Chapter 3
Dry Kiln Auxiliary Equipment

Chapter 3 was revised by R. Sidney Boone, Research Forest Products Technologist.

Certain auxiliary equipment is needed to operate a dry kiln in the most economical manner and to obtain good drying results. Drying schedules based upon moisture content cannot be successfully applied unless the moisture content of the stock is known. Therefore, equipment should be available for determining the moisture content of the stock. Equipment should also be available for determining the temperature, humidity, and velocity of air in the kiln to maintain uniform conditions for fast drying.

Equipment for Determining Moisture Content

Such items as balances, scales, saws, drying ovens, and electric moisture meters are used in determining the moisture content of wood. Distillation equipment is used for accurate determination of moisture content of woods that hold relatively large amounts of oil, resins, wood preservative, or fire-retardant chemicals.

Balances and Scales

Triple-Beam Balance

One of the most commonly used types of balances for weighing small moisture sections is the triple-beam balance, shown in figure 3-1. Balances best suited for weighing the recommended sizes of moisture sections (see preparation of kiln samples and moisture sections in ch. 6) should have a maximum capacity of at least 1,000 g and weigh to an accuracy of at least 0.1 g (0.01 g is preferable).

Electronic Top-Loading Balance

Electronic top-loading balances are available in a wide range of weighing capacities, precisions, styles, and price ranges. Models with printers that provide a written record of the weights and portable battery-operated models are also available. Two types suitable for weighing small moisture sections are shown in figure 3-2. Because of the size of the pieces to be weighed and the precision to which they need to be weighed, the same balance cannot be used to weigh the small moisture sections and the much larger sample boards (see preparation of kiln samples and moisture sections in ch. 6). For weighing moisture sections, the balance should have a maximum capacity of at least 1,000 g and weigh

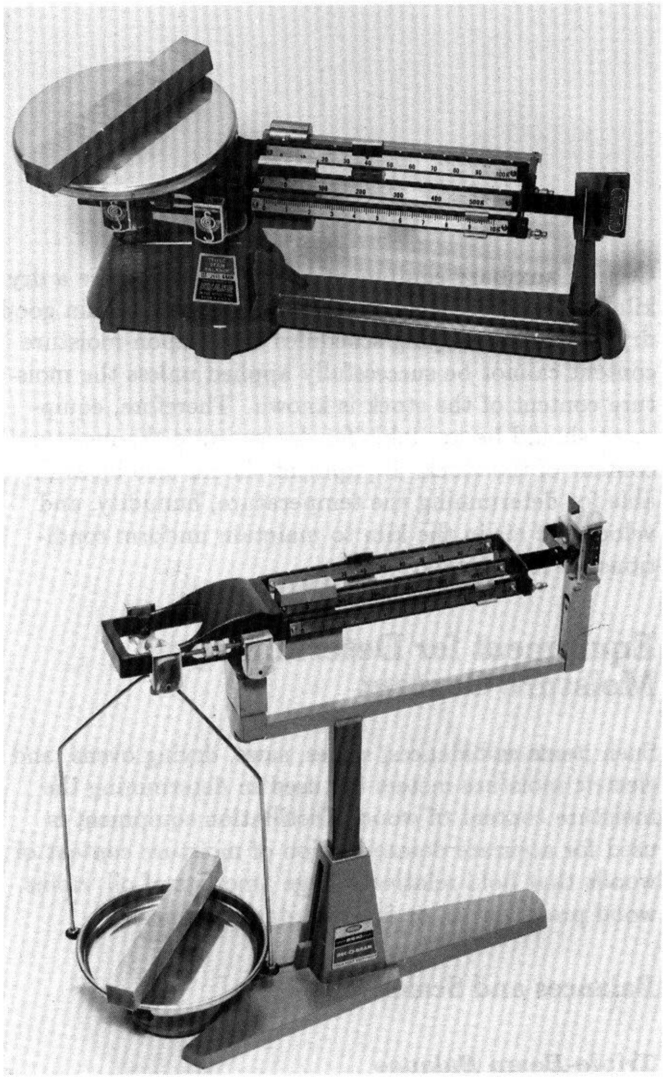

Figure 3-1—Two types of triple-beam balances suitable for weighing moisture sections. *(M87 0198, M87 0169)*

to at least 0.1 g (0.01 g is preferable). A type of balance suitable for weighing sample boards is shown in figure 3-3. For weighing sample boards, the balance should have a maximum capacity of at least 15,000 g and weigh to 1.0 g. Operations drying wide boards of higher density hard woods should consider having a maximum capacity of 20,000 to 30,000 g.

Self-Calculating Balance

To calculate moisture content, it is necessary to know the original and the ovendry weights of the wood sections. The loss in weight is divided by the ovendry weight (see ch. 6 for procedure). Self-calculating balances, similar to the one shown in the upper part of figure 3-4, have been developed to speed up these calculations or to eliminate them entirely. As shown in the lower part of figure 3-4, the moisture readings can be estimated to the nearest 0.5 percent when the values are less than 10 percent, and to the nearest 1.0 per-

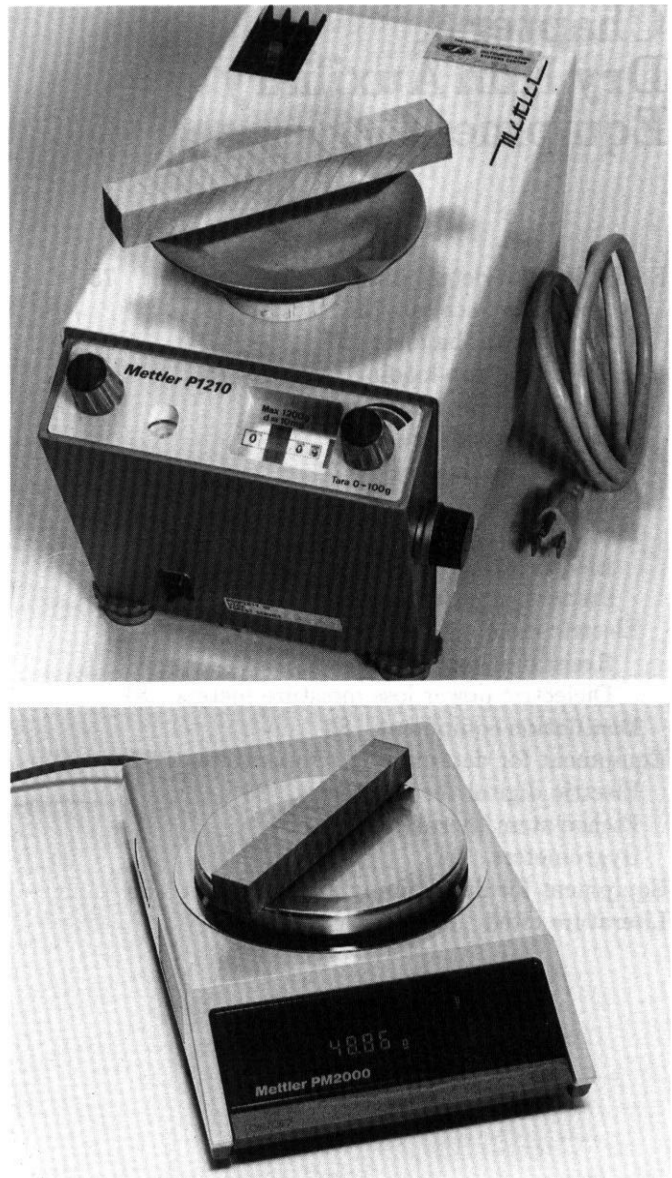

Figure 3-2*—Electronic top-loading balances suitable for weighing small moisture sections. (M87 020,M87 0175)*

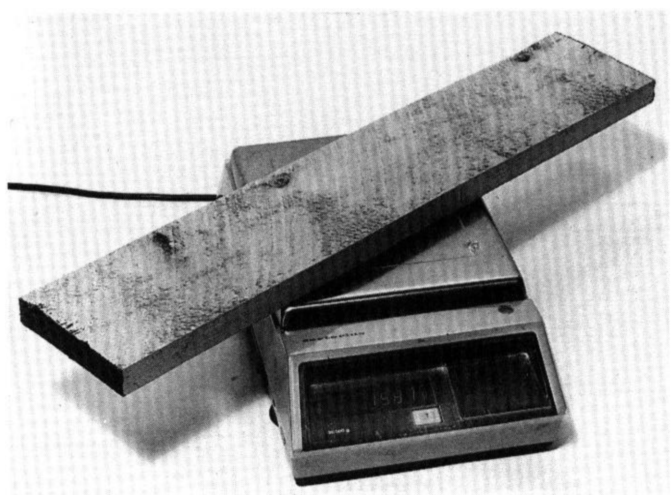

Figure 3-3—Electronic top-loading balance for weighing *sample boards. (M87 0174)*

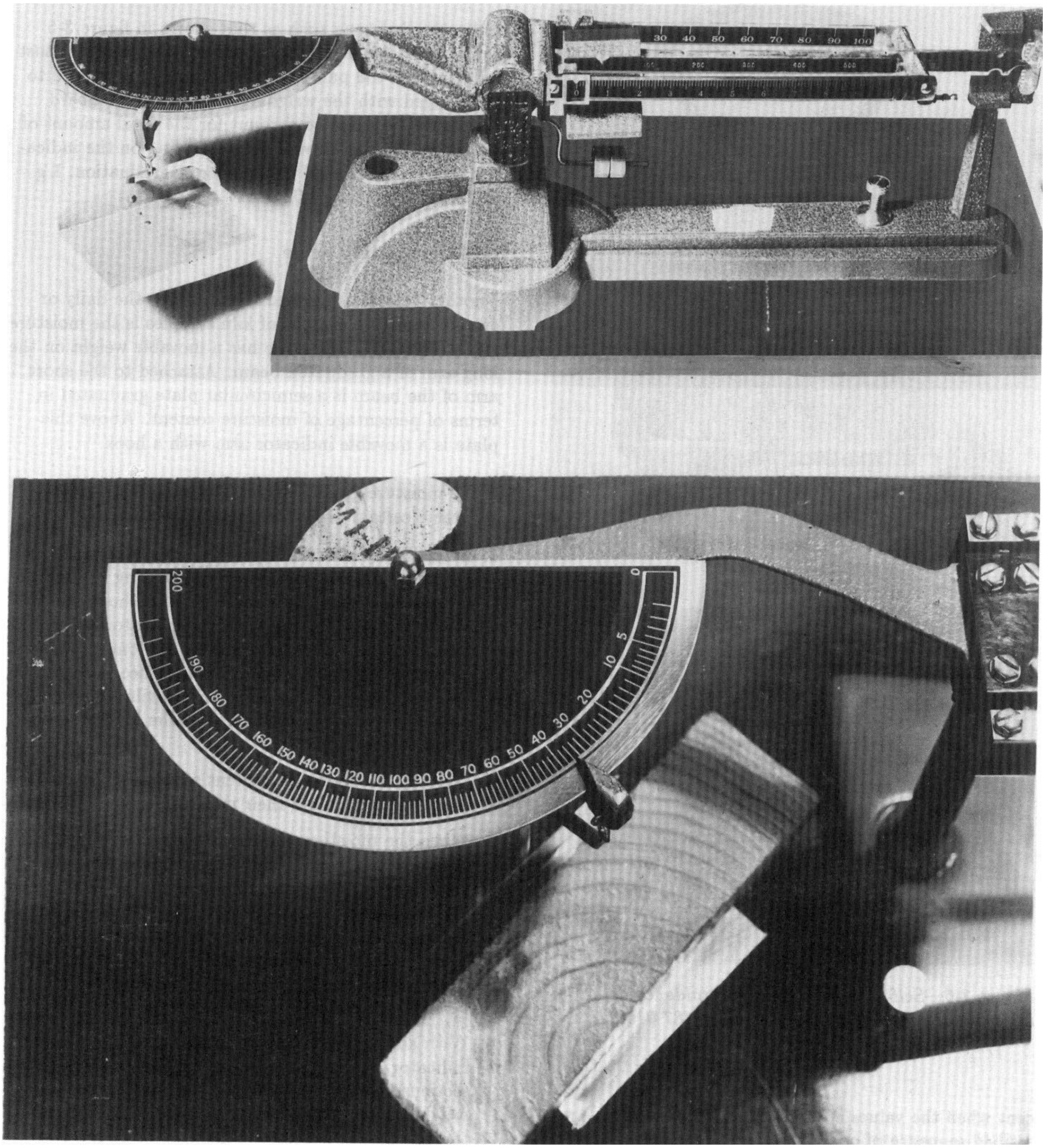

Figure 3-4—*Self-calculating moisture balance. Top: Triple-beam balance with special scale on specimen pan used to calculate moisture content of moisture section after ovendrying. Bottom: Specimen pan is carried on revolving indicator that indicates moisture content directly on scale. (M 90343)*

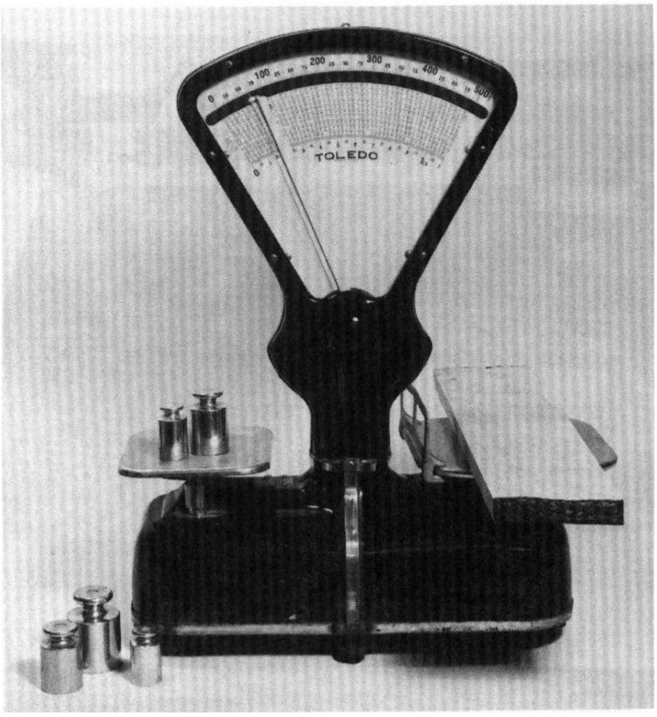

Figure 3-5—*Indicating balance. (M87 0199)*

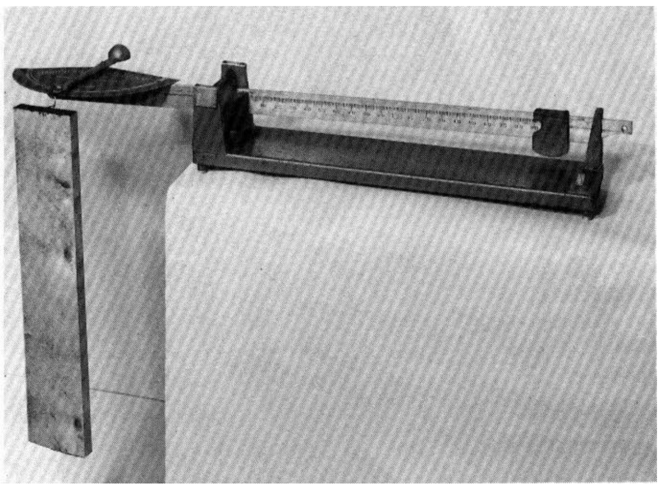

Figure 3-6—*Self-calculating scale or guide for determining moisture content of kiln sample. (M87 0168)*

cent when the values are more than 10 percent. A prescribed sequence of operating steps, supplied by the manufacturer, must be followed in carrying out a moisture content determination for moisture sections with this balance.

Indicating Balance

Indicating balances such as that shown in figure 3-5 can be used for weighing sample boards. Weights must be placed on the pan on the left side and may need to be changed with the weighing of each sample board. Care must be taken to account for the total amount of weight on the pan as well as the reading on the indicator, which can be read to the nearest graduation, 1 g or, on some models, 0.01 lb.

Self-calculating scale

Another type of scale used to determine the daily or current moisture content of kiln samples is the moisture guide (fig. 3-6). This scale has a movable weight on the long arm of a graduated beam. Attached to the short arm of the beam is a semicircular plate graduated in terms of percentage of moisture content. Above this plate is a movable indicator arm with a hook.

If the moisture guide is to be used with reasonable accuracy, certain procedures must be followed:

1. Immediately after the moisture content sections have been cut and weighed, apply end coating to the kiln sample, and hang the sample from the hook on the movable indicator arm, with the indicator set at zero. Move the sliding weight on the long beam to a point that brings the beam into balance. Record the value of the balancing point on the kiln sample, and place the sample in the kiln with the load of lumber it represents.

2 Ovendry the moisture content sections to constant weight and calculate their moisture content values.

3. When the moisture content of the sections has been obtained, remove the kiln sample board from the kiln, hang it on the movable indicator hook with the indicator set at zero, and move the sliding weight on the long beam to the setting determined in step 1. Then place metal weights, such as washers or lead slugs, on the end of the kiln sample until the long beam balances.

4. With added metal weights in place, set the movable indicator arm to the moisture content value of the sections determined in step 2, and move the sliding weight on the long beam until balance is again obtained. Erase or cross out the previously recorded value on the kiln sample and record the new balance value. This new value will be the setting of the sliding weight on the long beam used for all subsequent moisture determinations.

5. Remove the metal weights from the sample. With the sliding weight set at the new value obtained in step 4, move the indicator arm until the long beam balances. The current moisture content of the kiln sample can then be read on the semicircular plate.

6. Subsequent moisture content values of the samples are obtained by setting the sliding weight on the long beam at the new balance value obtained in step 4, hanging the kiln sample on the movable indicator hook, and moving the indicator arm until the long beam is balanced. The current moisture content is read on the semicircular plate.

Saws

Band, table, radial arm, swing, and portable saws are generally used for cutting moisture sections. Hand saws are not recommended. A band saw is particularly suitable for slotting and slicing small sections for moisture-distribution and casehardening tests. Saws should be sharp, have the proper set, and be provided with suitable safety devices. Saws that are not sharp or have improper set tend to overheat or burn the wood, thereby changing the moisture content of the section.

Drying Ovens

Several kinds of ovens are used for drying moisture sections. Drying ovens should be large enough to provide adequate open spaces between the sections of wood being dried. The temperature of the oven should be controlled with a thermostat or other means so it will stay within the desired setting (212 to 218 °F, 215 ± 3 °F). Excessive temperature will char the sections and may also start fires. Temperatures below 212 °F will not drive off all the water in the sections. The oven should have ventilators on the top or sides and bottom to allow the evaporating moisture to escape.

Electrically Heated Ovens

Electrically heated ovens are commonly used in kiln drying (fig. 3-7). Ovens containing fans to circulate the air and speed up drying are generally recommended, especially if large numbers of moisture sections are dried frequently. Natural draft ovens, those depending on the heat rising to create air circulation, are usually less efficient and require more time to remove all the moisture from the sections. Check the thermostat setting when the oven is empty, using a thermometer inserted in the hole provided in the top of the oven. When wet or moist wood is placed in the oven, the temperature will fall at first and then rise as the wood dries. Do not reset the thermostat higher after placing the wood in the oven or it will be above set point when the wood is dry.

Recently, an increasing number of operators have successfully used home-type microwave ovens to ovendry moisture sections. Considerable care must be used when drying moisture sections in a microwave oven. Although sections can be dried in minutes rather than hours, it is rather easy to overdry the section (burn it in the center) or to underdry the section (not remove all the moisture), resulting in an inaccurate ovendry weight of the moisture section. One procedure suggests using a medium-low to low power setting and an oven with a carousel tray to prevent uneven drying (Wengert 1984). Suggested time for ovendrying is about 10 min for dry pieces and about 20 min or longer for green pieces.

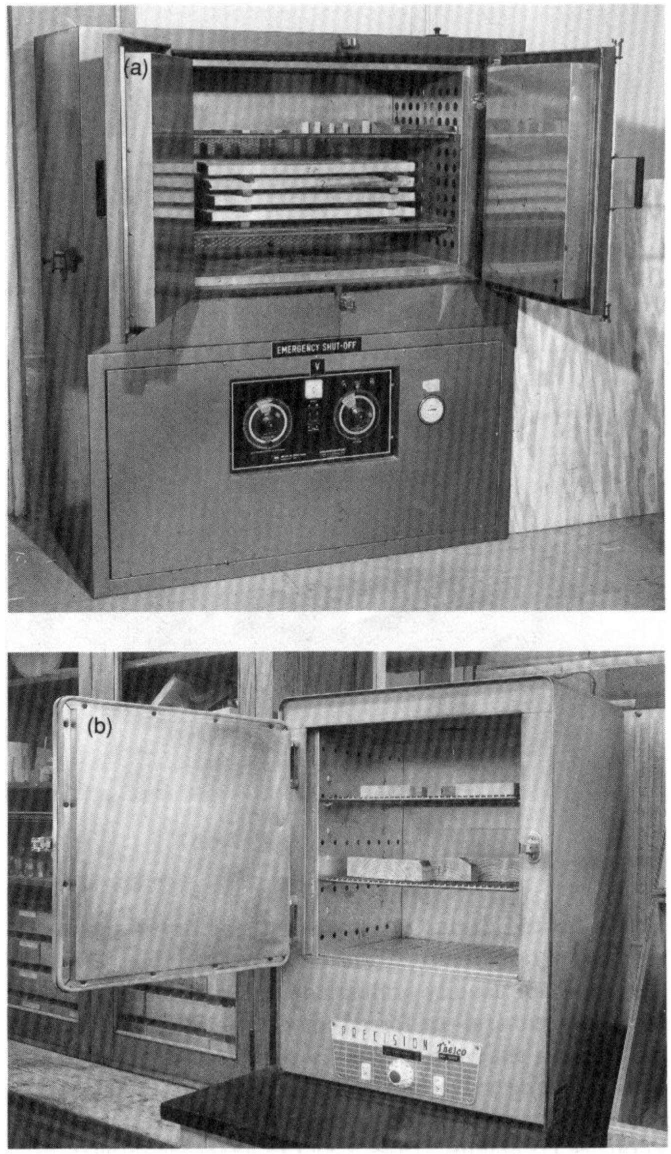

Figure 3-7—*Electrically heated ovens for drying moisture sections: (a) large floor model, (b) smaller tabletop model. (M87 0193-1, M87 0193-16)*

Steam-Heated Ovens

Steam-heated drying ovens are satisfactory if a suitable supply of steam is continuously available. Ovens of this type are usually homemade and may be equipped for either natural- or forced-air circulation. The temperature in the oven is usually regulated or controlled by a reducing valve on the steam feed line. The reducing valve is adjusted to maintain the desired ternperature (typically 215 ± 3 °F) in accordance with a thermometer inserted through the top of the oven. As with the electrically heated oven, set the temperature when the oven is empty, not after the moist wood has been placed in the oven. Shelves for the moisture sections should be made of perforated metal or large mesh, heavy wire. Provide ventilators to remove the moisture-laden air.

Electric Moisture Meters

Electric moisture meters, if properly used, provide a rapid, convenient, and, for most purposes, sufficiently accurate means of determining moisture content when it is less than 30 percent (James 1988). Woods treated with salts for preservation or fire-retardant purposes will generally, give meter readings that are too high, and the use of electric moisture meters to determine moisture content is not recommended. Electric moisture meters are available as portable hand-held units or as stationary units used to monitor moisture content of material moving along conveyor lines. In many situations, temperature and species corrections must be applied for accurate readings; correction data are usually supplied by the manufacturer of the equipment. There are two types of meters commonly available, resistance (or conductance) and dielectric.

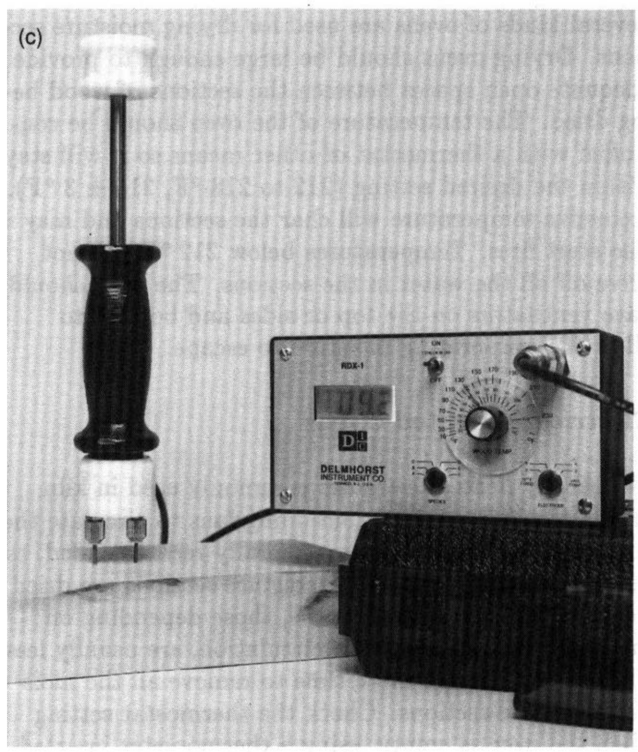

Figure 3-8—*Selected models of resistance-type moisture meters: (a) meter with insulated two-pin electrodes, dial readout; (b) meter with uninsulated two-pin electrodes; (c) meter with insulated two-pin electrodes, digital readout. (MC88 9030, M88 0131-13)*

Resistance Moisture Meters

The most common type of portable hand-held moisture meter is the resistance-type (also known as conductance-type) meter. Resistance-type meters use pin-type electrodes that penetrate the wood. The useful operating range of most meters of this type is between about 7 and 30 percent. Although some instruments have scales that read above the fiber saturation point (usually taken to be 30 percent moisture content), the accuracy above 30 percent is questionable. Selected models of resistance-type meters are shown in figure 3-8.

When using resistance-type meters on pieces of lumber with rectangular cross sections, pins should be driven one-fourth to one-fifth of the thickness of the piece to indicate an average moisture content. For circular cross sections, the depth of the pins should be one-sixth of the diameter. For the most accurate readings, orient pins so that the current flows parallel to the grain, with pins driven in the wider face of the piece. Pins driven parallel to the grain in the narrow face of the piece will give acceptable readings when ready access to the wide face is not convenient. If readings drift, take the reading immediately after the electrode is driven into the specimen. Actual moisture readings (subject to temperature and species correction) appear on the meter dial or readout.

Two-pin electrodes are quite commonly used with lumber, posts, or poles. Electrodes using l-in-long insulated pins are the type most commonly used (fig. 3-8a,c). Insulated pins are helpful in avoiding false readings if wood has been surface wetted with rain, snow, or dew. Also, by using pins that are insulated except at the tip, some indication of moisture content gradient can be determined as the pins are driven to differing depths in the wood. To get an estimate of the average moisture content of a pole or heavy timbers, extra long pins (2-1/2 in) are available. Short (5/16 in) uninsulated pins are used on models such as shown in figure 3-8b, and when inserted to the proper depth, these pins give accurate average moisture contents for stock up to 2 in thick.

Four-pin electrodes are more commonly used with veneer and sawn lumber less than 1 in. in thickness. As with two-pin electrodes, accurate readings can be obtained on stock up to 2 in thick using short (5/16 in) uninsulated pins.

Dielectric Power Loss Moisture Meters

A hand-held moisture meter of the dielectric power loss type is shown in figure 3-9. The surface-contact electrodes are nonpenetrating and may vary in design according to the material on which they are to be used.

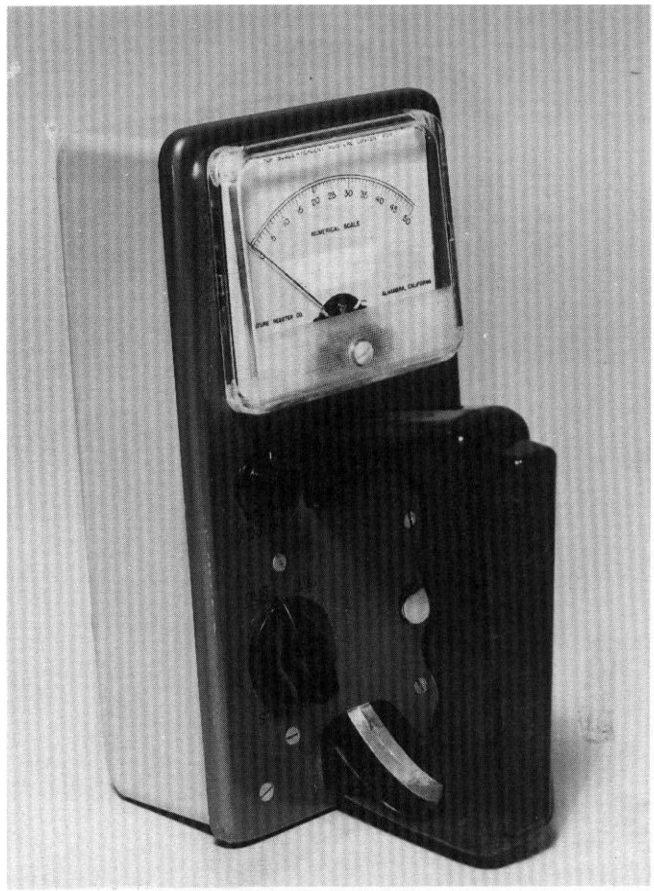

Figure 3-9—*A radiofrequency power loss type electric moisture meter. (M 133689)*

***Figure 3-10**—A dielectric electric moisture meter with smooth surface electrode. (M88 0239, M88 0238)*

The instrument shown has eight spring-cushioned contact points equally spaced on the circumference of a circle. This design is for use primarily on rough lumber. The electric field from this electrode penetrates about 3/4 in, so that specimen thicknesses up to about 1-1/2 in may be read. With surface-contact electrodes, the surface layers of the specimen have a predominant effect on the meter readings. Other electrode configurations are used for surfaced lumber and veneer. An example of a smooth surface electrode is shown in figure 3-10.

The range of these power-loss meters is from 0 to about 30 percent moisture content. Some manufacturers offer meters where actual moisture content is read on the dial. For others, the actual moisture content value is not read directly from the dial, but must be equated with moisture content from a separate table.

Stationary meter systems using noncontact sensors are available to monitor moisture content of moving lumber on a dry chain (fig. 3-11) or at the outfeed from a planer. Such systems can be equipped to mark or eject, or both, individual pieces that are outside preset moisture specifications. Some equipment offers a summary printout showing such items as total piece count, average moisture content of all pieces, and distribution of moisture content at specified moisture content intervals

Distillation Equipment

Some woods contain a high percentage of volatile compounds or are impregnated with oily preservatives. The volatiles will be driven off in the ovendrying process, resulting in an incorrect moisture content value. Distillation equipment should be used for determining the moisture content of such woods (American Society for Testing and Materials 1986).

Equipment for Determining Temperatures

Checking temperatures in a dry kiln is frequently necessary to determine the causes for nonuniform drying and the differences in temperature between the areas around the control bulbs and other areas in the kiln. Occasionally, it may be desirable to verify that the temperature indicated by the sensor for the recorder-controller is an accurate value. These temperature measurements are usually made on the entering-air side

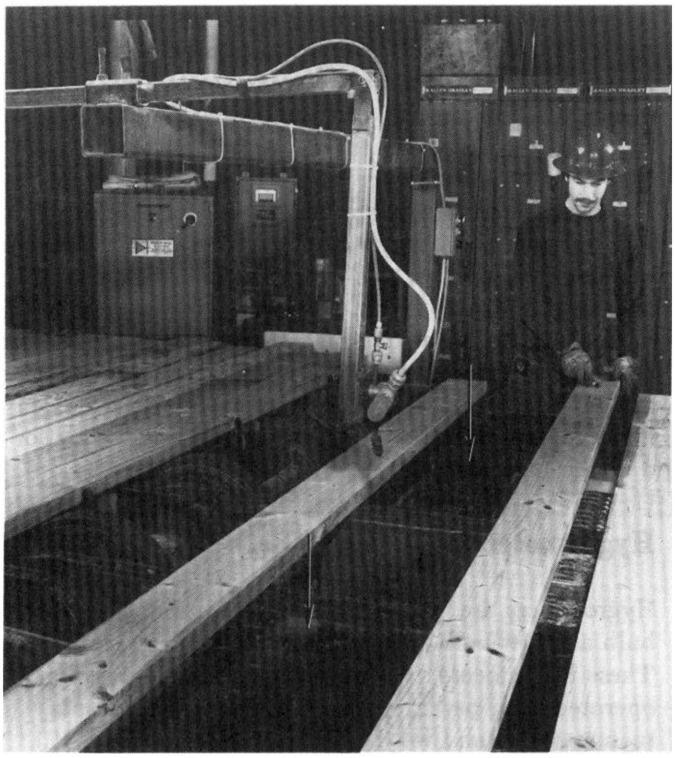

Figure 3-11*—Stationary inline moisture meter located on dry chain. Arrows show location of noncontact sensors. Note spray nozzle for marking pieces beyond preset limits. (MC88 9035)*

of the loads, although at times leaving-air temperatures are simultaneously obtained so that the temperature drop across the load can be determined. Electric digital thermometers, etched-stem glass thermometers, and occasionally hygrometers are used for this purpose.

Electric Digital Thermometers

Electric digital thermometers, using either thermocouples or resistance temperature detectors (RTD) as sensors or probes, are rapidly becoming a common way of measuring temperatures in dry kilns. They are available as portable hand-held models (fig. 3-12), or as panel or bench-top models, which can be mounted in the control room (fig. 3-13). For those designs using thermocouple sensors, type **T** (copper—constantan) thermocouple wire is commonly used in dry kiln environments, although type **J** (iron—constantan) or type **K** (chromel—alumel) is sometimes used. Thermocouple connections at the sensor should be soldered or fused together to make the junction. Some commercially prepared thermocouple sensors are enclosed in a metal sheath and look somewhat like RTD sensors. Resistance temperature detectors are usually of the platinum type, with all leads enclosed in a metal sheath (fig. 3-14).

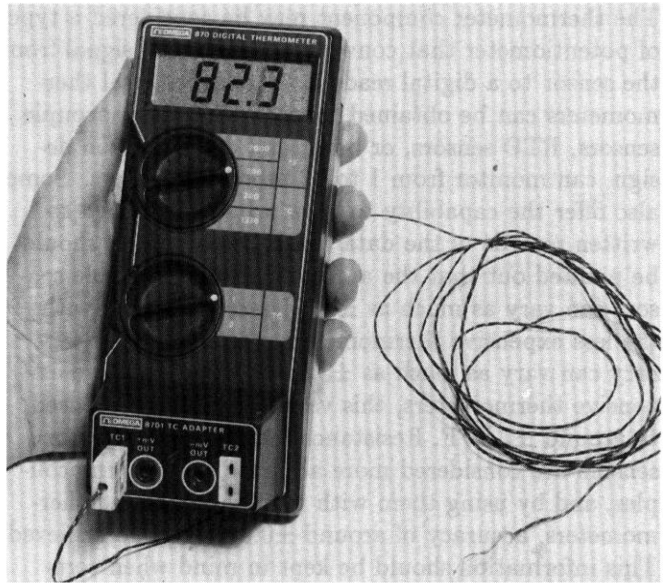

Figure 3-12—Hand-held digital thermometer *(M87 0171)*

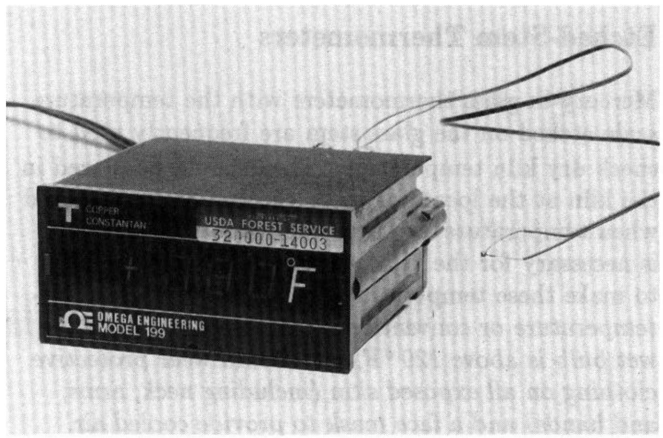

Figure 3-13*—Panel-mounted digital thermometer (M87 0197)*

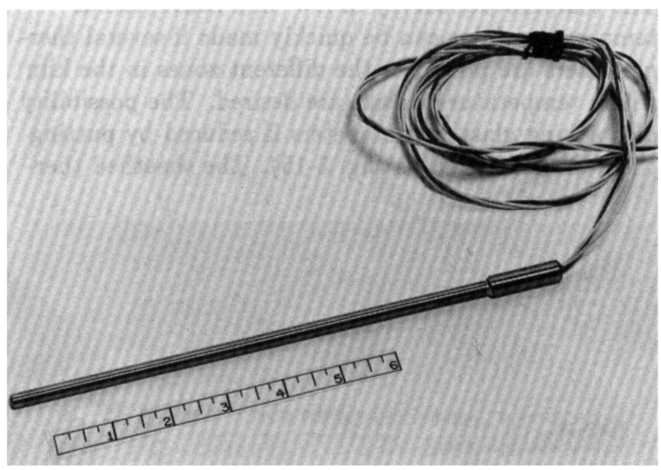

Figure 3-14*—Resistance temperature detector (RTD) sensor. (M87 0167)*

The thermometer component may be considered a type of potentiometer that converts the electrical signal from the sensor to a digital readout. These electrical thermometers can be obtained to work with thermocouple sensors, RTD sensors, or both, and depending on design, can monitor from 1 to 12 probes or sensors. Some also offer the capability to have printers attached so written records of the data can be obtained. It should be pointed out that the accuracy of thermocouple sensors can vary as much as ±2 °F and when used with the less expensive thermometers, the combined accuracy can vary as much as ±3.6 °F. By using more expensive thermometers, this variability can be reduced to around ±1.5 °F. Resistance temperature detector sensors are considered more accurate than thermocouples, and by using them with moderately priced thermometers, accuracy of around ±0.6 °F can be achieved. This information should be kept in mind when comparing temperature values from sensors located in the same area of the kiln or when comparing thermocouple readings to readings from the recorder-controller.

Etched-Stem Thermometers

Mercury-in-glass thermometers with the temperature scale etched on the glass stem are frequently used to check dry kiln temperature. They should be placed in the kiln at the locations to be checked and not moved when temperature readings are taken. Obviously, it is necessary for the kiln operator to go into the kiln to make these temperature readings. Note: In a low-temperature or conventional-temperature kiln, if the wet bulb is above 120 °F, one should wear protective clothing on all exposed skin (including neck, arms, and hands) and a face mask to provide cooled air. It is not recommended that elevated-temperature or high-temperature kilns be entered while the kilns are running.

The temperature survey of low- and conventional-temperature kilns can be quickly made if several thermometers are placed at the different zones in the kiln where temperature checks are desired. The possibility of breaking glass thermometers is reduced by putting them in metal sheaths (fig. 3-15). The sheathed thermometer is suitable for making dry-bulb measurements, but if wet-bulb temperatures are also being measured, the sheath must be removed so that a wick can be applied directly over the mercury bulb of the thermometer.

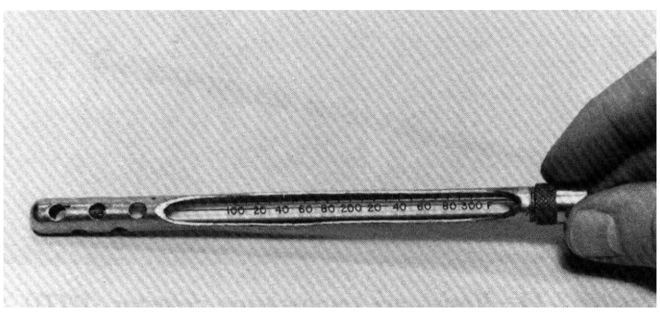

Figure 3-15—Etched-stem glass thermometer in metal protecting case. (M87 0195)

Maximum thermometers are also used for checking kiln temperatures. By mounting two maximum thermometers on a frame and supplying one with a wick and a water supply, both the maximum wet- and dry-bulb readings can be obtained. Care should be taken in choosing the location in the kiln for the thermometers as they will read the hottest temperature sensed, even for very brief periods, and thus there is a tendency for a biased high reading.

Hygrometers

Hygrometers are instruments for measuring the dry-bulb and wet-bulb temperatures of circulated air. These instruments vary from the hand-held and hand-operated sling psychrometer (fig. 3-16) to stationary mounted dry- and wet-bulb thermometers (fig. 3-17). Instruments that directly read relative humidity may also be considered hygrometers.

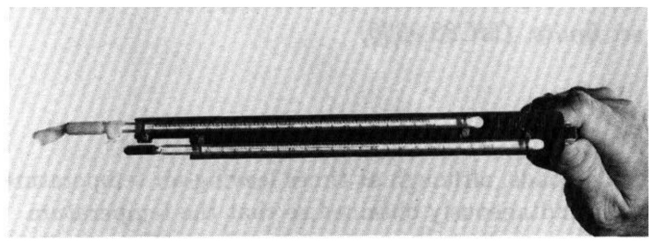

Figure 3-16—Sling psychrometer for determining relative humidity. (M87 0196)

Hygrometers similar to that shown in figure 3-18 are sometimes used to check kiln temperatures. Such hygrometers may use etched-stem thermometers or those with the calibrations on adjacent metal strips. One bulb must be continuously supplied with water to get wet-bulb readings. Using these data with the psychrometric chart in the appendix to chapter 1, equilibrium moisture content and relative humidity values can be determined. Sling psychrometers are helpful in spot checking wet- and dry-bulb temperatures (thereby determining relative humidity and electric moisture content) in a dry kiln or storage area. Hygrothermographs are instruments that measure and record temperature and relative humidity. They are helpful in providing a continuous written record of conditions in storage sheds or other areas where the temperature does not exceed about 120 °F (fig. 3-19).

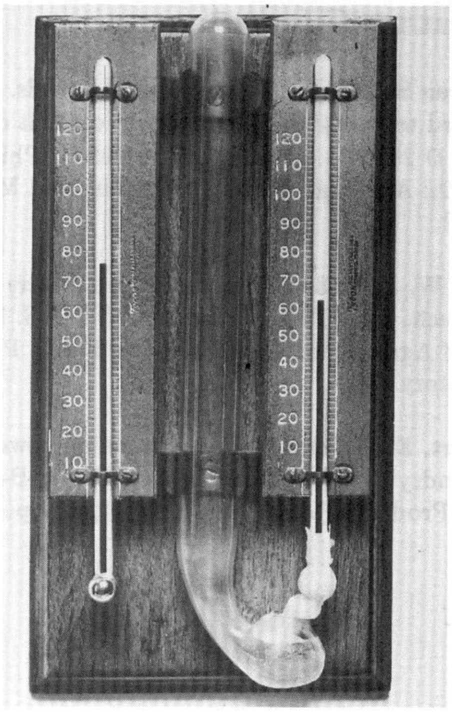

Figure 3-17—*Stationary mounted dry- and wet-bulb thermometers. (M 137003)*

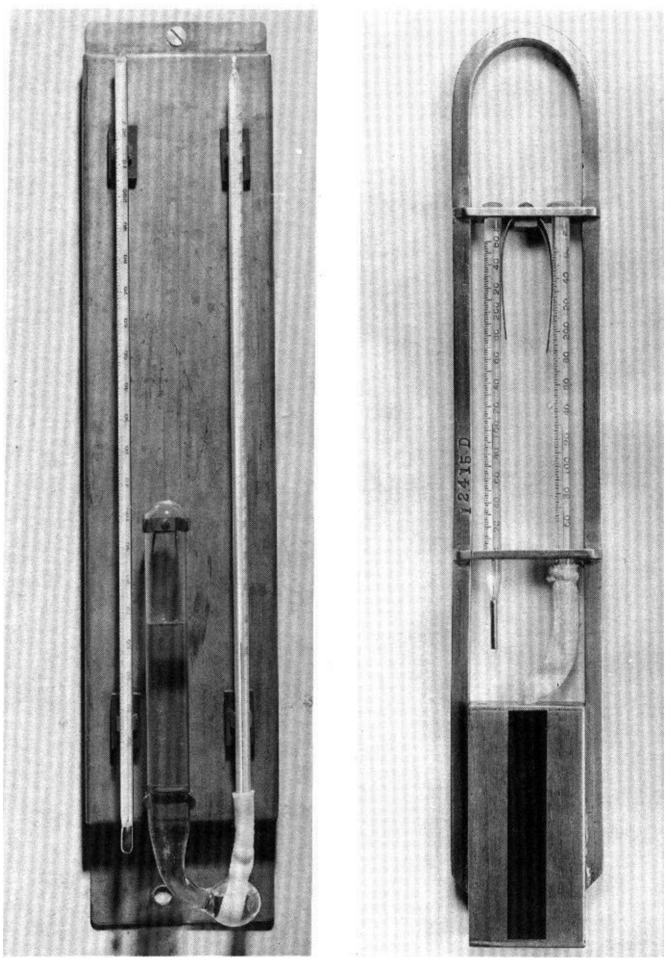

Figure 3-18—*Hygrometers: left, wet- and dry-bulb hygrometer made from two etched-stem glass thermometers; right, wet- and dry-bulb hygrometer with maximum thermometer. (M 86250, M 90337)*

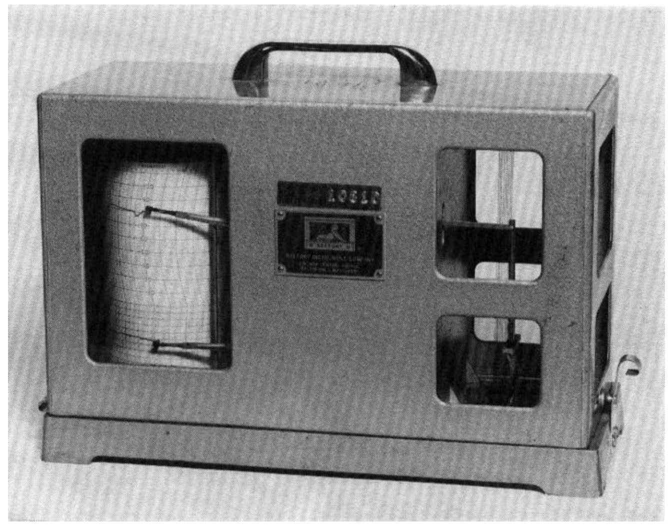

Figure 3-19—*Hygrothermograph for measuring and recording temperature and relative humidity (M87 0172)*

Equipment for Determining Air Movement

Since the direction and rate of airflow are important in the operation of a dry kiln, means of determining these factors are necessary. Rate of airflow may be measured with anemometers and the direction of flow may be inferred from these measurements.

Anemometers are instruments for measuring the velocity or force of air. Several types of anemometers, also called air meters, can be used to determine the velocity of air in dry kilns. One commonly used type is called a hot-wire or thermal anemometer (fig. 3-20). The wire in the probe is heated by electricity from a battery in the unit. The amount of cooling of the hot wire is proportional to the velocity of the air passing over the wire. Velocities are indicated directly on a scale calibrated in feet per minute.

In another commonly used type of anemometer, the air enters the instrument through a port or shutter, and velocity is read directly in feet per minute on a calibrated dial. This type, known as a deflection anemometer, is shown in figure 3-21.

Another type of anemometer occasionally used in dry kilns is the rotating vane anemometer. The sensor of this instrument is a disk fan mounted on pivot bearings and provided with a revolution counter. Air velocities, in feet per minute, are read directly on a dial or in some models on a digital readout.

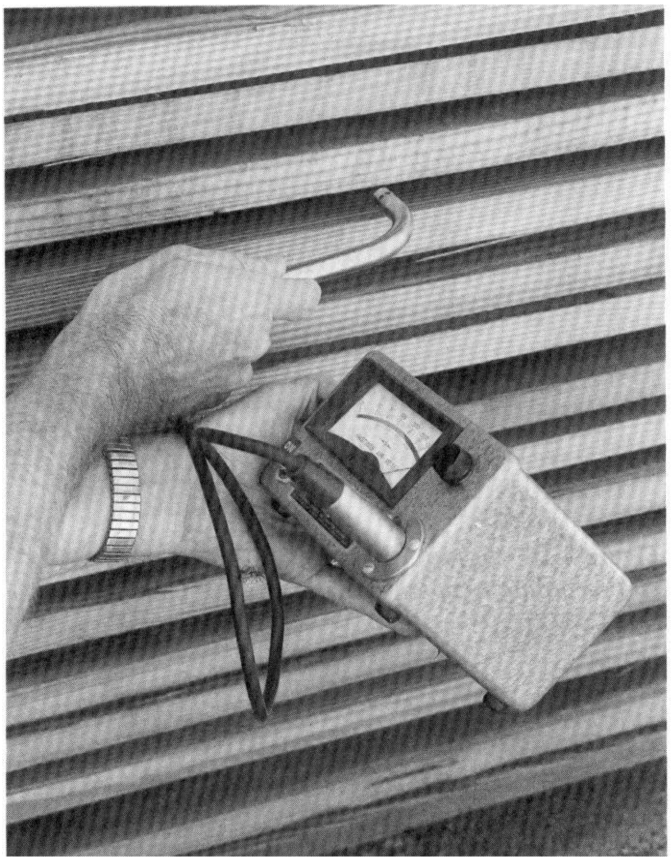

Figure 3-20—Hot-wire air meter. (M87 0194-18)

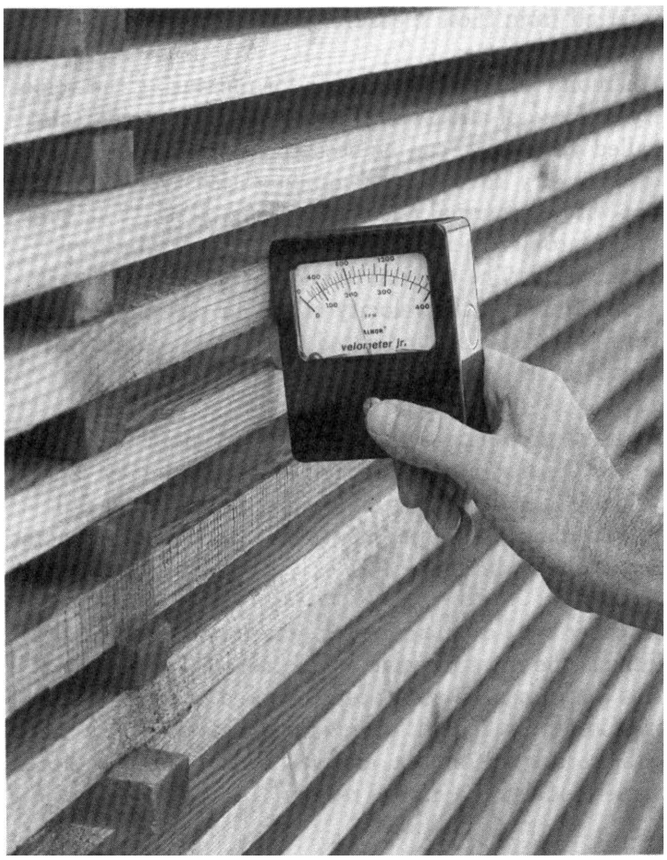

Figure 3-21—Deflection anemometer. A type of air velocity meter. (M87 0194-13)

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