low humidity ranges to assure that moist air surrounding the wet bulb is removed as rapidly as it forms. The small fan can be located 2 inches behind the thermometers, either on the lower shield or, for better weather protection, suspended from the underside of the upper shield. The airstream should be drawn over the wet bulb. The battery pack will fit behind the radiation shield spacer.

SUMMARY OF OBSERVATION PROCEDURE

1. Make certain that sunlight is not falling directly on either thermometer bulb. If it does, follow the procedure under Early Morning or Late Afternoon Readings.

2. Make certain that the wet-bulb wick is saturated. If it is not saturated at or near freezing temperatures, follow the procedure in section on Readings During Freezing Weather. If it is not saturated because of low humidity, follow the procedure in the section on Low Humidity Readings.

3. Make certain that there is sufficient wind for ventilation of wet bulb. If the wind is less than 6 miles per hour during dry weather (30 percent or less relative humidity, about 5 percent fine fuel moisture) or less than 3 miles per hour at any time, fan the wet bulb until a minimum reading is obtained.

4. Read the wet bulb first.

5. Read the dry bulb immediately afterward.