PART 2C. MANUAL-TYPE WEATHER STATIONS: OBSERVATIONAL PROCEDURES

This portion of the handbook describes how to take observations with the instruments used at manual weather stations. Apart from the instructions, proper observational techniques also depend upon familiarity with the various instruments—in particular, their operating principles and exposure requirements, which have been discussed in parts 2A and 2B. Observers who have read these parts will more easily understand the instructions that follow.

Some types of instruments, such as sunshine recorders, pyranometers, and soil moisture meters, are not included here, because little can be added to the general statements in part 2A. Operating instructions for these instruments are rather specialized and should be obtained from manufacturers' manuals.

The following instructions are repeated in abridged form in appendix 1, to provide a convenient reference.

CHAPTER 23. TEMPERATURE AND HUMIDITY

23.1 Thermometers

READING THERMOMETERS, GENERAL PRECAUTIONS

Take the following precautions when reading any liquid-in-glass thermometer:

1. Do not touch the glass or place hands near the bulb.
2. Do not breathe directly on the thermometer. Keep your face back as far as possible.
3. If the instrument is hand-held, stand in the shade or hold thermometer in your own shade. Wherever possible, face into the wind.
4. Avoid parallax error when reading thermometers. Notice in figure 23.1 that a straight line from the observer's eye to the meniscus or the index should form a right angle with the thermometer stem and scale.
5. Doublecheck the reading before recording it on the data form. It is easy, for example, to incorrectly read a 68 as a 63; or a 65 as a 55.
6. When rounding off temperatures to the nearest degree, an actual thermometer reading with a 0.5 decimal is raised to the next integer. A reading of 67.5 thus becomes 68.

23.2 Maximum and Minimum Thermometers

STANDARD LIQUID-IN-GLASS THERMOMETERS

The correct procedure for reading and setting the standard maximum and minimum thermometers, mounted in a Townsend support inside a cotton region shelter, is illustrated in figure 23.2. The steps are:

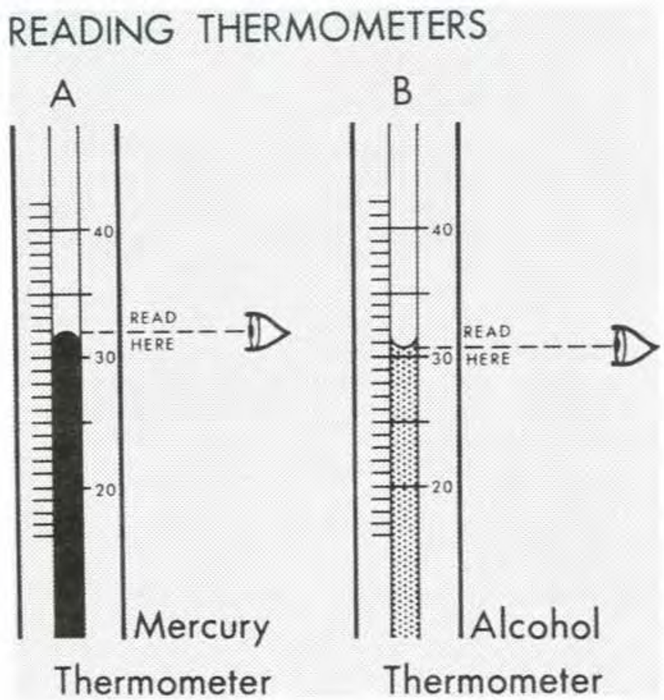


Figure 23.1—Reading thermometers; diagram shows correct eye position for avoiding parallax error.

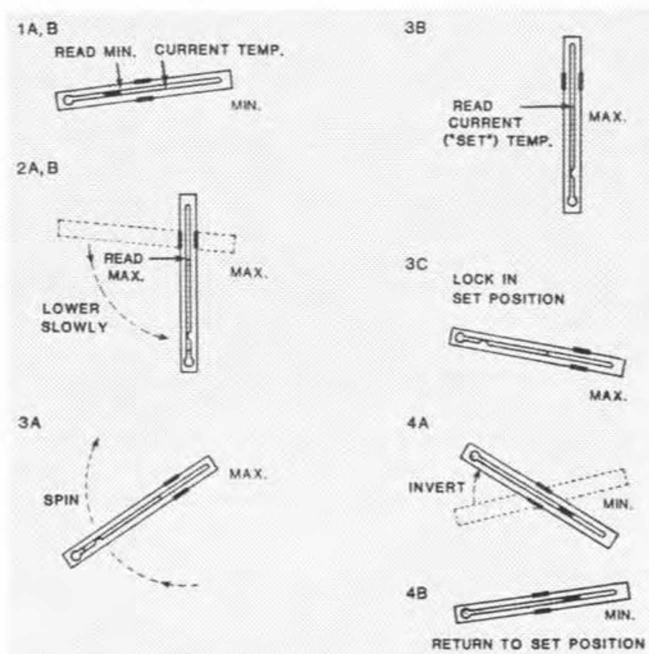


Figure 23.2—Reading and setting standard liquid-in-glass maximum (MAX.) and minimum (MIN.) thermometers. (Adapted from U.S. Department of Commerce 1972.) Panel numbers correspond to instruction numbers in text, section 23.2.

1. Read the minimum thermometer first, while in its set position (bulb end slightly below the horizontal).

a. Read minimum temperature from the upper end (right end) of the index.

b. Read current temperature from the top of the alcohol column.

c. Do not reset at this time.

2. Read the maximum thermometer.

a. Unlock the spinning shaft and slowly lower the maximum thermometer to a *vertical position* so that the mercury column is resting on the constriction in the bore.

b. Read maximum temperature from the top of the mercury column.

3. Set the maximum thermometer *first*.

a. Spin the thermometer in its clamp (several times if necessary, using moderate force) until its reading, in the vertical position, will not go lower. Always start the spin from this position.

b. Record the final reading as the "set maximum" reading.

c. Lock the maximum thermometer in its set position (bulb slightly above the horizontal).

4. Set the minimum thermometer *last*.

a. Invert the thermometer in its clamp until the index rod slides to the end of the alcohol column.

b. Return thermometer to its nearly horizontal position.

Precautions—Again, *always read the minimum thermometer first and reset it last*, because the index rod can be easily jarred during steps 2 and 3 and slide away from its correct position. *Always start the spin in step 3 from the vertical position*, to avoid a possible break in the mercury column or damage to the constriction in the bore (section 30.2).

The minimum thermometer index rod may slide downward due to vibration during windy conditions if the instrument shelter and its door are not rigidly secured. Check suspiciously low minimum temperatures against a hygrothermograph trace if this is available.

The set maximum reading (step 3b) and the current or set minimum thermometer reading (step 1b or 4b) should almost always agree within 1.0 °F; exceptions may occur during rapidly changing conditions or when body heat or reflected radiation has affected the instruments. If a discrepancy persists, the thermometers should be examined for defects. In particular, the minimum thermometer may have developed a bubble in its alcohol column (section 30.2).

SIX'S THERMOMETER

The observational steps are:

1. Read the maximum and minimum temperatures at the lower ends of the respective index rods (fig. 7.9).

a. Read the maximum temperature on the right-arm scale.

b. Read the minimum temperature on the left (inverted) scale.

2. Reset with furnished small magnet; slowly draw each index rod into contact with the mercury column. Carefully lift magnet away. On some models, reset with push-button device.

OTHER THERMOMETERS

Dial Thermometer—Maximum and minimum temperatures are read, to the nearest degree, from their respective pointers. After recording the data, reset the pointers by turning the center knob (fig. 7.10), following the manufacturer's instructions.

Digital Thermometer—Following the manufacturer's instructions, press the designated buttons (or membrane coverings) to obtain a display of the maximum and minimum temperatures. Record the data and reset the memory, again pressing designated buttons.

As mentioned in section 7.5, the Computemp digital thermometer automatically resets at midnight unless a special option is ordered in advance. Thus, where possible, this thermometer should be read in late afternoon (or in the evening), at a time after the day's maximum temperature has normally occurred. Such a reading may supplement the data from an earlier, basic observation time—with the later maximum assigned to the ensuing, basic 24-hour observation period.

RECORDING OF MAXIMUM AND MINIMUM TEMPERATURES

Daily maximum and minimum temperatures, as recorded in the afternoon at fire-weather stations and many climatological stations, are normally those for the 24-hour period between basic observation times. When this is the case, simply read the thermometers at the scheduled time, record the readings, and reset the thermometers.

When taking observations at the basic observation time, remember that the maximum temperature recorded for today cannot be *lower* than the minimum temperature read yesterday. Nor, in the case of standard liquid-in-glass thermometers, can it be lower than the set maximum thermometer reading of either yesterday or today. (The set maximum should agree closely with the concurrent dry bulb reading.) Likewise, the minimum recorded for today cannot be *higher* than the maximum read yesterday; nor can it be higher than the set maximum of either yesterday or today.

Adjustment to Calendar Day—With the basic observation time in early afternoon (as at fire-weather stations), the 24-hour maximum temperature often does not represent the actual calendar-day (midnight-to-midnight) maximum. The 24-hour minimum temperature usually suffices at least as the overnight minimum; exceptions may occur with showers and cold-front passages.

Where required, the maximum temperatures can usually be adjusted or revised to the calendar day—the recording period employed by the NWS at its primary (mostly airport) stations—without the need for direct midnight readings. The standard adjustment method (for both maximum and minimum temperatures), used if a thermograph or hygrothermograph is in operation, supplements the afternoon maximum and minimum readings with the temperature trace. Alternatively, the calendar day maximum temperature may usually be obtained by taking additional observations after sunset or early the following morning. When a supplemental morning reading is taken, follow this procedure:

At about 7 or 8 a.m. local time, read and reset the maximum thermometer. If the maximum temperature is higher than that recorded at yesterday's basic observation time, but well below the current temperature, the higher maximum temperature most likely occurred yesterday—after the basic observation. Revise yesterday's data entry accordingly.

When the maximum temperature is read in the morning, using standard liquid-in-glass thermometers, first read and record the minimum temperature; set the minimum thermometer last. This is done as a precaution against error (index displacement) due to jarring of the minimum thermometer when the maximum thermometer is set (by spinning).

23.3 Psychrometers

For fire-weather observations, the psychrometer (dry bulb and wet bulb thermometer) readings are usually recorded to the nearest degree (°F). Be sure to use the correct psychrometric tables, as designated for the station elevation (see table 7.1). Increased accuracy, if required, can be obtained by recording to the nearest 0.5 or 0.1 °F and interpolating in the psychrometric tables. This greater resolution will be more significant at lower temperatures.

GENERAL OPERATING INSTRUCTIONS

These general instructions apply to all types of psychrometers, although some differences occur for naturally ventilated types. Additional, specific details will follow.

1. The two thermometers should agree within one-half graduation when both are read as dry bulbs (wet-bulb wicking completely dry or removed). Thermometers having 1-°F graduations should thus agree within 0.5 °F; those having 2-°F graduations, within 1.0 °F. Closer agreement is advised at lower temperatures—within 0.3 °F at 32 °F for thermometers having 1-°F graduations.
2. Wet-bulb wicking must be clean, snug fitting, and in good, unfrayed condition. It must thoroughly cover the bulb, with some overlap. Securing the wick by thread is commonly required, sometimes a tedious task, but close-fitting wicking can merely be slipped over the bulb and pulled tight or secured only at the upper end. The wick should extend about one-half inch up the thermometer stem, above the bulb, and about three-fourths inch below the tip of the bulb (fig. 23.3).

Change the wick at the first appearance of dirt, crust, or discoloration—but at least every 4 weeks for psychrometers having daily use and constant exposure in an instrument shelter. Change the wick whenever it becomes difficult to wet completely. Use of only clean, mineral-free water for observations will help prolong a wick's serviceability to 4 weeks.

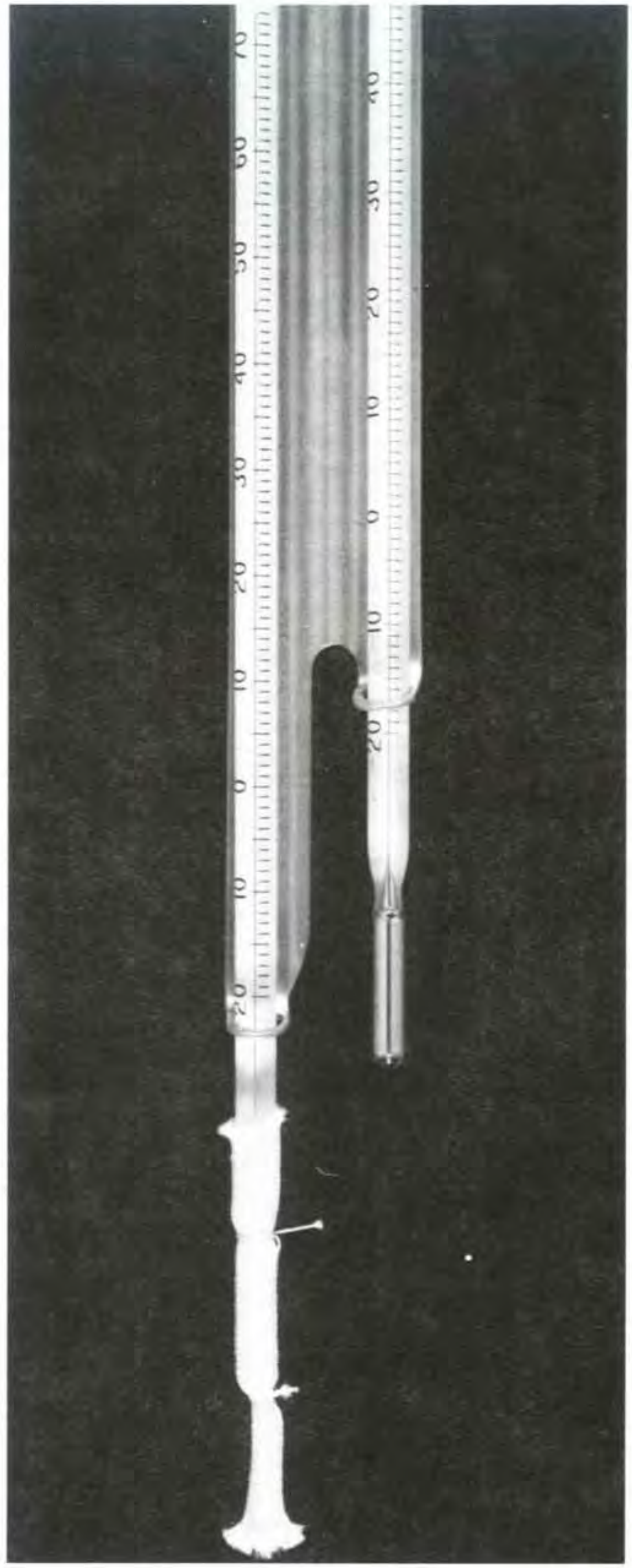


Figure 23.3—A properly installed psychrometer wick.

3. Make observations in a location exposed to free air movement—away from buildings, pavements, and dust sources—with the instrument shielded against sunshine and precipitation. A psychrometer employed inside a standard, properly sited instrument shelter will generally meet these requirements.

4. Wet the wet-bulb wick thoroughly just prior to ventilation by soaking it in a small container of water. A squirt applicator provided with some specially designed plastic containers may also be used, gently contacting all of the wick. Avoid getting water on the dry bulb. If water does get on the dry bulb, gently remove it with a tissue. Use only clean, mineral-free water, such as distilled water or rainwater, ideally near air temperature. Cap the water container when not in use.

5. Except in cases of extremely low humidity, do not wet the wick a second time during an observation. To prevent premature drying during low humidity conditions, wet the wick thoroughly and allow it to cool by natural ventilation until the mercury column completes its initial fall. Then apply forced ventilation as needed.

6. Force-ventilate the psychrometer at least 10 to 15 seconds between each reading during an observation. Air movement past the thermometers should be at least 13 ft/s (9 mi/h). Continue ventilation until the wet-bulb thermometer reaches its lowest reading (or until successive readings are the same). The time required will vary among observations, but may average 2 to 3 minutes.

7. Record the dry-bulb temperature that occurs in conjunction with the lowest or steady wet-bulb reading.

8. If the wet-bulb temperature starts to rise without a corresponding rise in the dry bulb, this may indicate that the wick has dried out prematurely. In this case, wet the wick again, allow it to precool with natural ventilation, and then resume forced ventilation. Repeat the above wet-bulb and dry-bulb reading procedure.

9. To prevent observer influences upon the readings, avoid touching and breathing on the thermometers. Face the wind when making observations outside an instrument shelter (as with a sling psychrometer).

10. Calculate the relative humidity and dewpoint from tables such as those provided in appendix 2 (see section 7.2). **Caution:** Relative humidity and dewpoint tables or slide rules furnished with many psychrometers are for use near sea level only.

Observations in Freezing Weather—During freezing weather, the water on the wick should be completely frozen before an observation is begun; the ice coating should be thin. Ventilate the thermometers until the wet bulb reaches a steady temperature below 32 °F; read first the wet bulb and then the dry bulb.

At temperatures only slightly below freezing, it may take many minutes for an ice coating to form and cool below 32 °F. To avoid this problem, wet the wick about 15 minutes prior to the observation time. Ventilation will speed the freezing process, as will touching the wet bulb with a cold, clean object. Remove old ice coatings by dipping the wick in warm (mineral-free) water prior to the observation.

23.4 Psychrometers, Specific Types

STANDARD ELECTRIC FAN PSYCHROMETER

The electric (battery-operated) fan psychrometer is designed for operation in an instrument shelter. The above general instructions apply. Specific instructions follow:

1. *Check the wick*—It must be clean and should cover the bulb snugly.

2. *Wet the wick*—Saturate with clean, mineral-free water near air temperature just prior to an observation. After wetting, replace cap on the water container.

3. *Ventilate the thermometers*—Turn on the fan switch. To maintain proper ventilation (at least 13 ft/s, or 9 mi/h), replace battery at the first sign of weakness. Be sure that the fan-motor wires are properly connected to the battery, so that the fan will rotate correctly and blow air toward the thermometers.

4. *Read the wet bulb*—Read the wet bulb thermometer first, after a wait of 1 or 2 minutes, when its falling temperature should begin to stabilize. Continue to watch the mercury column, and record the wet-bulb reading when the mercury reaches its lowest level (and the wick is still moist). During conditions of variable wind or sunshine, however, an average or fairly steady wet-bulb reading, rather than the lowest reading, may be more representative of the observation time.

5. *Read the dry bulb*—Read the dry bulb immediately after each wet-bulb reading. The recorded dry-bulb temperature will be the one concurrent with the recorded (lowest or most representative) wet-bulb temperature.

HAND FAN PSYCHROMETER

The hand fan psychrometer is designed for use in an instrument shelter. Except for the ventilation method, the observational instructions are identical to those just presented for the standard electric fan psychrometer. Ventilation is accomplished by rapidly cranking the fan. Cranking must continue without interruption until the lowest or fairly steady wet-bulb reading has been obtained.

PORTABLE ELECTRIC FAN PSYCHROMETER

Operate this psychrometer horizontally, with thermometers facing upward, in an open, representative location. Shade the instrument from sunshine—in your own shadow if necessary, while avoiding close presence that would affect the readings. Specific instructions follow:

1. *Check the wick*—It must be clean and should cover the bulb snugly.

2. *Check the thermometers*—Inspect the thermometers for any mercury column separation that may have occurred during transit (see section 30.2). Also, before operation, allow the instrument to stabilize with the air temperature at the observation site.

3. *Wet the wick*—Remove the air duct and point the thermometer bulbs downward. Thoroughly wet the wick with clean, mineral-free water; avoid getting water into the fan compartment. Replace the air duct. Hold the instrument body firmly and slide the duct smoothly to avoid accidental slippage that might break the thermometers.

4. *Ventilate the thermometers*—Be sure that the air duct fits snugly against the thermometer housing to avoid air leakage. Turn the fan on. The fan should draw air into the duct; if it does the opposite—blowing air out—check for proper battery installation. If the fan slows down or the thermometer-reading light dims, replace batteries.

5. *Read the wet bulb*—Read the wet bulb first, as described for the standard electric fan psychrometer. Record the lowest or most representative temperature.

6. *Read the dry bulb*—Read the dry bulb immediately after each wet-bulb reading. Record the temperature concurrent with the recorded wet bulb reading.

SLING PSYCHROMETER

For sling psychrometer observations, stand in a shaded but open spot. Stand away from obstacles that might be struck during whirling. Face into the wind, where light conditions permit, to minimize body heat influences on the thermometers. If rain is falling, seek overhead protection that will keep the thermometers dry while allowing air movement. Specific instructions follow:

1. *Check the instrument*—Be sure that the psychrometer handle and chain are in sound condition and proper alignment. Inspect the thermometers for possible mercury column separations (section 30.2). Be sure that the thermometers are securely mounted on their frame.

2. *Check the wick*—It must be clean and snugly secured to the wet bulb.

3. *Wet the wick*—Saturate with clean, mineral-free water just prior to each observation.

4. *Ventilate the thermometers*—Using a simple wrist action, whirl the psychrometer at full arm's length away from your face, with arm parallel to the ground. Before the initial wet-bulb reading, whirl for about 1 minute at a rate of at least 2 revolutions per second (about 13 ft/s) for a standard-size instrument; slighty faster for a pocket model (to obtain comparable ventilation). Always keep the other hand clear of the thermometers until whirling has stopped completely.

5. *Read the wet bulb*—After the initial wet-bulb reading, whirl for another 10 to 15 seconds and read again. Repeat as necessary until the reading is at its lowest or steady value. Record the temperature at this point.

If the relative humidity is very low and no shade is available, premature drying of the wet bulb may easily occur during ordinary whirling. To reduce this possibility, first wave the psychrometer in your own shadow, in a position open to the breeze if possible, for a few minutes until the wet bulb temperature appears to stabilize. Then whirl the psychrometer rapidly but briefly in full sunshine; after stopping, rapidly bring psychrometer back into your shadow for reading.

6. *Read the dry bulb*—Read and record the dry bulb temperature concurrent with the lowest or steady wet bulb reading.

MASON HYGROMETER

This instrument is designed for simple operation and easy readability, though not for greatest accuracy. Merely read the two thermometers (exposed in an instrument shelter) whenever a humidity measurement is desired. Leave the shelter door open until the lowest wet-bulb reading is attained; then read the dry bulb. Be sure that enough water is present in the water reservoir (at least one-third full), with the wick touching bottom. The reservoir can be refilled easily with a tapered-spout plastic squeeze bottle, of the type used for honey or ketchup. During very warm, dry weather, refilling may be necessary every 2 or 3 days; use only distilled or clean, mineral-free water.

With the dependence on natural ventilation, wet bulb readings will not be reliable when winds are light, particularly with ambient speeds less than 5 mi/h (section 7.6). Under such conditions, it is advisable to fan the thermometers with a piece of cardboard. Continue this for 2 or 3 minutes or until the lowest wet-bulb reading is attained; then read the dry bulb.

MORTARBOARD PSYCHROMETER

This psychrometer is operated at its fixed site, sheltered by its integral shield. When reading the thermometers, which are mounted horizontally, carefully position the eye to avoid parallax error (section 23.1). Specific instructions follow:

1. *Check the thermometers*—Sunshine should not fall on either of the thermometers (this is a possible problem at low sun angles, in early morning and late afternoon). If sunshine is a problem, artificial shading can be provided, but thermometer readings must be delayed until the wet bulb and dry bulb stabilize.

2. *Check the wick*—The special wicking, extending from above the wet bulb to the water reservoir, must be clean and fit snugly over the bulb. It must remain saturated with clean mineral-free water. The wick may dry out during extended periods of low relative humidity (below 30 percent for more than a few hours). To correct this situation, wet the wick several minutes before taking a reading; allow additional time for the wet bulb temperature to stabilize.

3. *Check the water cup*—The cap should fit tightly on the water cup and the plastic tubing should extend from near the bottom of the cup to 1 inch below the tip of the wet bulb (the wicking is threaded through the plastic tube). The cup should be at least half full of clean, mineral-free water before starting an observation.

4. *Obtain proper ventilation*—Insufficient natural ventilation of the thermometers may occur if winds are less than 3 mi/h at any time or less than 6 mi/h during dry weather (relative humidity 30 percent or lower) (Taylor 1963). To obtain proper ventilation, use a piece of cardboard to fan the thermometers for 2 or 3 minutes, until the lowest wet-bulb reading is noted. If an electric fan has been installed, refer to instructions already given for the standard electric fan psychrometer.

5. *Read the wet bulb*—Record the lowest wet-bulb reading.

6. *Read the dry bulb*—Read and record immediately after the lowest wet-bulb reading has been obtained.

23.5 Hygrothermographs

Expose the hygrothermograph in an instrument shelter, on the floor (or supporting blocks) on the left side, so that the sensing elements are near the center of the shelter. Always be sure that the hygrothermograph is far enough forward to allow clearance for the maximum thermometer when it is set by spinning. For operational (and maintenance) details, refer, if possible, to the manufacturer's instruction booklet. Basic operating procedures follow:

CHANGING THE CHART

Before installing a new chart, write the station name (and number) and the "on" date in the spaces provided at the left or right end of the chart (fig. 7.21).

To remove the old chart:

1. Lift pens off the chart, using shifting lever.
2. Unlatch and raise the instrument cover to a stable open position.
3. Lift drum from spindle, being careful not to hit the pens.
4. Pull retaining clip and remove chart from the drum. Avoid smearing undried ink remaining on recent portion of trace.
5. Record "off" time and date on chart near end of the temperature trace (fig. 7.21).
6. Wind the clock (if a traditional spring-wound clock is used). If the chart drive is battery operated, check to make sure that the chart drive (clock or motor) is running. Listen for the characteristic sound. Replace batteries if chart motion has stopped since the previous visit or if a replacement is due. If, however, chart motion has stopped but the chart drive is running, check to see if the gears are binding or meshing too tightly; cleaning of gears may be necessary.

To install a new chart:

1. Place chart snugly against the flange at bottom edge of drum, and wrap it tightly around the drum with right edge of chart overlapping the left edge. If chart is of tapered-edge type, first fold the tab on right edge. Align the right edge with the notch on upper edge of drum and the slot in bottom flange.
2. Insert the retaining clip through the slot in flange of drum, covering both ends of the chart if chart is square-end type. Insert clip underneath the right edge, along crease of foldover tab, if chart is tapered-edge type. Push head of clip securely into the notch on drum. Adjust the chart if necessary to obtain snug fit. If a slotted-type cylinder is used, insert ends of chart into the slot.
3. Reset the drum on spindle. Position drum so that chart time is slightly faster than the correct time.
4. Add ink to pens, if necessary (see instructions below).
5. Bring the pens into contact with the chart, using shifting lever. Check ink flow by rotating drum slightly back and forth (within its gear slack).
6. Turn the drum to position the pens at the correct chart time by rotating drum *counterclockwise* (against its normal direction of movement). This will take up any slack in the gears.
7. Lower and latch the instrument cover.

INKING THE PENS

1. Use purple glycerine-base ink made specially for hygrothermographs and other outdoor recording instruments.
2. Fill pen (of barrel type) by touching applicator to the open end of barrel. Do not overfill so that ink bulges beyond sides of barrel. With pens of the V-point type, fill the ink reservoir to slightly below the top.
3. In damp weather, the ink, being hygroscopic, may increase in volume and overflow from the pens; less ink should be used. The ink may also become so diluted as to produce a weak trace. In such a case, remove the ink from the pens, with lint-free paper, and replace with fresh ink.
4. To start the flow of ink and remove loose residue, draw a piece of chart paper through the pen nibs. To avoid catching fibers, do not use paper with a torn edge.

CHECKING THE CALIBRATION

If daily readings are taken, check the calibration at the basic observation time. If the station is not visited daily, check at least when the chart is changed. Because of the timelag of the hygrothermograph sensors, calibration checks of current values will be most reliable when the temperature and humidity are steady. Generally, this will occur around dawn and midafternoon, particularly during cloudy, breezy weather. For temperature, a comparison of the average maximum and minimum values may provide the best calibration check. Checking procedures are as follows:

1. Inspect instruments for mechanical defects; also for possible binding of linkages by dirt or possible spider webs.
2. Use a clean, dry camel's hair brush to remove loose dust or dirt on the sensing elements and linkages.
3. Make a time-check mark on the temperature and humidity traces, lightly deflecting each pen *downward*; a 1/8-inch vertical line is generally sufficient. (A short horizontal line, produced by gently rotating the drum within its gear slack, is advisable when the traces have a nearly vertical trend.) Do not deflect the humidity pen arm upward, as this may apply damaging force on the hairs or upset the calibration. Write the actual time near the pen mark or on the observation form. Compare this time with that indicated by both the temperature and humidity pens. If time error exceeds 30 minutes, rotate the drum as necessary to adjust the pen position.

Time disagreements between the temperature and humidity pens can often be corrected by a slight sliding of either pen on its arm; the pen should still hold firmly in place. Total agreement may be difficult to achieve, however, because the upward-downward arcs of the pens often are not perfectly parallel to the arcs of the chart time scales.

4. Compare the maximum, minimum, and current temperatures on the chart with the values obtained from

the maximum, minimum, and dry-bulb thermometers. Compare the differences over a number of days to see if there is a persistent discrepancy or error. Make necessary adjustments (section 30.5).

5. Compare the current relative humidity on the chart with that obtained from the psychrometer; compare the differences over a number of days. Also observe the relative humidity trace for evidence of too long or short a range. Make necessary adjustments (section 30.5).

CHAPTER 24. WIND

24.1 Average Windspeed

The following instructions are for anemometers exposed at a 20-ft standard height (20 ft plus adjustment for nearby obstructions and surface irregularities; see section 17.1). If the anemometer height is different from the 20-ft standard, the observed windspeed should be corrected as shown at the end of this section.

Windspeed at an observation time ordinarily refers to the average speed over a period of a few minutes or longer, which tends to smooth out gusts and lulls. A standard period of 10 minutes is used for fire-weather observations. Record the average to the nearest whole number (mi/h); a 0.5 decimal is raised to the next integer. Thus, an observed average windspeed of 6.5 mi/h is recorded as 7 mi/h.

Wherever possible, correct the observed windspeeds as specified in the anemometer manufacturer's instruction manual. Calibration tests of four anemometer models, reported by Haines and Frost (1984), indicate typical errors of ±0.5 to 1.5 mi/h at windspeeds from 5 to 40 mi/h.

Procedures for obtaining average windspeed with several types of anemometers and their counter devices follow:

CONTACTING ANEMOMETERS WITH 1/60-MILE CONTACTS

Readout by Reset Counter Equipped With Timer—

1. Reset the counter to zero, if not done previously.
2. Set the timer for exactly 10 minutes (in the case of fire-weather observations).
3. When the timer stops, read counter.
4. Obtain the 10-minute average windspeed in miles per hour by placing a decimal point in front of the final digit read on counter.
5. Reset the counter to zero.
6. If the average windspeed for a period other than 10 minutes is desired, simply set timer for the desired number of minutes and divide the final count by that number.

Readout by Reset Counter Without Timer—

1. Reset the counter to zero, if not done previously.
2. Start both the counter, using the "on-off" switch, and a stopwatch. Alternatively, a regular analog or digital watch may be used; start the counter when the digital watch reads 00 seconds or when the analog watch's second hand passes 12.
3. After exactly 10 minutes (in the case of fire-weather observations), stop the counter.
4. Obtain the 10-minute average windspeed in miles per hour by placing a decimal point in front of the final digit read on counter.
5. Reset the counter to zero.
6. If the average windspeed for a period other than 10 minutes is desired, let the counter run for the desired number of minutes and divide final count by that number.

Readout by Nonreset Counter—

1. Record the initial reading of the counter.
2. Start counter and stopwatch (see preceding set of instructions if a stopwatch is not available).
3. After exactly 10 minutes (for fire-weather observations), stop the counter.
4. Record the final reading of the counter.
5. Calculate the 10-minute average windspeed by subtracting the initial count from the final count. Place a decimal point in front of the resulting final digit.
6. If the average windspeed for a period other than 10 minutes is desired, let counter run for the desired number of minutes, subtract the initial count from the final count, and divide by the number of minutes.

Readout by Flasher or Buzzer—

1. Close the switch, turning on the flasher or buzzer.
2. Immediately after the first flash or buzz, start stopwatch or record the time to nearest second shown on other type of watch.
3. Count the number of flashes or buzzes for the desired time period (number of minutes).
4. Open the switch, turning off the flasher or buzzer.
5. Calculate the average windspeed by dividing total count by the number of minutes elapsed.

ANEMOMETERS WITH SELF-CONTAINED READOUT

Readout by Self-Contained Counter—

1. Record the initial count (miles and tenths).
2. Record the count at end of time interval for which average windspeed is desired.
3. Subtract the initial count from the final count. For short time intervals, divide the difference by the number of elapsed minutes and then multiply by 60, to obtain the average windspeed in miles per hour. For long time intervals, divide the difference by the equivalent number of hours and tenths.

Readout by Self-Contained Dial—

1. Read the dial at beginning of the period for which average speed is desired.

a. Read the inner dial first. The reading index for the inner dial is located in the outer dial. It is a small "zero" through which is drawn a vertical line (fig. 24.1). The inner dial is graduated in tens and hundreds of miles.

b. Read the outer dial. Its index is a small pointer located above and just to the left of the large dial (fig. 24.1). When the glass cover is on the dial, seeing the index requires a slight shift in viewing angle. The outer dial is graduated in miles and tenths.

Figure 24.1—Detailed view of anemometer dial, indicating 104 miles of accumulated air movement past the anemometer cups.

c. The total reading is obtained by adding the miles shown on the outer dial to the miles shown on the inner dial.

2. Read the dial at end of desired period.
3. Subtract the initial reading from the final reading. Divide the difference by the elapsed time, as explained in the preceding instructions, to obtain the average windspeed in miles per hour.

As noted in section 8.2, anemometers with the self-contained readout give a cumulative total. When, as most commonly applied, they are used to obtain 24-hour wind movement or average speed, subtract the preceding day's counter or dial reading from the current day's reading at the standard observation time; divide by 24 for the average speed. Section 27.2 gives further details for cases where the counter or dial has reached its maximum total and begun a new cycle.

GENERATOR ANEMOMETERS

Instantaneous-Reading Dial or Digital Types—To obtain an average windspeed from these anemometers, the following procedure is suggested:

1. Start stopwatch, or note the time on an ordinary watch, waiting until the watch indicates zero seconds. Simultaneously read and record the indicated windspeed; if there is a rapid windspeed fluctuation, record the average of the two extreme values.
2. Read and record the windspeed, as in step 1, at fixed intervals—suggested as every 60 seconds during a 10-minute observation; every 30 seconds if the observation is 5 minutes or shorter.
3. Divide the sum of recorded windspeeds by the number of readings.

Anemometers With Chart Recorders—To obtain an average windspeed:

1. Draw lines on the windspeed trace denoting the beginning and ending times of the 10-minute (or other) observation period. This resolution is usually attainable, as wind recording charts are usually ruled at 5- or 15-minute time intervals.
2. Through this trace segment, visually fit a straight line that represents an average speed; areas between the line and the trace on both sides should be about equal. In cases of large windspeed fluctuations, divide the trace segment into two 5-minute portions where possible; take an average of the two visual estimates.

Accumulating Type Anemometers—Obtaining average windspeeds from these anemometers, with their digital readout, is very simple (section 8.2). Merely observe the readout number and, if required, divide by the number of minutes elapsed. After each observation with the Natural Power accumulator, the memory may be erased (reset to zero) by momentarily turning the power off.

HAND-HELD ANEMOMETERS

Observations with hand-held instruments, most typically used in the field, often require only a few minutes' windspeed average, together with notation of gusts.

1. Hold the anemometer in an open, representative area at arm's length about head high, or atop a 6-ft post, with the scale or digital readout in view. With a cup anemometer, the observer need not face directly into the wind, but the instrument should still be well exposed to the wind.
2. When using instruments that show instantaneous windspeed, obtain an average speed by mental estimate or by recording the speeds at fixed intervals, as described earlier in this section.

Dwyer Hand-Held Wind Meter—

1. *Face the wind* and hold the meter at arm's length about head high, with the scale side in view (fig. 24.2). Hold the instrument about midway from either end, taking care not to block the two holes at the bottom or the pinhole on the side of the top stem.
2. Observe motion of the white ball in relation to the left (low) scale. If the ball remains within the range between 2 and 9 mi/h, read from the left scale (fig. 8.14). If the ball is rising to near 10 mi/h, cover the opening at top of stem with index finger (fig. 24.3) and read windspeed from the right (high) scale.
3. To obtain a reading, observe the height attained by the ball in relation to the appropriate scale. Often the height (windspeed) will vary noticeably during the observation period. Average speeds, usually taken over a few minutes' period, may be estimated mentally or by reading and recording at fixed intervals. The highest gust speeds may also be noted.

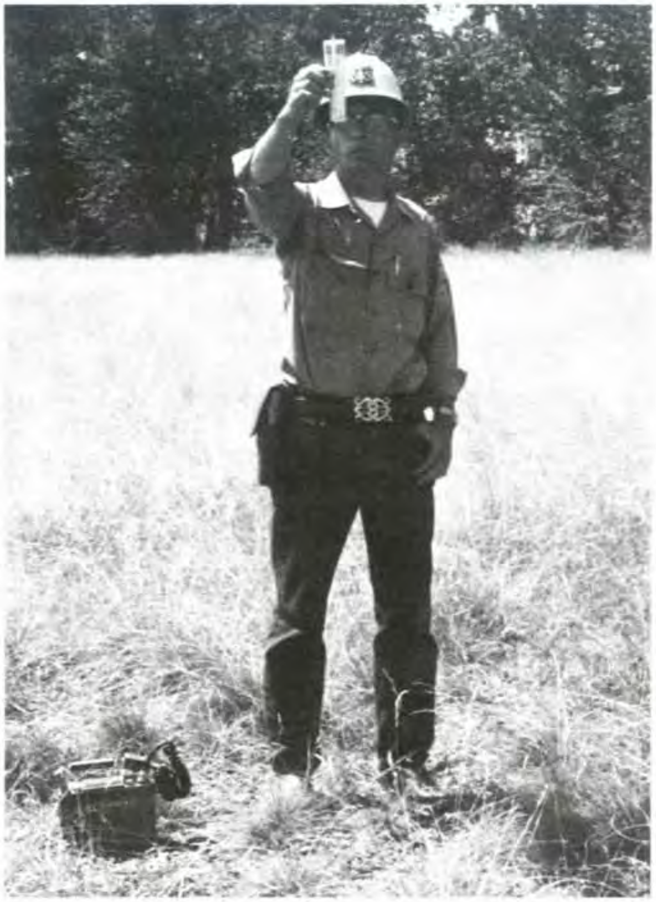


Figure 24.2—Use of Dwyer hand-held wind meter, facing into wind. Keep fingers clear of top stem when measuring winds less than 10 mi/h.

24.2 Correcting Windspeeds Observed at Heights Above or Below the 20-foot Standard

An anemometer installed on top of a building or on a fire lookout tower may exceed the 20-ft standard height, even when the standard height is adjusted upward because of nearby obstructions (section 17.1). The opposite may occur, with an anemometer installed below the standard height—or with the windspeeds observed from a hand-held instrument.

WINDS OBSERVED ABOVE STANDARD HEIGHT

In these cases, the observed afternoon windspeeds will generally be higher than those at the standard height and may require a correction or adjustment to lower values. The adjustment is an estimate based on an average wind profile, which shows decreasing frictional drag with increasing height above the ground; the actual profile will vary with surface roughness. Table 24.1 (Cramer and Moltzau 1968) provides conversion factors for this adjustment.

To adjust afternoon windspeeds observed *above* the standard height at a station, perform the following steps:

1. Determine the total, adjusted height (feet) above ground required for a 20-ft standard installation at the observation site (table 17.1).
2. Determine the actual height of the anemometer above ground.
3. Calculate the excessive height of the anemometer (step 2 minus step 1).
4. Using the result from step 3, find (or interpolate) the conversion factor in table 24.1.
5. Multiply observed windspeed by the conversion factor. Result is the estimated 20-ft standard windspeed.

WINDS OBSERVED BELOW STANDARD HEIGHT

Adjustments of windspeeds observed at low heights, to expected higher values at standard height, are generally less reliable than those in the preceding case. Published average profiles of daytime windspeed near the surface apply to a flat, open area. In forested areas, with obstruction by nearby trees, windspeeds observed near the ground may be much lower than those at the same height in an open area. Use of standard wind profiles (and their conversion factors) may thus seriously underestimate windspeeds above treetop level, at the adjusted 20-ft height.

Figure 24.3—To measure winds greater than 9 mi/h with Dwyer meter, face wind and cover top of stem with finger.

Table 24.1—Conversion factors for adjusting windspeeds observed at heights in excess of standard 20-ft height

Height of anemometer above 20-ft standard	Conversion factor
Feet	
0	1.00
10	.95
20	.91
30	.88
40	.86
50	.84
60	.82
70	.81
80	.80
105	.78
130	.75
180	.72

Nevertheless, in an open area, an average conversion (multiplication) factor of 1.5 is sometimes applied to a 6-ft daytime windspeed to estimate the corresponding 20-ft speed. Conversely, the 6-ft ("midflame-height") windspeed may be estimated by a two-thirds (0.67) factor applied to an observed 20-ft windspeed.

24.3 Estimating Windspeed From Beaufort Scale

Windspeed may be estimated by use of the Beaufort Scale (table 24.2) if an anemometer is not available or functioning properly, or if the windspeed is below the instrument's starting speed. Table 24.2 presents the standard specifications for use over land (World Meteorological Organization 1983), with some slight rewording (in part adapted from Schaefer and Day 1981). The windspeed equivalents are 10-minute average values designated for a height of 33 ft (10 m) above open flat ground. But the speeds should also be generally valid for a 20-ft height, because they are somewhat broad estimates.

Table 24.2—Windspeed equivalents, Beaufort scale; standard specifications (see text) for use over land

Beaufort number	Wind description	Windspeed	Observable effects of wind
		Mi/h	
0	Calm	Less than 1	No perceptible wind movement; smoke rises vertically.
1	Very light	1 to 3	Direction of wind shown by smoke drift; wind vane and anemometer cups may not move; leaves barely move.
2	Light	4 to 7	Wind felt on face; ordinary vanes move; leaves rustle; small twigs move.
3	Gentle	8 to 12	Leaves and small twigs in constant motion; light flag extended.
4	Moderate	13 to 18	Small branches are moved; wind raises dust and loose paper.
5	Fresh	19 to 24	Large branches and small trees in leaf begin to sway; crested wavelets form on inland waters.
6	Strong	25 to 31	Large branches in continuous motion; whistling heard in telephone wires; umbrellas used with difficulty.
7	Near gale	32 to 38	Whole trees in motion; inconvenience felt when walking against the wind.
8	Gale	39 to 46	Breaks twigs and small branches off trees; generally impedes progress when walking against wind.
9	Strong gale	47 to 54	Slight structural damage occurs (chimney bricks loosened; roofing slates blown off); broken branches litter ground.
10	Storm	55 to 63	Trees uprooted; considerable structural damage occurs.
11	Violent storm	64 to 73	Widespread damage.
12	Hurricane	Above 73	(Not specified.)

A modified version of the Beaufort Scale (MacCready and others 1955) is reproduced in figure 24.4. The specified wind effects were adapted for forested valley areas in the Northern Rocky Mountains but may also apply to similar areas elsewhere. Some discrepancies are found in comparison with the standard specifications (table 24.2); when in doubt, it is probably best to use the standard Beaufort Scale.

24.4 Wind Gusts; Peak Speeds

Sometimes it may be important to know the speed of gusts, in addition to standard average windspeed. As a prime example, gusts can greatly affect fire behavior (Crosby and Chandler 1966). A gust, as defined by the World Meteorological Organization (1983), is a positive or negative departure, lasting for not more than 2 minutes, of the windspeed from its average over a specified time interval. Generally only the positive departures are noted; a negative departure is commonly termed a lull. The National Weather Service in its operations defines gusts as rapid fluctuations in windspeed, with a variation of 10 knots (12 mi/h) or more between peaks and lulls. The reported peak windspeed is the highest instantaneous speed observed or recorded during an observational period.

Measurements of peak speeds are thus usually made by a continuous-reading anemometer, with its dial, chart, or digital readout; and also by the simple Dwyer wind meter. Such instruments, typically hand-held, are used at fires, where gust windspeeds can enter into worst-case predictions of fire behavior.

Where wind gust information is desired at stations with contacting anemometers, gusts can be recorded as highest average speeds over short time periods, such as 1 minute. The cumulative wind count may then be noted and recorded each minute during a standard 10-minute observation period, or at any other time of day.

Findings from several hundred observations at Salem, MO, by Crosby and Chandler (1966) indicate the possible gustiness of afternoon winds during the fire season. The results for a standard 20-ft height showed the probable maximum 1-minute average windspeed was generally 4 or 5 mi/h higher than the 10-minute average value. The probable average momentary gust speed ranged from 10 to 15 mi/h higher than the 10-minute average speed, for average speeds between 5 and 20 mi/h.

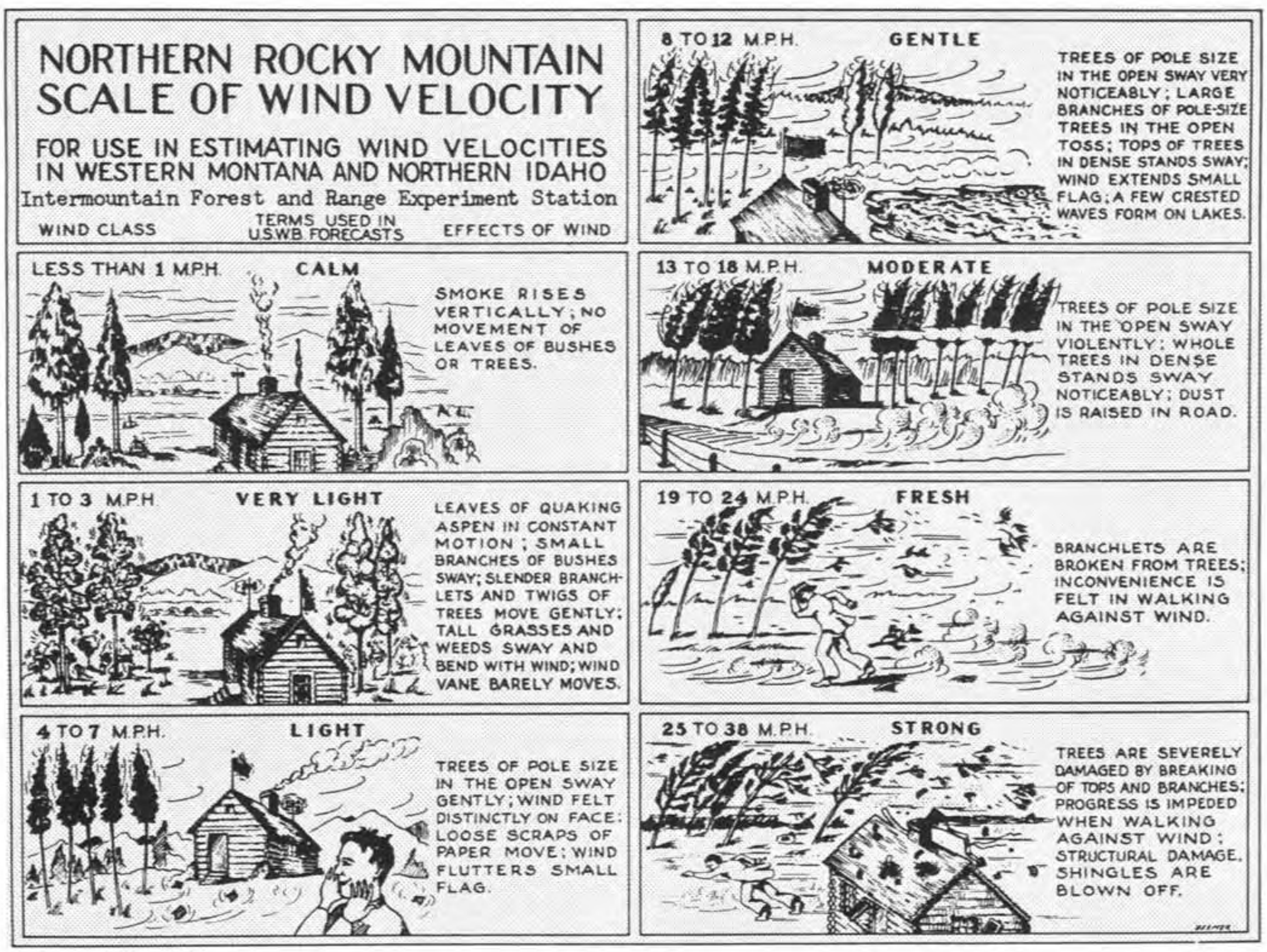


Figure 24.4—Modified Beaufort wind scale, devised for Northern Rocky Mountain area. (From MacCready and others 1955).

CHAPTER 25. PRECIPITATION

25.1 Nonrecording Gauges

TIMELY MEASUREMENT OF PRECIPITATION

To prevent possible loss by evaporation, measure rainfall as soon as possible after its ending when using nonstandard, small-orifice gauges. A supplemental early morning reading should be adequate for standard 8-inch gauges at stations with an afternoon basic observation time, provided the top section (the funnel) is on the gauge.

A test by Horton (1919), conducted during summer in the Northeastern United States, showed weekly evaporation as low as 0.01 inch from a standard, large-capacity gauge. The evaporation loss may well be higher in the drier Western United States. Tests with the standard Forest Service gauge at Missoula, MT, during warm, dry spells in April and August-September 1988 showed evaporation losses of typically 0.01 inch per day. (In both tests the measuring tube was initially filled with water to one-half capacity—to a stick depth of 0.25 inch.) A total of 0.28 inch was evaporated during 30 days. Larger daily losses can occur with the gauge funnel removed, as during the snowfall season, when either rain occurs or snow melts in the gauge.

At the basic observation time, record the total 24-hour precipitation obtained from all measurements.

STANDARD 8-INCH GAUGES

The following operating instructions apply to both the large-capacity and smaller capacity (Forest Service) standard 8-inch-diameter rain gauges. These and other gauges should be inspected regularly even during dry periods, so that possible insects and debris such as bird droppings can be removed before rain occurs.

Measuring Rainfall Within Measuring Tube—

1. Remove the funnel from top of rain gauge.
2. Slowly insert a clean, dry measuring stick vertically into the measuring tube, with the zero end resting on the bottom.
3. Remove the stick after 2 or 3 seconds.
4. Read the depth of precipitation, to the nearest 0.01 inch, as indicated by the waterline. Remember, each scale mark on the stick represents an increment of 0.01 inch. Precipitation amounting to less than one-half of 0.01 inch is recorded as a trace (T). A trace is also recorded when the gauge is dry but raindrops or snowflakes have been visually observed since the previous observation time.
5. Remove and empty the measuring tube, allowing it to drain for at least several seconds; then replace it inside the overflow can.
6. Replace the funnel, making sure that it rests squarely on top of the overflow can and over the measuring tube.

Measuring Rainfall When Measuring Tube Has Overflowed—

1. Record 0.50 inch precipitation, initially, for a completely filled measuring tube in the Forest Service gauge; 2.00 inches for a completely filled tube in the large-capacity gauge.
2. Carefully remove the measuring tube and dump the water; allow the tube to drain for at least several seconds.
3. Carefully pour water from the overflow can into the measuring tube; stop if water reaches the brim (this is more likely to occur with the smaller capacity Forest Service gauge).
4. If the measuring tube is filled to the brim in step 3, add another 0.50 inch or 2.00 inches to the initially recorded amount. Otherwise, insert stick and read the waterline as described in the preceding instructions, steps 2 through 4.
5. Repeat if necessary until all the water in the overflow can has been measured.
6. Record the total of all the increments.

Measuring Water Content of Snowfall—The gauge's funnel and measuring tube should be removed in advance of possible snowfall and freezing temperatures; these parts are stored indoors in a convenient place. Only the outer (overflow) can is exposed. When snow (or rain) then occurs:

1. Measure the precipitation as soon as possible after the snow (or rain) has ended. This will reduce the chance of error due to evaporation during ensuing sunny and mild or thawing weather. If there is only water (rain or melted snow) in the gauge (the overflow can), bring the overflow can indoors and follow the preceding instructions beginning with step 3. If there is unmelted snow, or ice, in the gauge, continue with the following steps.
2. Bring the overflow can indoors and heat just enough to melt all of the contents while avoiding evaporation. The melting can be accomplished with warm air or by partial immersion in hot water; keep a lid, such as a piece of cardboard, on the overflow can.
3. Pour the snowmelt water into the measuring tube; measure as previously described and record the result.
4. If there is a large amount of snow or ice in the overflow can, melting can be expedited by carefully pouring in a known (premeasured) amount of hot water from the measuring tube; for simplicity, a completely filled tube is often used. Add more hot water if necessary.

After all of the snow and ice has been melted, pour the contents from the overflow can into the measuring tube, as in step 3. To calculate the precipitation, subtract the amount of added hot water from the total amount of water that is poured out of the can and measured.

5. If snowfall has occurred before the funnel and measuring tube were removed from the gauge, the action taken depends on how much snow has fallen and on wind conditions. With light wind and relatively light snow accumulation on the funnel (snow not topping the knife-edge rim by more than 1 or 2 inches), gently tap any protruding snow downward along the rim, using the measuring stick or other ruler. Press the resulting snow section downward against the funnel, until it is securely contained, and bring the entire gauge into a warm indoor location for melting and measurement. If precipitation has ended, the gauge can remain indoors long enough for the snow to melt directly into the measuring tube; keep a lid on the funnel.

Snowfall Water Content From Snow Cores—Where the gauge catch of snow may be unreliable, due to improper gauge exposure (just described) or accompanying wind, the use of snow cores is recommended for measuring precipitation. The snow cores are cut with an empty overflow can, from snow lying on the ground (or other surface) in spots having a representative depth. Previously bare or cleared, even ground surfaces or a snow board can be used for this purpose, as follows:

1. Position the overflow can, upside down, over the newly fallen snow and press it downward to the ground surface or snow board. Avoid ground covered with weeds or tall grass.
2. Clear surrounding snow away from the overflow can, to allow working space for the next step.
3. Slide a sufficiently large sheet of rigid cardboard or metal completely under the mouth of the can, keeping contact with the rim; pick up all of new snow lying within the rim diameter.
4. Pressing the cardboard or metal sheet firmly against the can, rapidly turn the can upright. In this position, tap the sheet to shake all of the snow core into the can before removing sheet.
5. As described previously, melt the collected snow, pour the water into the measuring tube, and read the waterline on the measuring stick.

Estimating Precipitation From Snowfall—If the gauge catch of snowfall is poor due to windy conditions and a snow core cannot be taken, precipitation can be estimated by applying a ratio to the measured snowfall; a reliable snowfall measurement is, of course, required here.

An overall ratio (or snowfall density) of 0.10 is sometimes assumed, implying that 1 inch of water is contained in 10 inches of snow, but such a ratio is often too high. A ratio of 0.08 may be better as an average value, unless the snow is noticeably wet or if the snow has been packed by the wind. Under these conditions, the 0.10 ratio may be satisfactory.

The true ratio will vary between individual snowfalls; characteristic values may vary between climatic regions and times of year. Actual snowfall densities of 0.05 to 0.09 are frequently observed, and sometimes 0.02 or 0.03 with light, fluffy snow—at least when measurements are made before the snow has settled appreciably. But the very low densities, generally a result of much air space between the accumulated snowflakes, are highly unlikely with windy conditions.

SMALL-ORIFICE GAUGES

Four-Inch Clear Plastic Gauge—Measurement techniques are similar to those for the standard 8-inch gauges, except the level of water is read directly from the scale etched on the measuring tube. In this gauge, the overflow cylinder will contain rainfall in excess of 1.00 inch.

Wedge-Shaped Gauge—Simply read the water level directly from the scale etched on the plastic, making sure that the gauge is positioned vertically. With this gauge, it is particularly important to measure rainfall as soon as possible to avoid error due to evaporative loss.

25.2 Recording Gauges

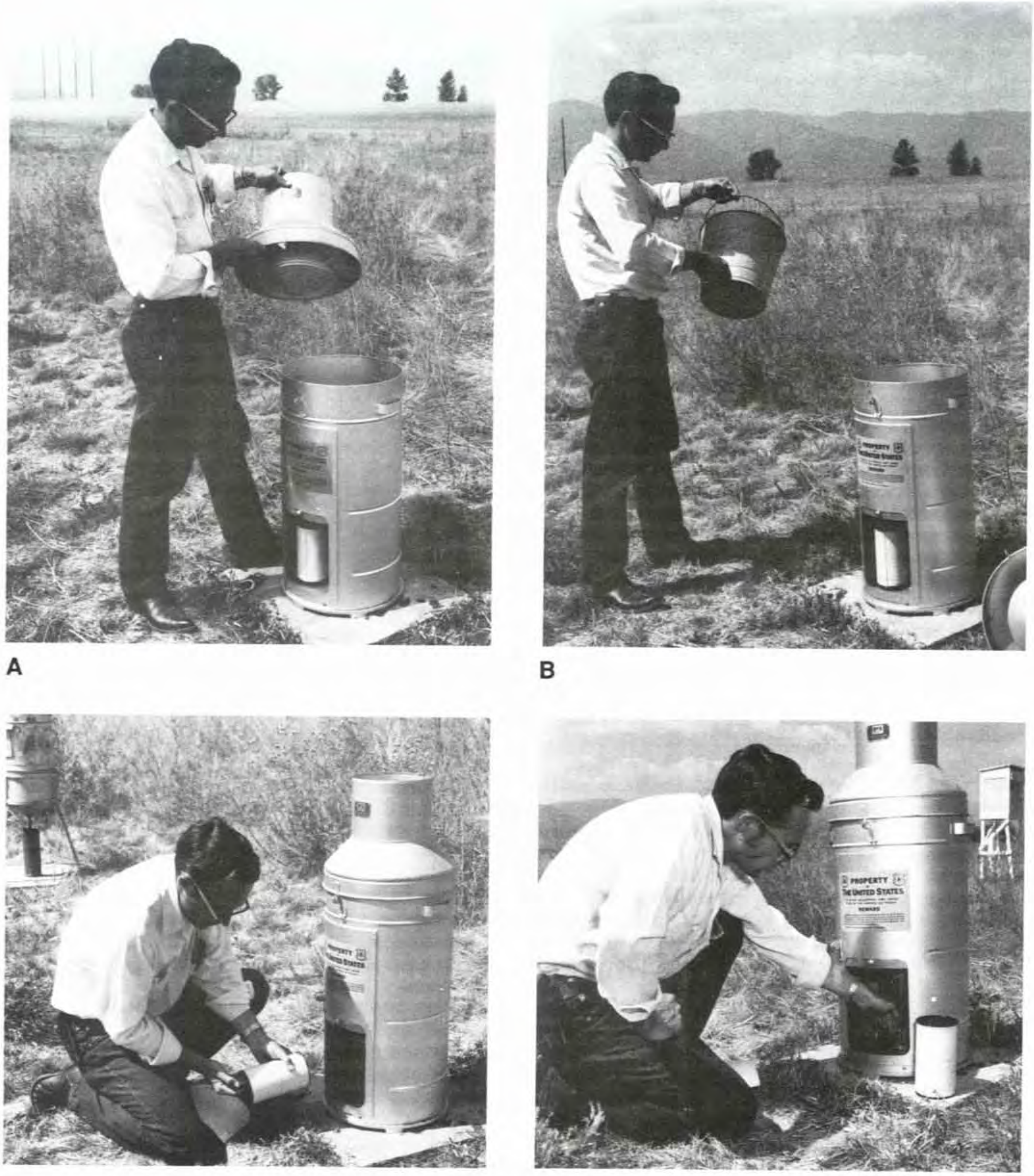
UNIVERSAL WEIGHING GAUGE

Daily Precipitation Measurements—Precipitation amounts between successive observations are read from the recording chart, subtracting the initial value shown by the pen trace from the current value. Likewise, hourly precipitation amounts can be obtained or intensities (rates of fall) can be calculated. Before reading, tap the floor of the gauge to free the pen arm and its linkage from possible frictional constraint.

Changing Charts—Charts having a weekly time scale are usually changed at that interval, on a Monday, unless accumulated precipitation is exceptionally heavy and approaches or exceeds chart capacity. Charts having a 24-hour time scale may be left on for periods of 1 or 2 weeks, if precipitation is absent or well below chart capacity. In this case, advance the pen slightly upward to a new line each day, with date and time notations made.

To change a chart during ordinary warm-season (fire-season) operation, follow this procedure (see fig. 25.1):

1. Open any locks used on gauge. Slide the inspection (access) door upward and, using the pen arm shifter, lift pen from the chart.
2. Lift the chart drum clear of spindle and then tilt to remove through access door. Remove chart, noting the date and "time off." Prepare a new chart, noting station name, date, and "time on" (fig. 9.7).
3. Remove the collector and bucket. If there is water in the bucket, check to verify that precipitation has been recorded on the chart just removed. Empty the bucket and replace both bucket and collector.
4. Install the new chart. Make sure that it fits snugly and rests squarely against the lower flange of the drum. (See hygrothermograph instructions, section 23.5.)
5. Wind the clock (where this is required), but do not overwind. If the chart drive is battery operated, check that the drive is running (see section 23.5).
6. Replace the chart drum and turn it counterclockwise (backward in time) until the pen is lined up with the correct time position on the new chart.
7. Add ink to the pen, if necessary, filling the V-point reservoir to slightly below the top. Remove and replace ink if it has diluted and overflowed during damp weather conditions.
8. Bring pen into contact with chart, using pen arm shifter, and make final time adjustment if necessary.
9. Check the pen setting. The pen should rest on the bottom horizontal line of the chart when the empty bucket is in place. Use the fine adjustment thumbscrew if necessary.
10. Be sure that ink is flowing from pen to chart. Pressing lightly on the pen should be sufficient to start this flow. If necessary, remove pen from the chart and draw a piece of lint-free paper through the nibs before returning and pressing again.
11. Close the access door of gauge, sliding it downward into groove, and secure locks.



A B C D

Figure 25.1—Operating procedure for Universal weighing gauge: A, remove the collector, after releasing pen from chart; B, empty bucket; C, remove chart drum and install new chart; D, wind clock; E, replace chart drum and zero the pen.

E

Figure 25.1 (Con.)

Operation During Freezing Weather—For operation during the snow season (and freezing weather):

1. Remove, by rotation, the funnel attached at the bottom of the collector; store indoors in a convenient place.
2. Place an antifreeze solution in the bucket. A solution of calcium chloride was widely used in the past, but this has been replaced by ethylene glycol as the prescribed agent (U.S. Department of Commerce 1972). The standard charge is 1 quart, consisting of 24 oz ethylene glycol plus 8 oz light oil (such as SAE 10 motor oil, transformer oil, or mineral oil) to prevent evaporation; no water is added.

Despite a higher cost, as compared with calcium chloride, an ethlylene glycol preparation (automobile antifreeze) has the advantage of being noncorrosive. It also minimizes the chance of top freezing, as it does not settle as readily as a calcium chloride solution.

Ethylene glycol, however, is toxic to plants and animals, even in small amounts, and thus spills should be avoided. It should never be drained onto the ground for disposal. The National Weather Service has most recently planned to convert to nontoxic propylene glycol (Blackburn 1988).

3. Addition of the ethylene glycol antifreeze solution will raise the zero position of the pen arm to between 1 and 2 inches on the recording chart. Using the fine adjustment thumbscrew, raise or lower the pen until it rests on the nearest horizontal line. This will simplify the reading of precipitation amounts.
4. Stir the antifreeze solution occasionally, particularly after precipitation occurs, to help maintain a uniform mixture.
5. Let precipitation accumulate in the bucket until the antifreeze becomes too diluted to prevent freezing or until the pen reaches about 5 inches on the chart. When this occurs, empty the bucket and recharge with antifreeze if still required.

PUNCHED-TAPE RECORDER

Only a general outline of operating instructions will be given here, as this type of gauge has been operated mostly under supervision of the NWS. Basically (U.S. Department of Commerce 1972), the observer should:

1. Inspect the gauge weekly to determine that the tape is at the correct time. Also, read and record the precipitation accumulation shown by the gauge's indicator dial.
2. Empty the bucket whenever an accumulation in excess of 10 inches is noted on the indicator dial.
3. Remove the funnel for operation during the snow season. Empty the bucket and add antifreeze—2 quarts of the solution described in the Universal gauge instructions. The indicator dial will then read between 2 and 3 inches. Empty and replace antifreeze, if still necessary, when the dial reads 10 inches.
4. After the end of each month, remove recorded portion of the tape supply and rethread remaining tape. Install a new roll of tape if the present supply is insufficient for the coming month.

TIPPING BUCKET GAUGE

Observations with this type of gauge basically consist of reading the connected event recorder chart or digital counter. Precipitation for the observational period, or for any desired time interval, is determined by the corresponding number of 0.01-inch steps on the chart or the difference in counter readings. If desired, the counter may be reset to zero after each observation.

To obtain supplemental stick measurements from gauges that have a reservoir:

1. Place the tipping bucket gauge's measuring tube directly underneath, open the draincock, and collect the discharged water.
2. Insert the tipping bucket gauge's measuring stick slowly into the tube, until the stick touches bottom, and read the graduation nearest to the waterline. (*Do not* use the measuring stick from the standard 8-inch rain gauge.)
3. If more than one tubeful of water is contained in the reservoir, add the measurements. (Draincock should be closed just as the tube fills to brim, then reopened for additional water after the tube has been emptied and again placed beneath the drain.)
4. When the reservoir is empty, close the draincock.
5. Compare the stick total with the total shown for the same time period on the recorder chart or counter. Stick amounts may be slightly higher than the originally recorded (chart or counter) amounts in cases of intense rainfall (section 9.2). The original amounts can be corrected accordingly. Stick amounts that are lower than the recorded amounts may result from evaporation of water in the reservoir, especially if the measurement has been delayed.

25.3 Storage Gauges

Storage gauge precipitation amounts, such as accumulated seasonal or annual totals, may be accurately determined by either depth or weight measurements. A stick or tape is used for the depth measurements. Depending on the type of gauge, weight measurements (USDA SCS 1972) are either (1) those of the gauge and its contents or (2) those of an auxiliary bucket containing contents drained from the gauge. In either case, the depth should be measured before draining, to serve as a check on the total weighed contents. This precaution will provide backup in case of accidental spill or calculation error.

WEIGHING PROCEDURE

For determining the precipitation by weighing, an accurate hand scale with at least 40 pounds capacity should be used—preferably the type shown in figure 9.3, which gives direct readings in inches of precipitation caught in a gauge with an 8-inch-diameter orifice. The readings are divided by 2.25 if this scale is used with a gauge having a 12-inch-diameter orifice. Always check the scales before use and adjust if necessary, by means of a screw, to be sure that the pointer is set at zero. In reading the scales, be sure to count the revolutions. Be sure that the attached gauge or auxiliary bucket is hanging freely.

To calculate the precipitation amount, subtract from the scale total the weight or equivalent inches of antifreeze solution (measured when this charge is poured into the storage gauge). Also subtract the weight of the empty gauge or auxiliary bucket, whichever is included in the weighing process.

In heavy precipitation areas, particularly where the storage gauge catch is weighed out only annually or seasonally, the amount to be weighed will often exceed the scale capacity. In these cases, the weighing is done in increments of the total catch. Specific weighing instructions follow:

Sacramento, Standpipe, and Can-Cone Gauges—Annual measurements are usually made in summer or early autumn, when the gauge contents should be entirely in liquid form.

1. Open the draincock and allow the gauge contents to run into a weighing bucket; to avoid possible spill, close the drain before the level of liquid inside the bucket exceeds a safe limit.
2. Weigh the contents of the bucket and record the scale reading (equivalent inches).
3. Empty the bucket, reopen the draincock, and repeat the filling and weighing steps. Repeat the process as many times as necessary until the gauge is completely drained.
4. Add the individual scale readings.
5. Subtract from this total the weight of the empty bucket, multiplied by the number of weighings.
6. Also subtract the amount of antifreeze solution, which was measured in advance of its use.

Straight-Sided Cans—These gauges, particularly the shorter (24-inch) cans, are commonly weighed together with their contents. A small hole is drilled near the top of the can for suspension from the scales. If the weight of the gauge and its contents exceeds the scale capacity, however, excess liquid or all of the liquid may be poured or drained from the gauge into an auxiliary bucket—in incremental steps as necessary.

1. Record and add the individual scale readings.
2. From this total, subtract the weight of the empty bucket for each time it was used.
3. Also subtract the weight of the empty can (gauge) if the can was included in the weighing process.
4. Subtract the premeasured amount of antifreeze solution.

25.4 Measurement of Snowfall and Snow Depth

SNOWFALL

Snowfall, the depth of newly fallen snow or ice pellets (sleet), should be measured concurrent with the snowfall water content (section 25.1)—as soon as possible after the snow has ended. Promptness should reduce errors that can result from melting, settling, or wind action. Snowfall can be measured on a previously bare or cleared grass surface, on an already existing snow surface (with identifiable crust), or on a snow board or other suitable surface that retains the snow.

1. Insert the rain gauge measuring stick, or a sturdier ruler if necessary, vertically into the snow until it rests on the measurement surface. When a grass surface is used, be sure the stick is pushed only to the bottom of the snow layer—not lower into the grass blades.
2. Read the snowfall depth to the nearest tenth of an inch (for example, 2.3 inches or 6.6 inches). This will be the actual linear measure on the rain gauge measuring stick (10 times the stick's scale reading in hundredths of an inch).
3. Repeat the measurement at several spots and calculate an average. Variations between measurement spots are commonplace and may result from uneven ground surfaces, differences in melting, and wind action. Avoid locations that are heavily drifted or blown clear.
4. Any snow cores used for measuring water content (section 25.1) should be taken from spots having an average, representative snowfall depth as determined above. Where a snow board is employed, it can be used for obtaining both the snowfall depth and a snow core.
5. Where a cleared or identifiable surface is difficult to find, snowfall may be approximated by subtracting the previously measured total snow depth (see following subsection) from the current snow depth. The result will be too low if the snow cover is compacting, which is often the case with heavy snowfall. If all of the precipitation during an observation period has been *nonmelting* snow, the recorded snowfall should probably be at least 10 times the melted gauge catch. Thus, with a gauge catch of 0.25 inch water, the snowfall should be 2.5 inches or greater.

SNOW DEPTH

Total depth of snow lying on the ground can be measured with the rain gauge measuring stick or a longer, sturdier stick. At least several spots are sampled. The stick should not penetrate grass blades below the snow. A heavy snow cover will tend to flatten an underlying grass surface, but such cover will usually require snow stakes (or sampling tubes) for measurement (USDA SCS 1972). Both the sticks and stakes are read to the nearest inch.

CHAPTER 26. FUEL MOISTURE

26.1 Use of Fuel Moisture Scales

The fuel moisture scale measurements, described below, may have to be corrected for aging changes in the fuel sticks (section 10.1).

FORESTER (APPALACHIAN) SCALE

To measure moisture content of the ½-inch ponderosa pine fuel moisture stick:

1. *Check the scale*—Be sure that the sliding weight on the balance arm is set and locked at 100 grams. The weight is locked by tightening the setscrew on top of the weight. Check calibration by hanging the 100-gram weight on the hook and tapping the pivot block lightly; the pointer should indicate zero (fig. 26.1). If adjustment is necessary, loosen the wing nuts and carefully move the scale until the pointer indicates zero.

2. *Remove the stick from rack*—Use a clean glove, piece of cloth, or paper, and remove the stick from its wire exposure rack. If stick is dry, lightly brush off any dust, using a clean, soft-bristle paint brush (fig. 26.2); if wet, shake off any free moisture.

3. *Weigh the stick*—Using its hook, hang the stick on the scale arm (fig. 26.2). Steady the stick and let the pointer come to rest; then tap the pivot block to overcome any binding due to friction. Close the shelter door, if necessary, to prevent wind interference. Read the moisture percentage shown on the scale by the pointer, and record to the nearest whole number (fig. 26.3).

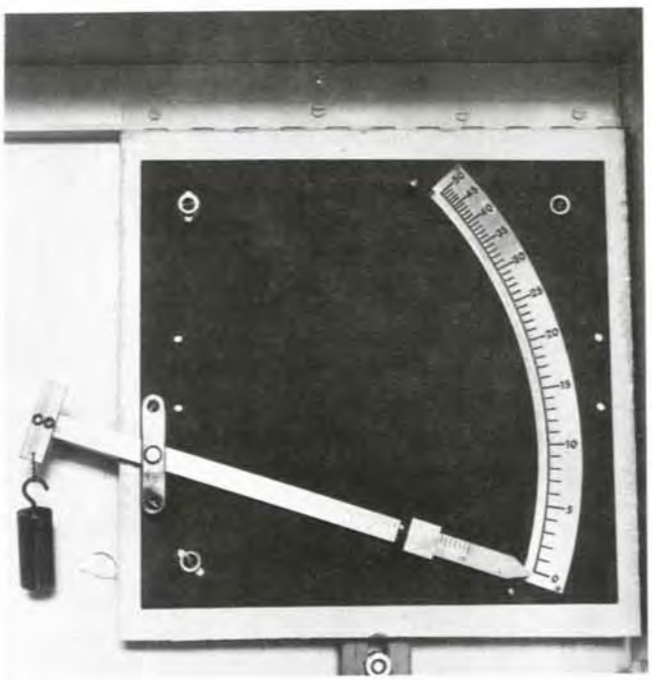


Figure 26.1—Use of a 100-gram test weight to check calibration of the Forester scale.

Figure 26.2—Weighing the fuel moisture stick on Forester scale: top left, remove dust, dirt, etc.; top right, carefully hang stick on scale; bottom, close door to protect stick from wind.

Figure 26.3—Reading the Forester scale. The stick weighs 108 grams, compared with 100 grams ovendry weight, so its moisture content is 8 percent as indicated by the pointer.

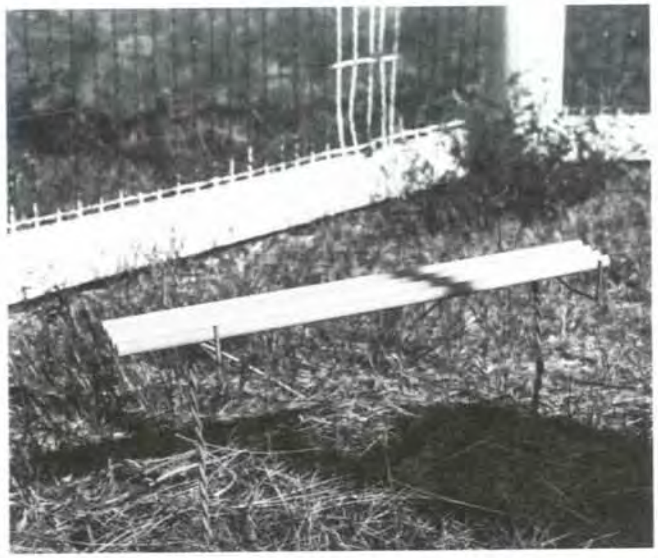


Figure 26.4—After weighing, replace the stick on wire rack, with hook to north and brads facing downward.

4. *Replace the stick*—Remove the stick from the scale and return it to the wire rack (fig. 26.4). Be sure that the correct side faces up (side with brads should face down) and that the end with the screw hook points north.

FORESTER (CHISHOLM) PORTABLE SCALE

This scale can be hand-held (fig. 26.5), but it is much easier to use if hung on a post, tree, etc. To operate:

1. *Check the scale*—Make sure the scale is plumb and that the pointer moves freely. Check calibration with the 100-gram test weight.
2. *Remove the stick from rack*—Remove the stick from wire rack and remove dust or free moisture, as described previously in the Forester (Appalachian) scale instructions.
3. *Weigh the stick*—Carefully hang the stick on the scale hook. Gently tap the pointer and read the moisture percentage that it shows on the scale. Record to the nearest whole number (fig. 26.5).
4. *Replace the stick*—Replace as described in the Forester (Appalachian) scale instructions.

WILLIAMS POCKET SCALE

1. Remove locking screw and scale cover.
2. Insert the locking screw as a handle for the scale.
3. *Check the scale*—Calibrate the scale by hanging its cover (100 grams) on hook (fig. 26.6); any deviation from 100 grams must be included as an adjustment in the final moisture calculation (step 6).

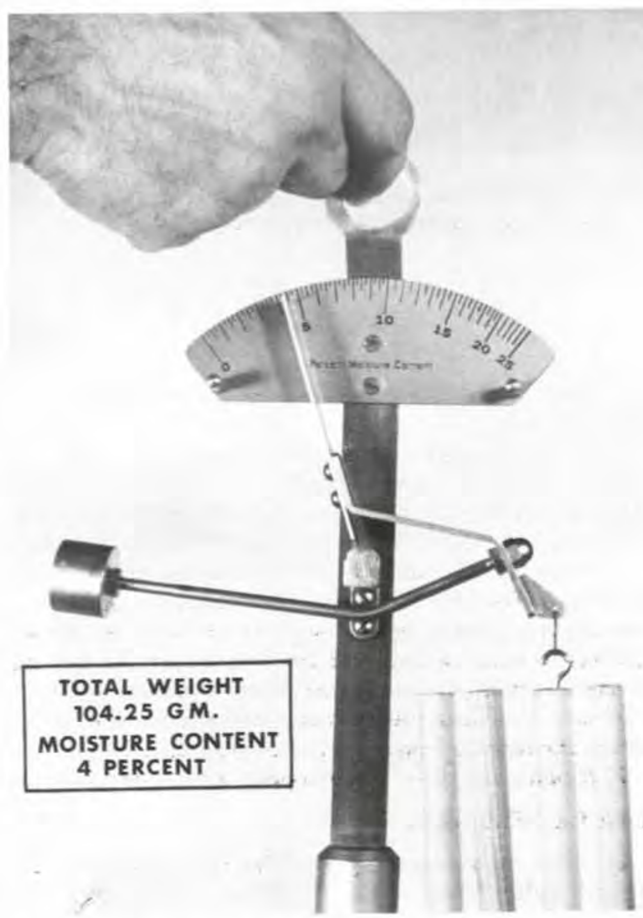


Figure 26.5—Weighing the fuel stick on Forester (Chisholm) portable scale. The stick weighs 104.25 grams, so its moisture content is 4 percent as indicated by the pointer.

Figure 26.6—Checking calibration of Williams pocket scale, using cover as a 100-gram weight.

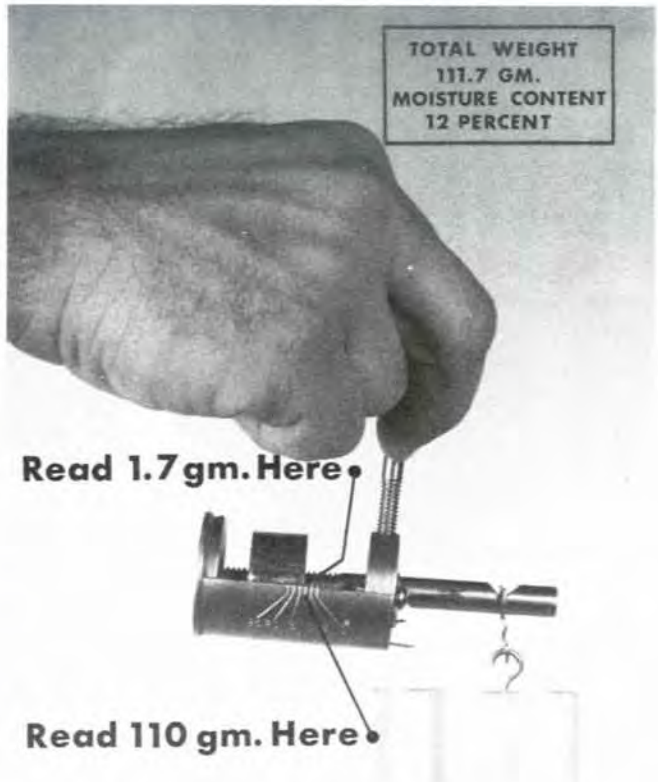


Figure 26.7—Weighing the fuel stick on Williams pocket scale. The stick weighs 111.7 grams, so its moisture content is 12 percent as indicated on scale.

4. *Remove the stick from rack*—(See Forester scale instructions.)

5. *Weigh the stick* —After removing scale cover (used in step 3), hang stick on the scale hook (fig. 26.7). Turn the circular weight until beam balances; at this point be sure that the scale body is horizontal and the handle vertical.

6. *Calculate the moisture value*—Read the graduations on both the rotating weight and the scale body. Add the two readings, adjusting for any deviation found in step 3. Recheck to make certain that the numbers are read in the proper direction on the rotating scale. From the result, subtract 100 grams (the standard fuel stick weight) to obtain the recorded moisture percentage (fig. 26.7).

7. *Replace the stick*—(See Forester scale instructions.)

TRIPLE BEAM BALANCE

1. *Check the balance*—Dust off the balance pan, using a clean, soft-bristle paint brush. Place a 100-gram weight on the pan and balance it at 100 grams (fig. 26.8).

2. *Remove the stick from rack*—(See Forester scale instructions.)

3. *Weigh the stick*—After removing the 100-gram calibration weight, place the stick evenly on the balance pan, with the center of the stick lying over the center of the pan (fig. 26.9). Move the two large weights along their respective beams until the pointer swings freely. Be sure that the weights are seated in the notches of their beams.

Then adjust the small sliding weight on the front beam until the pointer swings the same distance above and below the zero mark on the small vertical scale at the end of the pointer. *Always* tap the main bearing case with a finger or pencil as a precaution against possible sluggish balance action, so that the pointer will not settle too early in an incorrect position.

Read the scale and record, as the moisture percentage, the weight of the stick in excess of 100 grams (fig. 26.9).

4. *Replace the stick*—(See Forester scale instructions.)

5. Return all balance weights to zero.

HARVARD BALANCE

Operation of the double-pan Harvard balance is similar to that of the triple beam balance, except for the manipulation of the weights. Place the fuel moisture stick on one of the pans and a 100-gram weight on the second pan (fig. 26.10). Then place additional weights on the second pan until the vertical pointer swings freely. Use the sliding weight on the front scale to achieve the final balance.

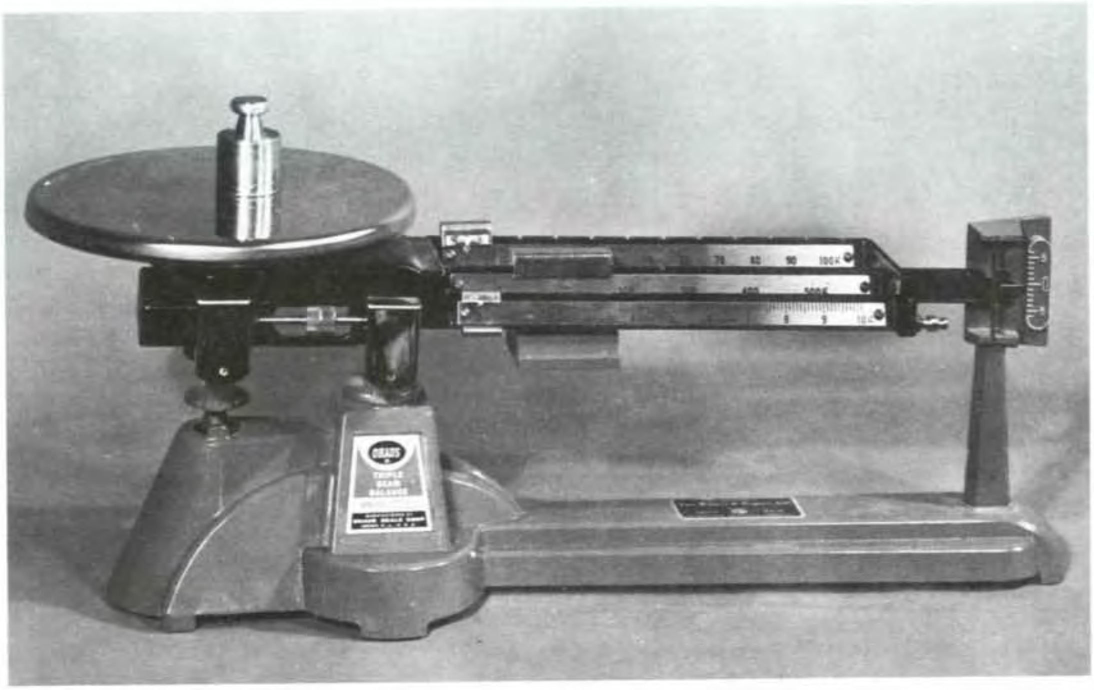


Figure 26.8—Checking the balance of triple beam balance.

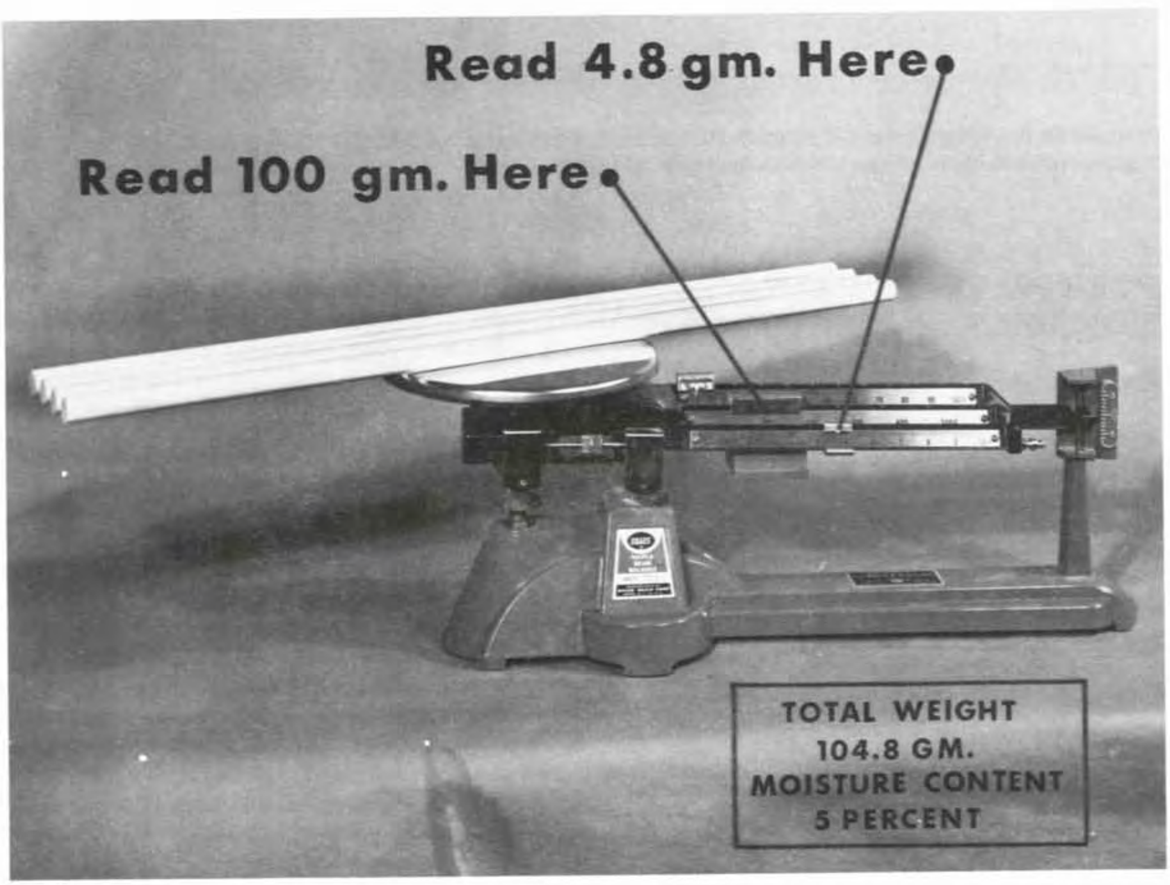


Figure 26.9—Weighing the fuel stick with triple beam balance. The stick weighs 104.8 grams, so its moisture content is 5 percent as indicated on the first scale bar.

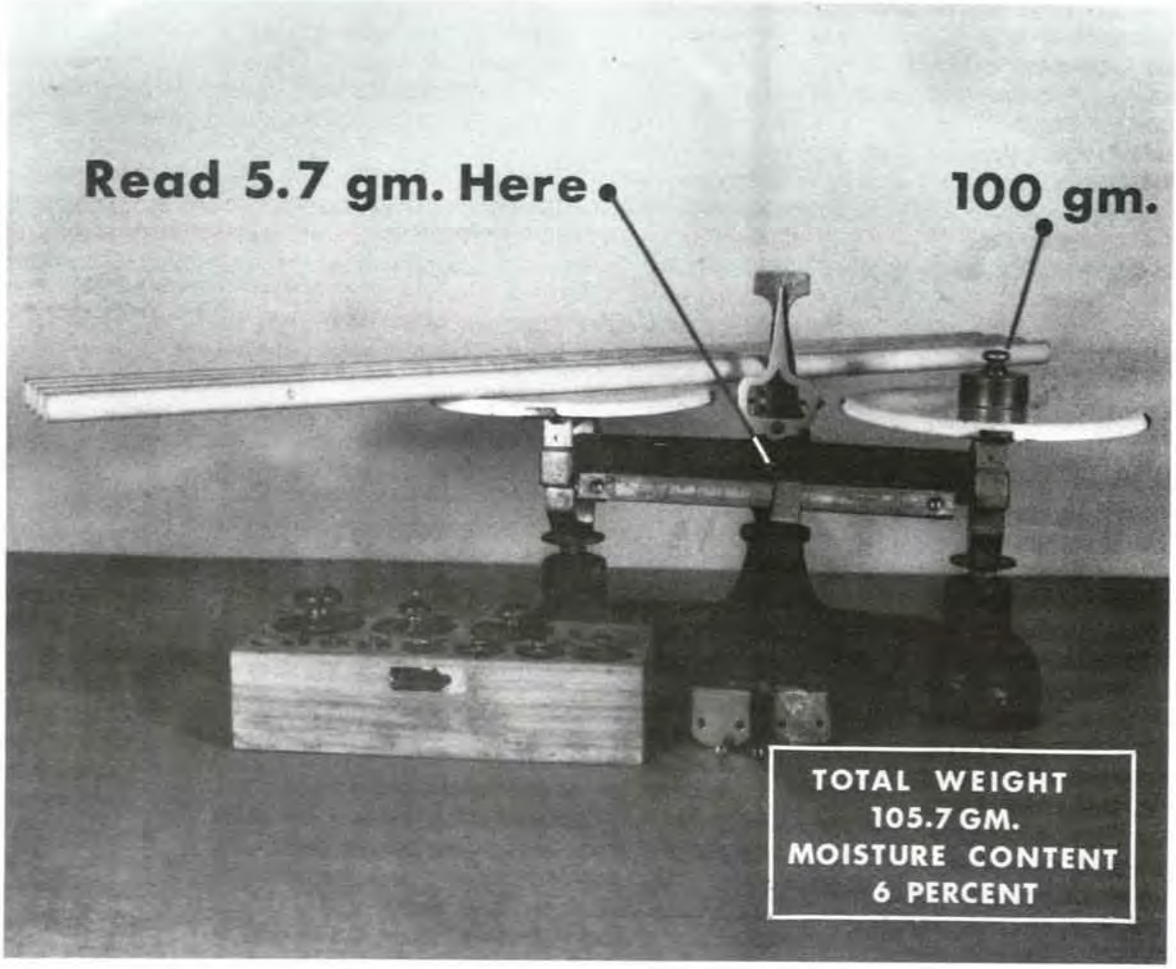


Figure 26.10—Weighing the fuel stick with Harvard balance. The stick weighs 105.7 grams, so its moisture content is 6 percent as indicated on the scale.

CHAPTER 27. EVAPORATION STATION MEASUREMENTS

27.1 Evaporation

The recorded evaporation is determined by the decrease in successive (daily) hook gauge readings or by the amount of water added in using the fixed-point gauge. As described below, adjustments are included for measured precipitation (sections 25.1 and 25.2).

USE OF THE HOOK GAUGE

At the time of observation, place the hook gauge atop the stilling well and adjust the hook until its point is below the water surface. Slowly turn the knurled adjusting nut (fig. 12.3) clockwise, raising the point until it just pierces the water surface. The sky's reflection in the water will aid in determining when this condition occurs. Remove the gauge and read its two scales.

The inches and tenths scale on the gauge stem is read in tenths of inches, as indicated by the first graduation at or above the top of the adjusting nut. Thus, a reading of 25 indicates 2.5 inches. The circular scale attached to the nut is read to the nearest hundredth of an inch, using the index line; a reading between 32 and 33 (thousandths) indicates a value between 0.03 and 0.04 inch, but closer to 0.03 inch. The recorded gauge reading is the sum of the two scale readings, or 2.53 inches in the above example.

Calculation of Daily Evaporation—Subtract the previous day's hook gauge reading from the current day's reading. When precipitation has occurred, add the 24-hour amount (measured at the current observation) to the previous hook-gauge reading; then subtract the sum from the current hook-gauge reading.

The height of the evaporation pan's rim above the water surface can affect the rate of evaporation. Therefore, at stations using hook gauges, refill the pan to a level 2 inches below the rim whenever the water surface has lowered 1 inch. Conversely, water may have to be removed in advance of expected heavy rain that may raise the water level beyond the range of the hook gauge (U.S. Department of Commerce 1972). All adjustments of water level should be done immediately following an observation. When this has been done on the previous day, the amount of water added (or removed) must be subtracted from (or added to) the current day's hook-gauge reading.

USE OF THE FIXED POINT GAUGE

At the time of observation, using the plastic measuring tube, add or remove water from the evaporation pan until the tip of the fixed point coincides with the water surface in the stilling well. When water must be added (to compensate for evaporation since the previous observation), fill the measuring tube to the zero mark (its upper marking) before pouring into the pan. Pour slowly as the water surface within the well approaches the tip of the point.

Calculation of Daily Evaporation—When no precipitation has occurred, simply observe the amount of water that was added to the pan. This is read from the marking (in hundredths of an inch) on the measuring tube nearest the remaining waterline; each tubeful of water added represents 0.15 inch evaporation. When precipitation has occurred but water must still be added to the pan, calculate the daily evaporation as the sum of the precipitation and added-water amounts.

To calculate daily evaporation when precipitation has occurred and water must be removed from the pan, subtract the amount of removed water from the amount of precipitation. To determine the amount of water that was removed (into the measuring tube), subtract the waterline marking from 15 (hundredths of an inch), which is the marking at the bottom of the tube (fig. 12.5). For example, if enough water is removed to reach the 5 marking on the tube, the correct amount removed is 15 minus 5, or 10, which is equivalent to 0.10 inch. Many tubefuls of water will have to be removed when substantial precipitation has occurred; a careful count must be kept.

27.2 Supplemental Data

WIND MOVEMENT

The anemometer counter is read daily at the time of evaporation measurement. Record to the nearest whole mile. The 24-hour wind movement is the difference between successive daily readings.

Reading Anemometer Counters—In the five-digit odometer type anemometer, the right-hand digit indicates tenths of a mile; the maximum total, 10,000 miles, is indicated as five zeros, which also coincides with zero miles for the succeeding 10,000-mile cycle of recording. To calculate the 24-hour wind movement when the current day's odometer reading is less than the preceding day's reading, add 10,000 to the current reading; then subtract the preceding reading.

The circular-dial anemometer (fig. 8.7) will register a maximum wind movement of 990 miles. To calculate the 24-hour wind movement when the current day's reading is less than the preceding day's reading, add 990 to the current reading; then subtract the preceding reading. Thus, if today's reading is 50 and yesterday's reading was 900, the 24-hour wind movement is (50 + 990) –900, or 1,040–900, equal to 140 miles.

MAXIMUM AND MINIMUM WATER TEMPERATURES

Reading and Setting Six's Thermometer—Read and record the maximum and minimum temperatures to the nearest whole degree Fahrenheit as indicated by the two metal index rods; read the index ends nearest the mercury column. If possible, the thermometer should be read while submerged. To reset, carefully remove the thermometer from the pan and use the furnished magnet to slowly draw each index rod into contact with the mercury. Carefully return the thermometer to its pan location.

CHAPTER 28. SOIL TEMPERATURE

28.1 Required Observations

The diurnal soil temperature range is often large at depths of a few inches, particularly without snow or other ground cover, but it decreases rapidly with further depth; it is reduced to about 1 °F at 20 inches. Thus, one observation per day, of current temperature, is adequate at 20 inches and deeper. Daily maximum and minimum temperatures are desirable at shallower depths. The daily observation time will usually be the basic time used for other observations at the station.

READING THERMOMETERS

The dial or mercury-in-glass thermometers should be read to the nearest whole degree Fahrenheit. Be careful to avoid parallax error (section 23.1). Before each reading, check mercury-in-glass thermometers for possible column separations (section 30.2). After reading and recording the data, reset maximum-minimum thermometers; reset the dial type by turning the center knob.