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Weather Station Handbook—an Interagency Guide for Wildland Managers

Arnold I. Finklin
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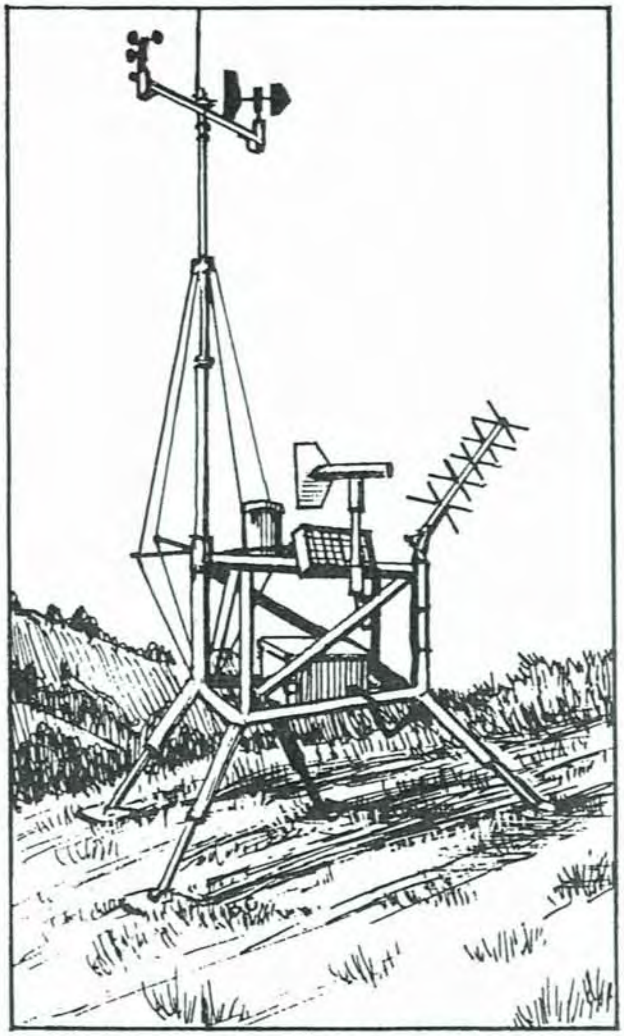

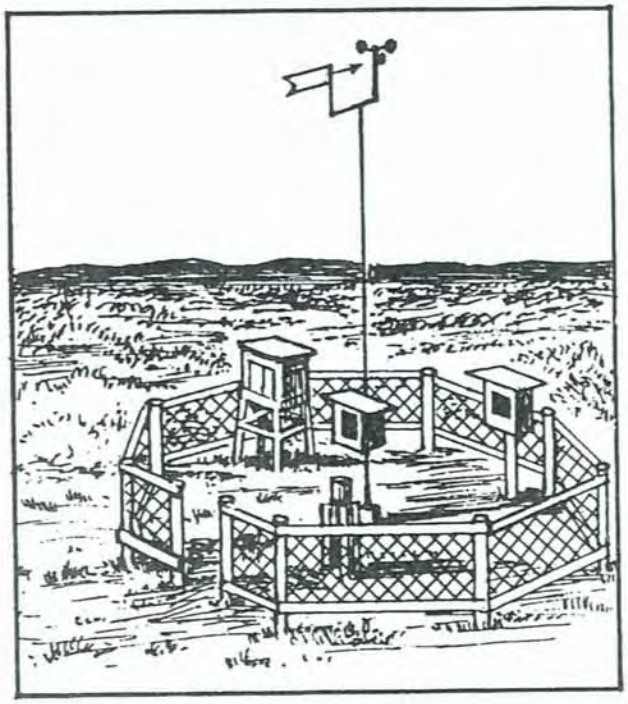

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The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.

Station laboratories are located in:

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Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

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INTRODUCTION

Background

The U.S. Department of Agriculture (USDA), Forest Service (FS), the U.S. Department of the Interior (USDI), Bureau of Land Management (BLM), and the USDI National Park Service (NPS) share common objectives in the management of natural resources. Likewise, they are often faced with the same need for accurate and timely weather data. These data are vital to many operational and program decisions. Most of the required data must come from the agencies' own weather stations. The total number of these stations is rather large. As of 1988, the FS operated approximately 1,000 manual and 265 automatic-type stations; the BLM, more than 165 automatic stations. The NPS maintains a skeleton network of manual and automatic stations. The USDI Bureau of Indian Affairs (BIA) and various State and private agencies or organizations also require weather data and operate weather stations.

The data collected from these stations are used for a variety of purposes. The primary use has been for National Fire Danger Rating System (NFDRS) calculations. But resource management now commands a major share of use in some areas, particularly where automatic stations are operated year-round (for example, in the Siskiyou National Forest in Oregon). Weather records have a key role in fire planning efforts, and the NFDRS outputs (indexes) are sensitive to inaccuracies in the acquired weather data. Thus, if the historical or current fire weather data contain errors (or values from poorly sited or exposed instruments), fire management plans and operational guidance derived from such data can be seriously affected.

Although each agency has its own network of weather stations, these networks are often maintained through cooperative interagency efforts. The data gathered by the different agency networks are also shared among the agencies through a common data base and communications medium.

Currently, the Administrative Forest Fire Information Retrieval and Management System (AFFIRMS) is the common medium for forestry weather data management. AFFIRMS was designed in the 1970's to address primarily fire weather data requirements identified at that time. Additional weather data needs have subsequently been identified. Many of these are not fire related and are not being addressed by AFFIRMS. A comprehensive Weather Information Management System (WIMS) is therefore being developed to meet current needs. WIMS is expected to be available for initial testing in 1990 and to become operational in January 1992.

In an effort to standardize and improve data acquisition practices, and ultimately promote high data quality, an interagency committee representing the BLM, FS, and NPS was formed to oversee the joint publication of an interagency weather station handbook. The committee first met in Boise, ID, in July 1987, with the following members present: Buddy Adams (BLM), John Bowdler (NPS), William C. Fischer (FS), Russell A. Gripp (FS), Donald A. Haines (FS), Phillip F. Sielaff (BLM), Roger A. Tucker (FS), and John R. Warren (FS). The members developed plans and guidelines that have led to the present handbook. Although weather station requirements may vary between agencies or within a given region, forest, park, or district, certain basic requirements are common to all jurisdictions.

Objective

The overall purpose of this handbook is to aid personnel of the Bureau of Land Management, Forest Service, and National Park Service—and other Federal, State, and private wildland resource agencies—in obtaining needed, reliable weather data. Such data must be accurate, complete, representative, and comparable between stations. Toward this, the handbook offers certain standards and procedures designed to minimize sources of error and other problems affecting weather data. Specific attention is given to instrumental equipment—and its siting, installation, and maintenance—and operating (observational) practices.

Concurrently, this handbook also has the purpose of providing a reference that meets the requirements of each agency, thereby avoiding duplication of publication efforts among the agencies.

Basis of Handbook

This handbook is largely a revised, updated version of the Fire-Weather Observers' Handbook by Fischer and Hardy (1976), with expanded content including unmanned, automated ("automatic") weather stations. Details concerning remote automatic weather stations are in large part based on a BLM manual (USDI BLM, RAWS Support Facility 1987). The BLM manual, revised by Robert McCormick and Buddy Adams, was written mainly by Phillip F. Sielaff in 1984. The content of the present handbook provides for a broad range of applications. The standards and procedures presented here are consistent with well-established practices of meteorological organizations, hydrological services, and fire control agencies. Publications by the U.S. Department of Commerce (1972) and the World Meteorological Organization (1983) were among the primary contributing sources.

In addition to the material obtained from publications, updated information was furnished by several individuals. These contributors, all affiliated with the Forest Service, include: Russell A. Gripp, Siskiyou National Forest, Donald A. Haines, North Central Forest Experiment Station, and John R. Warren, Fire and Aviation Management, at Boise, ID. Bonnie Mason, Watershed and Air Management, Washington, DC, contributed to the Introduction. Catalogs or literature from various companies provided information describing weather-station equipment.

Figure Credits—Unless otherwise credited in the captions, photographs and other figures in this handbook are from the USDA Forest Service. Most of the Forest Service photos and drawings are derived from Fischer and Hardy (1976); citations are given in the case of other Forest Service publications.

Scope of Handbook

This handbook is meant to be a comprehensive reference, although it cannot be all-inclusive—particularly on details concerning technically complex or specialized equipment and systems. The discussions of station siting, instruments, and related standards pertain to manual and automatic weather stations operated for a variety of resource management, monitoring, and research purposes. This should be understood despite the predominant reference to fire-weather stations.

The observational equipment discussed is that currently in use, or available for use, at weather stations operated by United States government agencies. Much of the the manual, direct-reading equipment is the standard National Weather Service or Forest Service type; but suitable, less expensive or more convenient alternative types or models are included for consideration. These alternatives include newer instruments incorporating electronic features and digital readout. Conversely, some of the models discussed here, particularly for windspeed measurement, may no longer be manufactured but are still in use. Such models, if included in the handbook by Fischer and Hardy (1976), are retained in the present handbook.

Because of the nature and variety of manual instruments, which can be operated and maintained by nonspecialists after relatively simple instruction, their coverage in this handbook is much lengthier than that of the automatic equipment. Corresponding instructions pertaining to automatic equipment are, largely, left to operating and service manuals provided by the manufacturers.

Handbook Organization

This handbook is organized into three main parts, each containing chapters whose numbering sequence continues from one part to another.

Part 1 discusses basic considerations that apply to both manual and automatic weather stations. The topics include station networks, site selection standards, equipment requirements, and data management. Part 2 pertains to manual stations, with four subdivisions (A, B, C, and D, respectively) describing the various weather instruments, their installation, observational procedures, and maintenance. This separation, used by Fischer and Hardy 1976, was adopted as a convenient and logical way of presenting the large amount of material to users. In many cases, separate individuals are involved in the installation, observing, and maintenance tasks. Numerous figures (mostly photographs) are included for illustration and easy reference. Part 3 discusses automatic stations, with details focused mainly on remote automatic weather stations (RAWS).

The handbook contains several appendices. These include an abridged set of observational instructions for manual stations, psychrometric tables, a fire-weather station maintenance checklist, user instructions for retrieving RAWS data via computer terminal, and a list of equipment manufacturers or suppliers. An index of subject matter is also included.

Units

With a few customary exceptions (as in chapter 10), the measurement units given here are those in the English system. English units remain in predominant use for surface weather observations in the United States. Metric equivalents can be obtained from conversion formulas in appendix 8.

PART 1. BASIC CONSIDERATIONS

CHAPTER 1. STATIONS; STATION NETWORKS

1.1 Purposes of Station Data

Stations and their networks are established for a primary purpose or type of application, although other applications may also be served. The main purposes of fire-weather (or fire-danger-rating) stations, hydrological monitoring stations, climatological stations, evaporation stations, and air quality monitoring stations are self-evident. The station and network configurations should thus be adapted to user requirements. These requirements will govern what weather elements are measured (for example, fire-weather stations ordinarily do not measure barometric pressure; basic climatological stations measure only temperature and precipitation). These requirements also determine the acceptable instrumental response and accuracy, although there are minimum standards.

1.2 Representativeness

In serving a need, weather stations must, individually or collectively, represent conditions occurring over a designated area. Network data should adequately reveal spatial variations and patterns, besides their possible use for interpolations and calculation of areal mean values (see section 1.3). While they may contribute to a larger area representation, the individual stations are usually intended to also represent a specific location or type of location. In some cases, as in site-specific research or monitoring, the required representative area may be quite small. Usually, however, a station's data are applied to many tens of square miles, if not hundreds of square miles.

Station adequacy may vary depending on what weather conditions or parameters are represented. Among individual parameters, windspeed and wind direction can vary greatly within small distances, as can precipitation. In contrast, afternoon temperature and relative humidity (away from sea-breeze zones or timber canopies) tend to show much areal similarity (at similar elevations) or a usable correlation with elevation.

For fire-danger rating, indexes integrating the weather factors are intended to represent "average worst" conditions, as would be experienced in an open area on a lower south-facing slope—where at least the afternoon fire-danger indexes tend to be relatively high. Because of convenience constraints, this open area at manual fire-weather stations has generally been in a valley bottom near an administrative or field office, where observers are close by.

COMPARABILITY OF STATION DATA

To best fulfill their purpose, it is important that the observed data are comparable among stations in a network. Thus, instrumentation standards and measurement techniques must be similar at all stations; likewise, standard siting and exposure criteria must be adopted. Daily observation times, at which current and 24-hour data are observed, must also be similar. In addition, data from a particular type of network should, as much as possible, be comparable with data from other networks; this will maximize the use of often scarce data for a variety of applications. For example, fire-weather data may fill gaps in the National Weather Service (NWS) climatological station network.

1.3 Network Designs

In establishing or modifying networks of weather stations, there are at least two major questions that arise: (1) What is the minimum number of stations required for adequate data sampling? and (2) where should the stations be located? When budgetary and personnel constraints may force the closure of one or more stations in an existing network, the immediate question becomes which station(s) should be closed; usually, a decision having the least impact on the data sample is sought. The answers will depend upon what is being measured, the type of equipment and the the purpose of the stations, the resolution or accuracy required, and logistical constraints such as accessibility.

Stations within a network may be used to obtain areal averages of weather or fire-weather conditions, but this is usually not sufficient. The stations should also sample the areal variability of conditions, while representing conditions for adjacent and similar subareas. Similarity here refers to topography and ground cover (for example, timber cover and fuel types). It may also be important that the stations enable reliable interpolations of weather or climate at other points.

Several approaches or methods have been used or explored for designing or modifying station networks. To date, in practice, the approaches have been mostly intuitive or subjective, or guided by logistics. These approaches have been the only recourse, given both the lack of information required for objective methods and the practical siting constraints; these constraints have lessened with the advent of remote automatic weather stations (RAWS). Objective methods have been described or reviewed by Fujioka (1985; 1986), Furman (1975), King and Furman (1976), and Munn (1985).

OBJECTIVE METHODS

As outlined by Munn (1985), the three principal objective methods are (1) statistical, (2) modeling, which can be used when the physical systems and spatial weather or climatic patterns are understood, and (3) statistical-modeling (combined statistical and modeling). Statistically derived network designs may be based on the accuracy of interpolated values at points between stations (Munn 1985, citing the method of Gandin 1970). Information required may include numerical values of a "space structure function" (related to the spatial pattern or gradient of a weather parameter) in the region of interest, the variance of errors in station data, and the maximum acceptable interpolation error. Solution of equations will then give a maximum acceptable distance between weather stations, from which the minimum number of stations within a numerically defined area can be calculated.

Acceptable errors in daily spatial mean values of the NFDRS Burning Index (BI) formed the basis for maximum station spacings calculated by King and Furman (1976). The greater the BI diversity found among the actual stations sampled, the larger was the number of required stations. Equations utilized the estimated and "actual" BI values for each test day, together with the estimated spatial variance.

These statistical approaches give uniform station spacings, which, of course, can only be used as an approximation in mountainous terrain. Aside from the terrain logistics involved, even for remote automatic stations, certain assumptions or simplifications present problems. For example, interpolation-based methods as just described assume that spatial weather correlations are related only to horizontal distances between stations or points. Fujioka (1985) emphasizes that aspect, elevation, and other characteristics should also be considered.

A design method presented by Fujioka (1985), of the combined statistical-modeling type, considers the climatology and other available information to construct a "target field"—a model of the spatial variability of a weather parameter during a critical period. The data user has an essential role in defining the critical periods, the weather parameters (or variables) used in the decision process, and the area in which the network will lie. A computer evaluates different network designs by estimating the target field, given a particular network arrangement, and comparing the result with the "actual" target field. The error information is used to find better station locations, and the evaluation is repeated until the locations chosen minimize the analysis error.

Fujioka (1986) presents an application of his design method, generating a statistically optimum fire-weather station network for a southern California area. This network is based on a target field representing a Fire Weather Index (calculated from the dry-bulb temperature, relative humidity, and windspeed) during Santa Ana (warm, dry, downslope wind) conditions. These conditions create the greatest fire potential in that area. Fujioka (1986) concluded that further study is required on both the practical and theoretical implications of the network designs that are generated. One important aspect requiring further work is that of defining the target fields.

PRESENT STATUS; SUGGESTIONS

As indicated above, no definitive objective approach is as yet available for network design. Even if a truly optimum station placement were to be generated, suggested relocations of existing stations would be questionable from the standpoint of data continuity. Where new stations are to be added, in the case of RAWS, experience of local personnel and primary representation purposes will be key considerations. Additional stations should ideally contribute maximum information not available from already existing stations. Differences in vegetation types may indicate locations with distinctive differences in some of the weather variables. In mountainous areas, station networks should ideally include stations in a variety of terrain situations, such as valley bottom, slope, and ridgetop. The resulting data, besides revealing variations important for management decisions, will contribute to models that attempt to describe a three-dimensional pattern such as a target field.

CHAPTER 2. STATION TYPES; SITING

2.1 Manual-Type Weather Stations

Traditional, manual-type weather stations (hereafter termed manual weather stations) provide data through the presence of an observer who reads the instruments at scheduled times, enters the data on appropriate forms, and, as required, communicates the data to a central office on a delayed or current basis. The data are obtained on-site—from direct-reading instruments (such as liquid-in-glass thermometers and a "stick" rain gauge) and from mechanically recording instruments (such as a hygrothermograph and a weighing rain gauge)—or in a nearby office through electrically connected readout devices. These devices include dials and strip charts.

Manual weather stations vary in their instrumentation, depending on their purpose. These stations (apart from those staffed by the NWS or the Federal Aviation Administration for primary forecasting and information services to the public) fall into three main types (and networks). These are: (1) climatological stations, as in the NWS extensive network of substations (cooperative stations) reporting only daily temperatures and precipitation, (2) evaporation stations, and (3) fire-weather stations. Additional manual stations are operated to provide weather and climatic data for a variety of research and monitoring needs. Some details, focusing on fire-weather stations, will follow.

2.2 Manual Fire-Weather Stations

INSTRUMENTAL EQUIPMENT

To provide the data necessary for computing fire-danger rating (NFDRS) indexes, a fire-weather station should contain the following basic equipment. More specific forms of equipment for a "standard" fire-weather station are listed in section 6.1.

1. Dry- and wet-bulb thermometers (psychrometer).
2. Maximum and minimum thermometers.
3. Instrument shelter for housing the thermometers.
4. Anemometer and windspeed readout device (mechanical counter, buzzer, or flashing lamp).
5. Wind vane and possible direction readout device.
6. Fuel moisture sticks and scale.
7. Nonrecording ("stick") rain gauge.

A hygrothermograph and recording rain gauge will help further, providing daily maximum and minimum relative humidity values and duration of precipitation, respectively. They also provide a check of the basic thermometer and rain gauge readings.

OBSERVATIONS AND TRANSMISSION OF DATA; AFFIRMS

Instruments at standard fire-weather stations throughout the United States are read once daily at either 12 noon or 1 p.m. (1200 or 1300), local standard time (l.s.t.). Some of the data are values for the preceding 24-hour period; these include the maximum and minimum temperatures, maximum and minimum relative humidity, and the precipitation amount and duration (Deeming and others 1977). The data are manually encoded and transmitted by telephone or radio to a central office (such as a National Forest Supervisor's Office) or a subcentral office. There, the data are entered by computer terminal into the Administrative Forest Fire Information Retrieval and Management System (AFFIRMS). AFFIRMS (Helfman and others 1987) is a user-oriented, interactive computer program that enables the display of data and computed fire danger indexes at any terminal in the network. A major function of AFFIRMS is the automatic archiving of the daily observations, which become part of the National Fire Weather Data Library, Fort Collins, CO (Furman and Brink 1975).

LIMITATIONS

The traditional, manual fire-weather stations have been a valuable source of data since their inception in the 1920's. Certain inherent limitations are, nevertheless, recognized, pertaining to station location and number of daily observations. Manual stations have usually been located on the grounds of ranger stations or similar field offices, where observers are conveniently available; also, mostly in the past, at fire lookouts. Particularly in the mountainous Western United States, and with the phase-out of lookout weather stations, the available data often will not indicate the conditions on higher terrain and other pertinent areas. Further, the data from the now once-daily standard observation may not adequately describe a day's important weather features, particularly wind conditions. During fires or other critical situations, personnel may not always be available to read the weather instruments and transmit the data.

Such limitations have led to the development and deployment of remote automatic weather stations (RAWS) (Warren and Vance 1981). These stations are adapted to serve fire-weather and other resource management applications.

2.3 "RAWS" and Other Automatic-Type Stations

The term RAWS refers specifically to the remote automatic weather stations adopted for operational use by the BLM, FS, and NPS. The present units are procured from Handar, which meets agency specifications originally developed by the BLM and FS in 1978. Commercially produced RAWS were first installed in that year and operated for field evaluation. The early RAWS units were procured from LaBarge, and a few of these remain in use.

RAWS units enable much flexibility in the location of weather stations, whether for permanent or semipermanent installations or for temporary use, such as near fires or project work sites. These electronically operated stations are powered by batteries charged by solar panels. The processed data are automatically transmitted via satellite to a downlink such as the BLM's direct readout ground station (DRGS) at Boise, ID. Here, a computer transfers the data to AFFIRMS. Users can access the latest AFFIRMS store of data via commercial telephone connection to a computer terminal or printer (section 38.4). Data can also be retrieved directly from a RAWS platform, appropriately equipped, via telephone or radio links. RAWS data are normally available for each hour of the day and night, adding greatly to knowledge of weather affecting specific problem areas and to the general knowledge of mountain meteorology and climatology.

Other automatic weather stations are available from more than a dozen companies. These stations, referred to as AWS, are similar in many ways to RAWS but generally do not transmit their data via satellite. The various AWS units may be used in either remote or nearby locations. Their data may be retrieved via local cable connection to office devices and displays; by telephone, radio, or infrared links; or on a delayed basis from cassette tape, solid-state storage modules, or strip charts.

2.4 Other Station Configurations

As previously indicated, automatic stations find use in applications besides fire weather. With the same basic complement of sensors and appropriate additions, RAWS and AWS can be used for various resource management needs, environmental and hydrological monitoring, and research purposes. (Further details are given in section 37.1.) Manual stations for these applications generally use the fire-weather configuration with appropriate additions or omissions. A basic (NWS) climatological station consists only of the maximum and minimum thermometers, mounted in an instrument shelter, and a precipitation gauge. To these, an evaporation pan and its accessories are added at a standard evaporation station; a recording precipitation gauge, psychrometer, and soil thermometers may also be added.

2.5 Site Selection Standards

The following rules should govern the location of a standard fire-weather station, whether a manually operated station or RAWS. The rules apply also to other weather stations.

1. *Locate the station in a place that is representative of the conditions existing in the general area of concern.* Consider vegetative cover, topographic features, elevation, local airflow patterns, etc.

2. *Select a site that will provide for long-term operation and a relatively unchanged exposure.* Consider site development plans—for example, roads, buildings, and parking areas; growth of nearby vegetation; observer availability;

and site accessibility during the intended operational period.

3. *Arrange the station so as to obtain data that are representative of the specific area in which the station is located.* Consider exposure requirements for each instrument in relation to factors such as (1) prevailing wind, (2) obstructions to wind, precipitation, and sunshine, (3) vegetative cover, (4) nearby reflective or radiative surfaces, and (5) topography.

In accordance with the above rules, the following situations should be avoided when selecting a station site:

1. *Sources of dust* such as roads and parking areas. If these are unavoidable, locate the station at least 100 ft away on the prevailing windward (upwind) side of the source.
2. *Sources of surface moisture* such as irrigated lawns, pastures, gardens, lakes, swamps, and rivers. If these are unavoidable, locate the station several hundred feet windward from the source.
3. *Large reflective surfaces* such as white painted buildings; also, natural reflective surfaces such as large rock surfaces. If these are unavoidable, locate the station on the north side of the surface, far enough away to avoid artificial shading (a distance equal at least to the height of the reflective surface or 50 ft, whichever is greater).
4. *Extensive paved or blacktopped areas.* If these are unavoidable, locate the station at least 50 ft to the windward.
5. *Large buildings, trees, and dense vegetation.* Locate the station at a distance at least equal to the height of the obstruction.
6. *Distinct changes in topography* such as hummocks, gullies, peaks, ridges, steep slopes, and narrow valleys.

Additional exposure precautions may be necessary for precipitation gauges (section 18.1), to avoid gauge-catch losses due to wind.

CHAPTER 3. GENERAL REQUIREMENTS OF EQUIPMENT

3.1 Characteristics of Instruments

DESIRABLE CHARACTERISTICS

As stated by the World Meteorological Organization (1983), the most important requirements of meteorological instruments are:

1. Reliability.
2. Accuracy.
3. Simplicity of design.
4. Convenience of operation and maintenance.
5. Strength of construction.

These attributes apply to both manually (or mechanically) and electronically operated instruments. In certain ways, some of the characteristics may be related, while others may require compromises. In addition, cost is certainly an important factor in the actual selection of equipment.

Reliability refers to the maintenance of accuracy over a long period of time and also to continuous performance without loss of data—in the case of instruments with mechanical parts, clocks, and electrical or electronic components. Simplicity of design generally promotes convenience of operation and maintenance and may favor long-time, problem-free operation. This is particularly important where stations are remote from repair facilities. On the other hand, simplicity of design may compromise accuracy or resolution. Resolution refers to the readability of data in fine numerical increments.

Sturdy construction is particularly important where stations are operated in severe or extreme weather conditions, such as powerful winds and riming. Under these conditions, compromise may again be necessary, as a rugged anemometer typically has a higher starting (threshold) speed than a sensitive instrument required for certain applications.

RECORDING INSTRUMENTS

Continuous-recording instruments at manual weather stations have commonly employed charts on clock-driven cylinders (drums); the chart record consists of an ink trace from pens linked to the sensing elements. Instruments of this type include those used to record temperature, relative humidity, precipitation, solar radiation, and barometric pressure. Other recorders, mostly for wind direction and speed, employ a strip chart moving between reels; traces on some of these are produced by inkless pen contact with pressure-sensitive paper.

Linkages in recording instruments should be as free as possible from friction, which would dampen the sensor responses; likewise, pressure between the pen and paper should be adjustable to a minimum consistent with a continuous legible trace. Calibration adjustments, determined from comparisons with accurate direct-reading instruments, should be easily and smoothly accomplished with a thumbscrew or other device.

Chart Drives—The chart drive mechanism, which turns the chart drum, most commonly employs a spring-wound or battery-operated clock movement. Newer mechanisms available on some Belfort instruments employ a stepper motor governed by a battery-operated quartz-crystal oscillator.

The clock is either located inside the drum (turning with it) or fixed to the base of the instrument. In the latter design, the drum revolves around the clock. This arrangement makes it easier to eliminate backlash, which can cause timing errors. It also lessens the risk of jarring the clock when charts are changed, since only the drum is removed. Further, when the drum is brought indoors to change the chart during cold weather, the clock can remain in place outdoors; this avoids possible condensation on the clock surfaces and resulting problems.

3.2 Accuracy Standards

The term "accuracy" refers to the closeness to which an instrument reading approaches the true value. Errors can result from the instrument calibration (or shifts in calibration) and from instrument lag during changing conditions. Apart from instrument error, individual readings may suffer from parallax error by the observer when the line of vision is not at right angles to the scale (particularly the scale of a thermometer). Further details concerning accuracy are given by the World Meteorological Organization (1983).

For the purposes of this handbook, instrument accuracy standards are concerned mainly with calibration. The accuracy, specified in various instrument catalogues, typically varies along the instrument's range or scale.

MANUAL-TYPE EQUIPMENT

The following accuracy standards are suggested for manual-type instruments used for fire-weather, climatological, and hydrological purposes. The standards are based largely on values from the World Meteorological Organization (1983). Errors should not be larger than the following (plus or minus) values:

1. Dry bulb and wet bulb thermometers	± 0.3 °F
2. Maximum and minimum thermometers	0.5 °F
except minimum thermometer, below 0 °F	1.0 °F
3. Hygrothermograph temperature	1.0 °F
4. Hygrothermograph relative humidity,	
at 20-80 percent	3 percent
at extremes	5 percent
5. Relative humidity, calculated from dry and wet bulb	3 percent
6. Wind direction	10 degrees
7. Windspeed	1 mi/h
8. Daily precipitation	0.01 inch
9. Daily evaporation	0.01 inch
10. Fuel temperature	1.0 °F

RAWS EQUIPMENT

Some accuracy specifications for sensors at automatic weather stations may be stricter than those listed above (see section 44.2). Sensors for RAWS units, supplied by Handar, have the following specified accuracy:

1. Temperature	± 0.2 °F
2. Relative humidity,	
0 to 80 percent	2 percent
80 to 100 percent	5 percent
3. Windspeed	0.25 mi/h or 2 percent of value
4. Wind direction	2 degrees
5. Tipping bucket precipitation	0.01 inch at rate of 2 in/h
6. Solar radiation	5 percent
7. Barometric pressure	0.02 inch

CHAPTER 4. RESPONSIBILITIES

Typically, different personnel are involved in the installation, observations, and technical maintenance at a weather station. As explained in the Introduction, this handbook treats these tasks pertaining to manual weather stations in three separate parts.

4.1 Installation and Maintenance

Installation of Bureau of Land Management RAWS equipment is performed by personnel from the BLM RAWS Support Facility, located at the Boise Interagency Fire Center (BIFC). Most of the Forest Service RAWS installation is done by agency personnel, with technical support and advice from the BLM RAWS Facility.

The BLM's maintenance organization (chapters 42 and 43) provides much of the maintenance, on contract, for the Forest Service RAWS equipment. At present, most of the contracted FS maintenance is of the "depot" or bench type, which covers repair and calibration of equipment. Forest Service personnel are responsible for field (or preventive-type) maintenance and for transporting equipment to the depot facility at BIFC. Beginning in 1988, under a new agreement, all FS RAWS will receive BLM depot maintenance; the BLM will also perform a "watchdog" (quality-control data monitoring) service on all data downlinked at Boise. A smaller number of Forest Service stations have contracts for "full-ride" maintenance, which includes field maintenance (USDA FS, Pacific Northwest Region, RAWS Work Group 1987).

Equipment at manual stations likewise should be installed by qualified personnel, who may be on staff at district or central headquarters of an agency. In the past, installation of fire-weather equipment was often done under supervision of the National Weather Service. Simple, daily maintenance can be done by trained observers, but technical maintenance in the field or at a workbench facility should be performed by agency specialists or contracted to local shops (chapter 29).

4.2 Observer Requirements

Observers at manual stations of the BLM, FS, and NPS are typically persons with specialties outside the field of weather (meteorology). As a prerequisite, therefore, training should be provided to foster proper skills and awareness in observing practices; familiarity with instruments and simple maintenance measures should be included. For best results, the training should be through formal courses, conducted either through correspondence or at a central location. Periodic refresher training and contact with other observers is also advisable (World Meteorological Organization 1983).

Observer responsibilities include the following tasks (further details are contained in various chapters of Parts 2C and 2D):

1. Making the required observations at the required times with the required accuracy.
2. Encoding and logging or dispatching the data as necessary; actual transmission of data, by radio or telephone, may be the task of another person.
3. Changing the charts of recording instruments on scheduled days; maintaining proper inking of pens.
4. Performing calibration checks of recording instruments and making simple adjustments as necessary.
5. Maintaining the instruments in good order. This includes daily or periodic external dusting and cleaning of instruments (with water or cleaning solvent as necessary) to maintain easy readability of marked graduations, maintain free movement of linkages on recording instruments, and deter corrosion.
6. Noting instrumental defects, such as column separations in thermometers; applying simple corrective measures or reporting to supervisor for further action.

4.3 Management

This section describes the responsibilities for managing a network of weather stations. Specific details are given for the Forest Service, but an analogous order of management exists for Bureau of Land Management and National Park Service stations.

Within the Forest Service, Fire Management has retained the overall management of manual stations and the RAWS network at both the Regional and Forest levels. At the Forest level, the station programs are managed, in most cases, by the Supervisor's Office fire organization; here, the Forest Dispatchers and Assistant Fire Staffs have chief responsibility. At the District level, either the Fire Management Officer or other key personnel are responsible for management or assisting in management (USDA FS, Pacific Northwest Region, RAWS Work Group 1987). As recommended by the RAWS Work Group, this general arrangement should continue with appropriate staffing as the role requires. Establishment of a RAWS regional information sharing exchange, with assigned responsibilities, is also recommended. Interagency sharing of information is an additional goal.

CHAPTER 5. DATA MANAGEMENT

As discussed here, data management refers to steps or treatment measures taken with the weather data after their collection (observation) and transmission/retrieval. The data collection and means of retrieval have been described earlier (sections 2.2 and 2.3) and will be covered in greater detail in succeeding chapters and in appendix 6. Beyond these fundamental requirements, management pertains to storage (of retrieved RAWS data), quality control, archiving, and display and use of the data. The use of data refers to its analysis, particularly by computer processing, to obtain various statistical and graphical outputs (section 5.4).

5.1 Storage of Retrieved RAWS Data

Beginning in 1988, all RAWS data downlinked by the BLM at Boise will be automatically stored on computer tape; previously, only the BLM RAWS data were stored in this manner. Within 2 weeks following each quarter of the year, the BLM will send the RAWS data tape to the Western Regional Climate Center (WRCC), located at the Desert Research Institute, Reno, NV. Here, the data will be permanently stored and archived (section 5.2).

In the absence of automatic data storage, one of the most common methods of storing user-retrieved RAWS data has been to retain hard-copy, 24-hour printouts from AFFIRMS. The resulting data file, however, is not in an efficient form, particularly for data analyses. An alternate storage method has been to transfer ("dump") each day's data from AFFIRMS into a Data General (DG) computer file, or onto a hard disk of a personal computer that is interfaced with the DG system. This approach enables the user to build a data base and perform data analyses using a variety of currently available software.

5.2 Archiving of Data

As stated above, all RAWS data downlinked at Boise will be permanently archived at WRCC; previously, the BLM RAWS data were archived in a file maintained at BIFC. At WRCC, the RAWS data (for all 24 hours of the day) will be stored as received from the BLM. The data will also be converted to National Climatic Data Center (NCDC) format and archived for standard climatological use.

In addition, AFFIRMS will continue to archive the 1300 l.s.t. RAWS data in the National Fire-Weather Data Library (NFWDL), where all agencies' manual fire-weather data reside. The library is located at the USDA's National Computer Center at Fort Collins, CO (NCC-FC). For NFWDL archiving, the data must first be transferred or entered into AFFIRMS in NFDRS format. This transfer has been done automatically for BLM RAWS data, but until 1988 it was a manual process for FS RAWS data.

To more fully automate the NFWDL archiving, all RAWS data downlinked at Boise are now automatically transferred to AFFIRMS, which also performs NFDRS calculations. Without this automatic transfer, user-retrieved 1300 RAWS data (appendix 6) must be manually transposed to NFDRS format and then manually entered into AFFIRMS; the appropriate data are obtained from the listing retrieved shortly after the nearest 3-hourly RAWS transmission time (for example, near 1300 P.s.t.; 1400 m.s.t.).

The past dependence on manually entering FS RAWS data, for archiving in the NFWDL, has led to many missing daily records and provides an opportunity for error (USDA FS, Pacific Northwest Region, RAWS Work Group 1987). RAWS data from some locations were never archived. In areas with year-round RAWS operation, such as the FS Pacific Northwest Region, data from many stations have been archived only during the main fire season. The new arrangement, described above, should greatly reduce such problems.

5.3 Quality Control

Before they are archived, whether on paper forms or computer tape, weather data should be checked for possible errors. In the case of RAWS data, current AFFIRMS listings can be checked and corrections entered where necessary. Depending on the type of weather station or data collection system, several major sources of error exist. These include instrument error, observational error, and transmission or transcription error. (Poor exposure of sensors can also lower the data quality; thus siting and installation standards, outlined in section 2.5 and in later chapters, must be followed.)

In most cases, station data can be spot-checked or otherwise verified by the observer or persons involved in data entry or retrieval. Readings at manual stations can be compared with traces from recording instruments. In some cases, particularly with relative humidity, the recording instrument will be found in error. Data from a RAWS, if situated nearby, can be checked with manual observations.

Comparison with neighboring stations and knowledge of basic meteorology and local climatic conditions can help in detecting highly unlikely data values. Reasonable or acceptable values will vary with the particular weather situation and time of year. Quality-control results with this type of data checking will, unfortunately, vary with the individual's meteorological background and experience.

The RAWS data are checked by BLM watchdog procedures, which provide a daily computerized screening of data downlinked at Boise; further details are given in section 43.1. Prior to 1988, the watchdog service was limited mainly to BLM RAWS data.

National Weather Service personnel also monitor RAWS data, primarily for fire-weather forecasting, and may call the appropriate office if there appears to be a problem. In addition, data entered into AFFIRMS for archiving at the NFWDL undergo a screening program (Furman and Brink 1975). The acceptability criteria, however, are rather loose. For example, dry bulb temperatures are accepted between –99 and +136 °F; 24-hour precipitation, as high as 9.99 inches.

Questionable or missing data can be treated in several ways, ranging from taking no action to estimating or synthesizing replacement data. For purposes of fire-danger calculations or future analyses, it is better to relegate highly questionable data into the missing category than to leave the data "as is." When creating substitute data, one may interpolate from adjacent stations if such data are available, applying adjustments for known average differences (Finklin 1983). For RAWS data, information from the preceding hour or two may be used as the basis for corrections. Unless a storm has occurred, diurnal trends may be extrapolated from the typical hourly changes on other days.

5.4 Data Display and Use

Toward their application, station data may be displayed on a current basis, together with derivative parameters, on a computer screen or in printout form. Or a set of archived data may be summarized or analyzed by computer program.

DISPLAY OF FIRE-WEATHER DATA

Standard display formats are available in AFFIRMS (Helfman and others 1987) to display fire-weather data (RAWS or manual station data). A display including fire-danger rating outputs can be generated immediately after the RAWS or manual-station data have been entered into AFFIRMS. Custom display features can be utilized to track key outputs such as the various fuel-moisture parameters.

COMPUTER PROGRAMS USING ARCHIVED DATA

Programs discussed here are mostly those accessible at the NCC-FC. These programs apply to data archived in the NFWDL. Among programs or software available for applications with other data bases, most comprehensive is the CLICOM system (below), which can be used with a personal computer.

Programs at National Computer Center at Fort Collins—Several computer programs are available at the NCC-FC to summarize weather data from the NFWDL. A set of two programs was developed to aid fire managers in planning prescribed burning (Bradshaw and Fischer 1981a,b). These programs, RXWTHR (Prescribed Fire Weather) and RXBURN (Prescribed Fire Conditions), provide climatic probabilities of obtaining prescription conditions during successive 10-day periods of the fire season. Furman (1979) provides two programs, PRESCRB and MERG3, that also identify the most climatologically favorable 10-day periods for burning, with the additional consideration of smoke management.

The FIREFAMILY program (Main and others 1982) is a set of three major routines designed to aid a wide range of fire management planning. The FIRDAT routine produces frequency distributions, tables, and graphs of NFDRS indexes and components. It can also produce a list of daily weather, fuel moisture, and NFDRS outputs for convenient tracking of changing values.

Programs RXBUILD and RXFIRES (Bevins and Fischer 1983) examine both NFWDL data and archived fire report information to evaluate alternative prescriptions for unscheduled (naturally or accidentally ignited) prescribed fires. Qualifying fires are, in the computations, "allowed to burn" under prevailing weather conditions until extinguished by precipitation or until they burn out of prescription. The output information enables fire managers to assess how well various prescriptions meet prescribed-fire goals.

Another set of programs (Bradshaw and Fischer 1984) was designed to aid in a broad range of wildland management activities and research studies. These programs provide tables showing average values, standard deviations, extreme values, etc., in addition to probabilities (frequency distributions), of the basic weather elements. Programs can also adjust averages that are based on short periods of record or incomplete data.

These and other devised programs require a weather data base covering enough years to give a representative sampling, ideally at least 10 to 20 years, depending on the weather parameter (Finklin 1983). With the archived RAWS data covering only a few years, to date, the programs should at present be run only with manual data bases, or with combined manual and RAWS data at sites where a RAWS has replaced the manual station. The archived manual fire-weather data extend back to the 1950's for Forest Service Northern Region stations and to the 1960's in other Regions.

CLICOM System—CLICOM (Climate Computing) is a climatological data processing system that has become well established since its release in early 1986. CLICOM was developed at the NCDC under sponsorship of the World Meteorological Organization. Designed for use with a microcomputer (personal computer), CLICOM incorporates both commercial and NCDC software. The software includes a database management system and a comprehensive set of programs for summarizing and graphing climatological and related types of data. Processing includes quality-control (data-validation) procedures.

CLICOM was designed originally to serve needs in developing nations, particularly to help archive climatological data from old manuscript forms, and this goal is being implemented. But CLICOM has also become a standard component of official climatological operations in the United States. An improved version, designated CLICOM Version 2.0, was released in early 1988. The WRCC is in the process of installing CLICOM systems (Version 2.0) in each of the 11 State Climatologist offices in the Western Region. Although current users are mainly climatologists, CLICOM has a potential for a wider range of applications. Further details about the system can be obtained from:

National Climatic Data Center
Database Administration
Attention: CLICOM
Federal Building
Asheville, NC 28801-2696
Phone: (704) 259-0387 (FTS 672-0387)

PART 2A. MANUAL WEATHER STATIONS: MEASUREMENTS; INSTRUMENTS

This portion of the handbook focuses on manual weather station instruments and their operational features. The individual chapters first define and describe the weather elements or parameters that are measured at fire-weather and other stations.

Observers with a basic understanding of weather instruments, and what the measurements represent, are better prepared toward obtaining accurate weather data. They will be better able to recognize an erroneous reading or defective instrument. Similarly, persons assigned the task will be more likely to properly install and maintain the instruments.

In addition, an increased understanding of the instruments may bring greater satisfaction to what might otherwise become a routine, mechanical task. An understanding of the weather elements and processes may further stimulate interest. The text by Schroeder and Buck (1970) is particularly recommended.

The instrument description in the various chapters begins with the standard, recommended equipment in present use (prefixed by the word "standard"), except where a standard design or model has not been adopted. It also includes commonly used or recommended alternatives, as explained in the Introduction.

A brief, advance listing of the standard or recommended equipment is given in chapter 6.

CHAPTER 6. STANDARD EQUIPMENT LIST

6.1 Manual Fire-Weather Station

A standard manual fire-weather station contains the following equipment:

1. Cotton region instrument shelter, with support legs.
2. Liquid-in-glass maximum and minimum thermometers, having scales graduated in 1-°F increments, and Townsend support. Two separate thermometers are used; the maximum is mercury-in-glass and the minimum is alcohol-in-glass.
3. Electric (battery-operated) fan psychrometer, consisting of dry bulb and wet bulb thermometers graduated in 1-°F increments.
4. Anemometer, either contacting type with 1/60-mile contacts or a suitable generator type, and mounting pole or mast. No particular model has been adopted as the standard.

Contacting anemometers are the most widely used type at present but are becoming more difficult to obtain. Of the three most popular makes or models—the Forester anemometer (several models), the Stewart aluminum cup anemometer, and the Bendix-Friez small Airways type anemometer—the latter two are no longer manufactured. Recent generator models, available from Natural Power Inc. and NRG Systems, have been recommended as a possible replacement.

5. Mechanical wind counter equipped with a timer (Forester 10-Minute Wind Counter), or other suitable readout device, such as the Forester (Haytronics) Totalizing Wind Counter. The counter enables measurement of average windspeed in miles per hour. The generator anemometers mentioned above have an electronic accumulator or odometer that can give a digital readout of 10-minute average windspeed.
6. Wind direction system—including wind vane and remote readout device. Again, no particular model has been adopted as the standard.
7. Nonrecording ("stick") rain gauge, with support; gauge has 8-inch diameter and may be either large capacity type or Forest Service type. Measuring stick gives rainfall in hundredths of an inch.
8. Fuel moisture stick (1/2-inch ponderosa pine dowels) and supporting rack.
9. Fuel moisture scale (Forester model), mounted in a scale shelter such as the recommended Appalachian scale shelter.

Additional recommended items are: (1) a hygrothermograph, Belfort or Bendix-Friez type, and (2) recording precipitation gauge, Universal weighing type.

6.2 Evaporation Station

A standard evaporation station, operated for hydrological or agricultural/forestry applications, contains the following equipment:

1. Class "A" evaporation pan, on wooden ground support; also a water supply tank.
2. Micrometer hook gauge and stilling well; or a fixed-point gauge, stilling well, and measuring tube.
3. Totalizing anemometer and display-stand support. Widely used models, with self-contained mechanical counters, include the Belfort Totalizing Anemometer and the Weathertronics Totalizing Anemometer.
4. Six's type (U-tube) maximum-minimum water thermometer, with submerged mount or float mount. Graduations are etched on the glass tube in 1-°F increments.
5. Cotton region instrument shelter, with support legs.
6. Liquid-in-glass maximum and minimum thermometers and Townsend support, as described for fire-weather station.
7. Nonrecording ("stick") rain gauge, 8-inch diameter large capacity type.

Additional, optional items are (1) a hygrothermograph, (2) weighing precipitation gauge, (3) psychrometer, electric-fan or sling type, and (4) mercury-in-steel or electrical soil thermometers, with head shelter.

6.3 Climatological Station

A basic climatological station of the National Weather Service (NWS) type, measuring only temperature and precipitation (including snowfall), consists of evaporation station items 5, 6, and 7. Evaporation stations and fire-weather stations may thus also serve as climatological stations. In recent years, a digital thermometer inside a small radiation shield has replaced items 5 and 6 at many of the NWS stations. A more complete climatological station will include observations of wind, humidity, and sunshine (or solar radiation).

CHAPTER 7. TEMPERATURE AND HUMIDITY

7.1 Temperature

Simply stated, temperature is a measure of the degree of hotness or coldness—in the present context, hotness or coldness of the air. Temperature measurements routinely taken at fire-weather stations are: dry bulb, wet bulb, maximum, and minimum. Dry-bulb temperature represents the air temperature at observation time.

Dry- and wet-bulb temperature measurements are taken to calculate relative humidity and dewpoint and are discussed further in section 7.2. Recorded maximum and minimum temperatures are the highest and lowest values occurring during a specified period of time, such as 24 hours. At fire-weather stations, this period covers the 24 hours preceding the basic afternoon observation time. Maximum and minimum temperatures are arithmetically averaged to obtain a generally good approximation of the 24-hour average temperature.

For fire-weather and climatological purposes in this country, temperatures are obtained from thermometers calibrated in degrees Fahrenheit (°F). The air temperatures are normally measured about 5 ft above the ground; this height may be altered at locations experiencing deep snow cover.

Available thermometers (sections 7.4, 7.5, and 7.7) are of several types, differing both in design and in operating principle. Liquid-in-glass thermometers, Bourdon thermometers, and bimetal thermometers are commonly used. A newer, electronic type has a digital readout.

7.2 Relative Humidity and Dewpoint

Relative humidity (RH) is the percentage ratio of (1) the actual amount of water vapor in the air to (2) the amount of water vapor required for saturation at the existing temperature. These amounts are often expressed in terms of vapor pressures (Countryman 1971; Schaefer and Day 1981; Schroeder and Buck 1970). The saturation vapor pressure increases with temperature. Thus, RH is largely dependent upon temperature, with an inverse relationship. It tends to be lowest during the afternoon, when the temperature is near its daily maximum, and highest near dawn, when the temperature is near its minimum.

Dewpoint (DP) is the temperature at which the air, if cooled, would reach saturation. At this temperature, dew (or frost) will start to form on an exposed surface. In standard calculations, both DP and RH are based on saturation with respect to water even at temperatures below freezing. This convention gives lower DP and RH values than those with respect to ice, because of differences between saturation vapor pressures over ice and (supercooled) water at similar temperatures (Schaefer and Day 1981). Thus, at saturation, the calculated RH will be 100 percent at temperatures above freezing but will be only 94 percent at 20 °F and 84 percent at 0 °F. Above freezing, the dewpoint and dry- and wet-bulb temperature values will all be equal at 100 percent relative humidity.

Table 7.1—Selection of psychrometric tables according to elevation above sea level[1]

Elevation above sea level		Psychrometric table
Alaska	**All other States**	**Pressure**
Feet		*Inches of mercury*
0 - 300	0 - 500	30
301 - 1,700	501 - 1,900	29
1,701 - 3,600	1,901 - 3,900	27
3,601 - 5,700	3,901 - 6,100	25
5,701 - 7,900	6,101 - 8,500	23

[1] At higher elevations, to about 10,000 ft, table for 23 inches may be used; obtained values will be slightly low.

Relative humidity is the primary humidity variable used in standard fire-weather observations, although dewpoint is also important (Countryman 1971). As mentioned previously, the current RH and DP are calculated from dry- and wet-bulb temperatures. These temperatures are measured with a psychrometer (section 7.6). Daily maximum and minimum relative humidity, for the 24 hours preceding the basic observation time, are usually obtained from a hygrothermograph (section 7.7). In fire-weather observations, these two humidity values are used to estimate a 24-hour average.

USE OF PSYCHROMETRIC TABLES

Relative humidity and dewpoint are determined from dry- and wet-bulb temperatures by use of NWS "Relative Humidity and Dewpoint Tables," also known as "psychrometric" tables. Separate tables are provided for each of five levels of atmospheric pressure and corresponding ranges of elevation above sea level (see table 7.1). These tables are available in appendix 2.

Another type of table is based on the dry-bulb temperature and the wet-bulb depression. The wet-bulb depression is simply the difference between the dry- and wet-bulb readings. Special slide-rule calculators may also be used; again, these are valid only for their specific pressure or elevational range.

7.3 Instrument Shelters

Temperature and humidity instruments (sections 7.4 through 7.7) are typically exposed inside a specially designed, white-painted enclosure or shelter. This instrument shelter, also termed a thermometer shelter or screen, serves to shield the instruments from precipitation and sunshine, while allowing adequate ventilation. Shelters have traditionally been constructed from wood, but aluminimum and plastic materials have also been used. The standard "cotton region" shelter (described below) provides space for a complement of several instruments and is generally effective in representing conditions of the surrounding outside air.

COTTON REGION SHELTER

The cotton region type of instrument shelter (fig. 7.1) has been standard at National Weather Service climatological stations and is recommended for use at all manual stations employing both temperature and humidity equipment. This is a medium-size shelter constructed of wood and painted white both inside and outside. The white, reflective outside coating minimizes absorption of solar radiation, which otherwise could cause excessively high daytime temperatures inside the shelter. Radiation errors may, nevertheless, sometimes reach 2 or 3 °F, given calm wind conditions combined with strong sunshine. Conversely, temperature readings on clear, calm nights can be 1 or 2 °F too low, due to cooling of the shelter by outgoing (longwave) radiation.

The cotton region shelter has a double roof, louvered sides, and slotted openings in the floor. Interior dimensions are 30 inches wide, 32 inches high, and 20 inches deep. The interior contains a crossboard for mounting thermometers. The shelter door, usually hinged at the bottom so that it opens downward, faces north when the shelter is properly oriented. Except when the instruments are read, this door should be kept closed at all times to keep out indirect or reflected solar radiation. The shelter is mounted on an open wooden or aluminum stand that is firmly anchored to the ground.

A variety of homemade instrument shelters of different design have been used at many fire-weather stations in the past. The use of such shelters is now discouraged as they lessen the comparability of data between stations.

Figure 7.1—Cotton region instrument shelter; the standard design in use at manual fire-weather, climatological, and evaporation stations.

Figure 7.2—Gill multiplate solar radiation shield (R.M. Young Company); naturally ventilated type made of plastic, used with electrical or electronic temperature and humidity sensors. (Photo courtesy of Sierra-Misco, Inc.)

SOLAR RADIATION SHIELDS

Small radiation shields constructed of metal (anodized or white-painted aluminum) or white plastic are used in conjunction with sensors of remote-reading, electronic thermometers; the shields are similar to those used at automatic weather stations (Part 3). Two of these shields are shown in figures 7.2 and 7.3. In common with the cotton region shelter, these shields allow natural ventilation while reflecting solar radiation and keeping out precipitation. A shield of the cylindrical, stacked-plate type (fig. 7.2) is used by the National Weather Service in its new maximum-minimum temperature (MMT) system at cooperative climatological stations. The MMT system has replaced the cotton region shelter and liquid-in-glass thermometers (section 7.4) at many locations. This particular system is not available to other agencies, and it is not as yet (as of 1989) problem-free.

These radiation shields would not be adequate for manual stations where fan psychrometers and hygrothermographs are employed in addition to maximum-minimum thermometers. Such instrumentation requires the housing afforded by a cotton region type shelter.

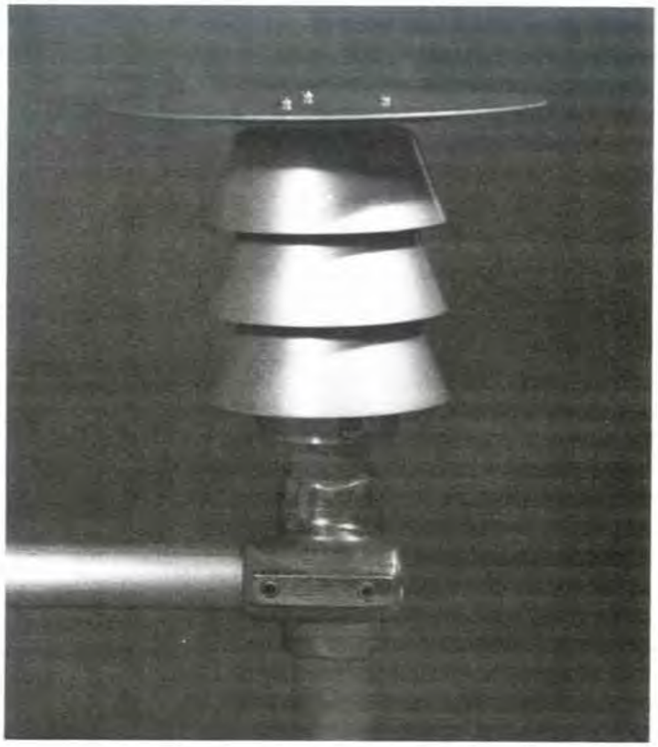


Figure 7.3—"Pagoda" type solar radiation shield; naturally ventilated type made of anodized aluminum. (Photo courtesy of Qualimetrics, Inc.)

PORTABLE SHELTERS

Various portable instrument shelters can be used for fire-weather and other purposes. Some are small wooden shelters; others are aluminum or plastic shelters. All should be painted white. The adequacy of these shelters depends to a large extent on shelter design, the instruments used, and the required accuracy of the data to be collected. They are not meant for use at permanent stations but rather serve as alternatives to the cotton region shelter at temporary field locations.

Aluminum Shelter—A field installation of a portable aluminum instrument shelter is shown in figure 7.4. This shelter can be collapsed to a compact size (fig. 7.5) for relatively easy portability. With 2-ft-square louvered side panels, it has the advantage of being generally comparable in size and similar in design to the cotton region shelter. When compared with the cotton region type (USDA FS 1964a; Finklin 1979), aluminum shelters tend to produce larger radiation errors; the test results indicate temperature corrections that may be applied.

Orchard-Type Shelter—This white plastic shelter (fig. 7.6), commercially labeled "ThermoShelter," offers an inexpensive means of exposing a minimum thermometer or compatible Six's maximum-minimum thermometer. More properly categorized as a shield, it may be particularly suited where numerous measurement points are required. The curve-shaped construction provides an

Figure 7.4—A portable aluminum instrument shelter installed at a temporary field station.

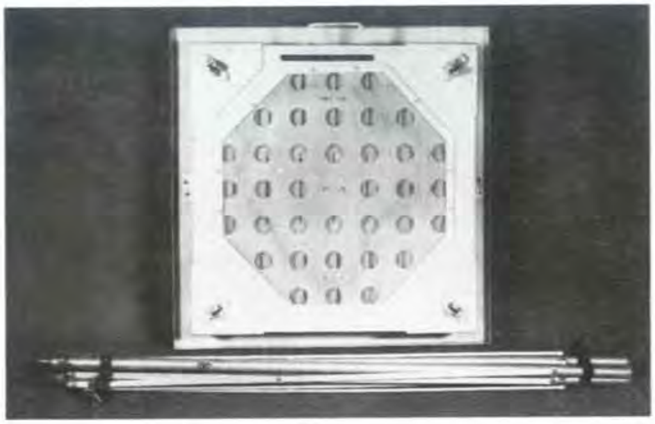


Figure 7.5—Portable aluminum instrument shelter, knocked down for easy transport.

Figure 7.6—Orchard type shelter, made of molded plastic. (With mounted Six's type maximum-minimum thermometer.)

overhang but leaves the thermometer (mounted horizontally) unshielded in forward, sideward, and downward directions. The shelter should be mounted on a post or tree, with the thermometer facing slightly east of north.

When exposed in full sunshine, this shelter is less efficient than the standard cotton region shelter in curtailing radiation errors; the errors are often 1 to 3 °F greater. Nighttime errors resulting from radiational cooling may also be greater, by about 1 °F.

With this shelter, the sun's rays can fall on a north-facing thermometer early and late in the day during spring and summer. Shelter orientation somewhat east of north will reduce this sunshine intrusion late in the day, when it would more likely affect maximum temperature readings. Natural or artificial shading may also be helpful during these times of day. Shelter placement should avoid nearby light-colored, reflective ground (soil or rock) surfaces, which can reflect solar radiation upward to the shelter interior and thermometer bulb, raising temperature readings by more than a few degrees (see MacHattie 1965). Likewise, the shelter is not suitable for use during months of snow cover, which presents a highly reflective surface.

7.4 Liquid-in-Glass Thermometers

Liquid-in-glass thermometers indicate temperature by the difference in expansion between the liquid (mercury or alcohol) and the glass bore in which the liquid is enclosed. The bulb at the bottom of the glass bore acts as a reservoir for the liquid, which rises or falls as the temperature changes.

Mercury-filled thermometers are designed to measure temperatures above –38 °F (the freezing point of mercury). Alcohol- or spirit-filled thermometers can measure much lower temperatures, well below –100 °F.

Liquid-in-glass thermometers vary in length of stem and shape of bulb. As a general rule, long-stemmed thermometers can be read more precisely than those with short stems. Everything else being equal, a thermometer with a relatively narrow, cylindrical bulb (fig. 7.7C) will indicate changes in air temperature faster (will have less time lag) than one with a spherical bulb (fig. 7.7A).

STANDARD MAXIMUM AND MINIMUM THERMOMETERS

The standard, recommended maximum and minimum thermometers are two separate thermometers mounted (in a near-horizontal position) in a special device called a Townsend support (fig. 7.8). Accuracy of new thermometers, as specified in some instrument catalogues, should be within 0.3 to 0.5 °F at temperatures above 0 °F.

Maximum Thermometer—The standard maximum thermometer is mercury-filled and has a small constriction in the capillary (the fine bore of the tube) just above the bulb (fig. 7.7A). As the mercury in the bulb expands with increasing temperature, some of it is forced past this constriction and upward through the bore. When the temperature falls, the mercury normally cannot recede through the constriction. Hence, when the bulb end of the

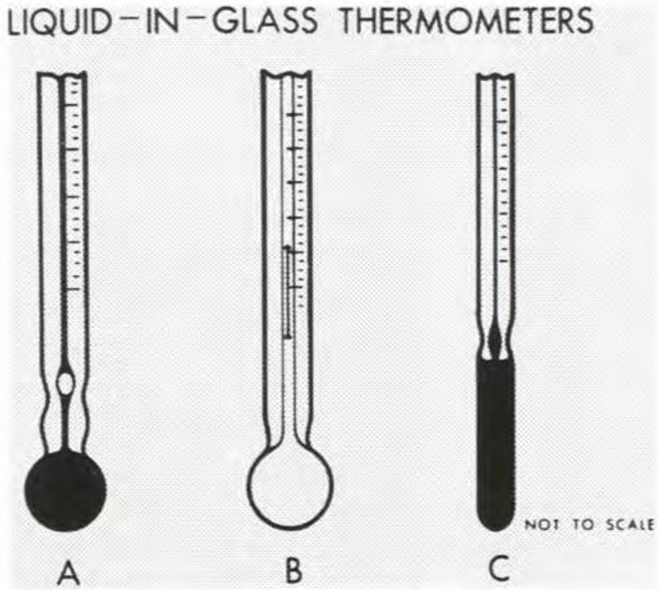


Figure 7.7—Liquid-in-glass thermometers: A, mercury-filled maximum thermometer; B, alcohol-filled minimum thermometer; C, standard mercury dry-bulb thermometer.

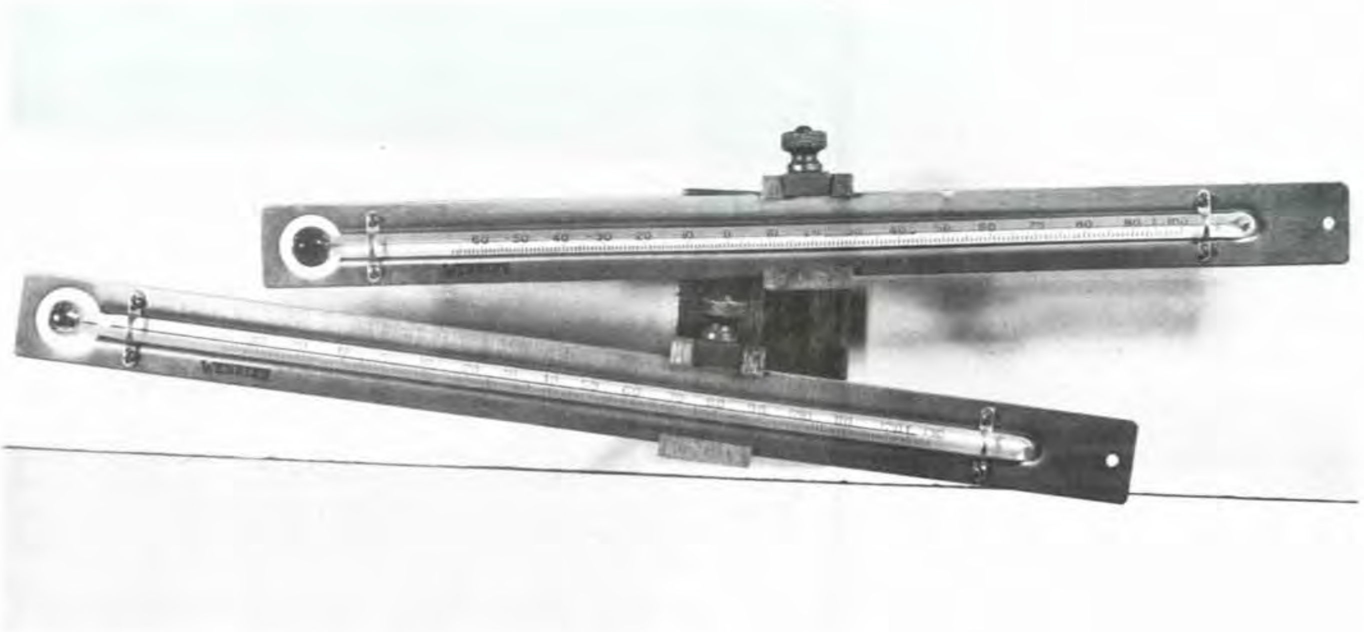


Figure 7.8—Standard maximum and minimum thermometers mounted in a Townsend support; in the lower and upper clamps, respectively.

thermometer is lowered to a reading position, the top of the mercury column indicates the highest temperature attained.

After the maximum temperature is read, the thermometer is reset by spinning it, fastened in its mounting clamp. This forces the mercury downward through the constriction and back into the bulb.

Minimum Thermometer—The standard minimum thermometer is alcohol-filled and has a small glass index rod immersed in the alcohol (fig. 7.7B); this index can move freely through the bore. When the temperature falls, the retreating alcohol column drags the index with it by means of surface tension at the top of the column. When the temperature again rises, the alcohol column moves past the index, which remains at its lowest temperature position.

The thermometer is reset by inverting it, fastened in its mounting clamp, until the index returns to rest against the top of the alcohol column.

Townsend Support—The Townsend support, with its spinning and rotating clamps, facilitates reading and setting of the maximum and minimum thermometers. This support is designed for mounting on the crossboard inside an instrument shelter.

SIX'S (COMBINED) MAXIMUM-MINIMUM THERMOMETER

The Six's, or combined maximum-minimum thermometer is distinguished by its U-shaped tube. This is a spirit-filled (creosote) thermometer employing an imbedded mercury column as an indicator. It is a less expensive, but generally less accurate, alternative to the standard maximum and minimum thermometers. It may serve (with calibration checks) in temporary field use or in other applications where great precision is not essential. A special model is employed to obtain maximum and minimum water temperatures at evaporation stations (chapter 12).

A metal, dumbbell-shaped index rod is enclosed above the mercury column in each arm of the U-tube (fig. 7.9). When reset, the indexes rest against the ends (or tops) of the mercury columns. The scale along the right arm of the U-tube indicates maximum temperature; the left scale, which is inverted, indicates minimum temperature. The top of the mercury column in either arm always indicates the current temperature.

The index rods are pushed upward in the tube by the mercury column, which rises up the right or left arm as the temperature rises or falls. The rods remain in place at their extreme positions when the mercury column retreats. The rods do not slide downward even though the Six's thermometer is normally exposed in a vertical position.

The maximum and minimum temperature values are read at the **lower ends** of the respective index rods. After each observation, the thermometer is reset with a small magnet, drawing the metal index rods down to the tops of the mercury columns. In some models, the index rods are reset with a push-button device.

The Six's maximum-minimum thermometer most commonly has temperature scales marked only on its backing, with 2-°F graduations, but higher priced models have the scales etched on the glass. The model used for water temperatures at evaporation stations has 1-°F graduations on the glass. Six's thermometers should be periodically checked against a standard dry bulb thermometer (section 7.6). Where errors are not due to column separations (section 30.2), corrections may be applied. Alternatively, the thermometer's scale plates may be shifted

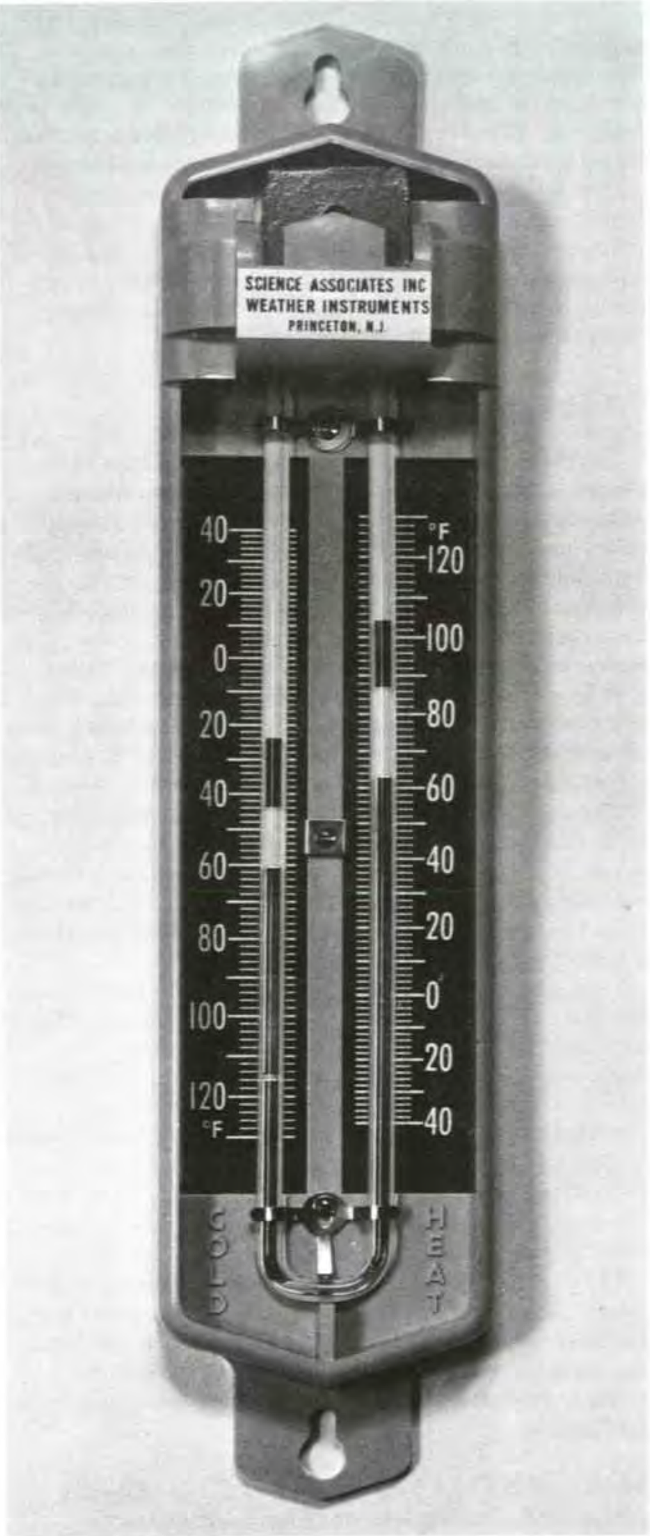


Figure 7.9—Six's type maximum-minimum thermometer. Maximum temperature is read on the right; minimum temperature, on the left. (Also see thermometer included in fig. 7.6.)

where this is possible, as in a Taylor model. For air temperature measurements, the thermometer should be exposed in adequate shade and free-moving air (preferably inside an instrument shelter).

Figure 7.10—Dial type maximum-minimum thermometer, employing a mercury-in-steel sensing element with direct-drive Bourdon spring. (Photo courtesy of Palmer Instruments, Inc.)

7.5 Other Thermometers

BOURDON AND BIMETAL THERMOMETERS

Because they are designed to change form with corresponding changes in temperature, Bourdon and bimetal thermometers are often referred to collectively as "deformation" thermometers. Deformation thermometers are used as temperature-sensing elements in dial thermometers and thermographs (and hygrothermographs), discussed later.

Dial Maximum-Minimum Thermometer—A good-quality dial maximum-minimum thermometer can provide a satisfactory substitute for the standard liquid-in-glass type. And it has the advantage of being less prone to breakage. The dial type usually has three separate pointers for the current, maximum, and minimum temperatures. The scales are graduated in 1- or 2-°F increments. The sensing element is typically a bimetal strip wound into a continuous multiple helix, which is contained in a sealed tube extending to the rear of the dial. A more expensive, improved design (fig. 7.10) has a mercury-actuated sensing bulb together with a direct-drive Bourdon spring. Dial thermometers can be mounted on the crossboard inside a cotton region instrument shelter.

ELECTRICAL/ELECTRONIC THERMOMETERS

Remote-Reading Digital Thermometer—Modern electrical thermometers suitable for use at basically manual type weather stations operate in conjunction with a microprocessor to produce a digital, remote readout. The sensor is usually a resistance thermometer, thermistor, thermocouple, or diode junction (Fritschen and Gay 1979; Sceicz 1975), enclosed within a metal probe that is typically exposed in a solar radiation shield. The probe can also be exposed in a standard cotton region shelter, particularly when the shelter is required for additional instruments. The readout unit and its enclosed electronics can be located in an office up to 100 ft or more distant.

The most accurate (and expensive) resistance thermometers utilize platinum wire, but those using nickel wire are quite satisfactory. The electrical resistance of the wire is proportional to ambient temperature. Thermistors, which are small beads of a semiconductor, also measure temperature through its effect on resistance. Thermocouples, in principle, consist of two junctions of dissimilar metals (usually copper and constantan) that generate a voltage proportional to the temperature difference between the junctions, one of which is a reference junction kept at a constant, known temperature (typically 32 °F, in an ice bath). Modern thermocouples utilize electrical compensation instead of the reference junction. Diode junctions measure temperature through its effect on voltage drop across a junction. Whatever type of sensor is used, the resulting electrical current or voltage that reaches the microprocessor is converted to a temperature in digital display.

Figure 7.11—Digital maximum-minimum thermometer, Computemp 5 model. (Photo courtesy of Rodco Products Company, Inc.)

Instruments such as the Rodco Computemp (fig. 7.11) and the more expensive Sensor Nimbus have a memory that stores the maximum and minimum temperatures, which can be retrieved by pressing a button (or membrane covering). (The Nimbus also stores hourly temperatures, for up to 35 days.) The standard Computemp automatically resets at midnight and thus will erase maximum temperatures that may occur after an afternoon observation time. As an option, the instrument can be ordered with a manual reset. Specified accuracy of these instruments is within 1 °F over most of the operating range; calibration can be adjusted where necessary.

7.6 Psychrometers

The psychrometer is the most widely used type of instrument for current relative humidity measurements at manual weather stations. Another type of humidity instrument is the hair hygrometer, which finds use in the hygrothermograph (section 7.7). The psychrometer consists basically of two matched, mercury-in-glass thermometers mounted side-by-side on a common frame. The bulb of one thermometer, termed the "wet bulb," is covered by a thin, closely woven cotton (muslin) wick, which is wetted with water when measurements are taken. The other thermometer, not covered, is termed the "dry bulb."

During an observation, evaporation from the wet bulb will cause its temperature to fall below that of the dry bulb. The amount of evaporational cooling, at a given temperature (and atmospheric pressure), varies inversely with the relative humidity of the air. Thus, the lower the relative humidity, the greater is the spread between the dry-bulb and wet-bulb temperatures.

From the dry- and wet-bulb readings, both relative humidity and dewpoint are easily determined from standard psychrometric tables. These tables assume that there is adequate ventilation of the wet bulb. For this reason, artificially ventilated (force-ventilated) psychrometers are generally more reliable than those that depend on natural air movement. The dry and wet bulb thermometers are normally read to the nearest 1 °F for fire-weather observations, but where desirable and possible they may be read to the nearest 0.5 or 0.1 °F.

The electric fan psychrometer, described below, is the standard instrument recommended at permanent manual fire-weather stations. Other psychrometers, employed at some stations or for temporary field use, are also described. Most are designed to cool the wet bulb by forced ventilation.

STANDARD ELECTRIC FAN PSYCHROMETER

An electric (battery-operated) fan psychrometer is shown in figure 7.12. When mounted inside a suitable instrument shelter, this psychrometer can provide consistently accurate dry- and wet-bulb measurements. Its primary advantage is that effective ventilation is easily obtained. Since tiresome hand-cranking or slinging is eliminated, observers are more likely to continue ventilation until the wet bulb cools to its lowest reading. The two thermometers are 9½ inches long and normally have a range from –20 to +120 °F, in 1-°F increments.

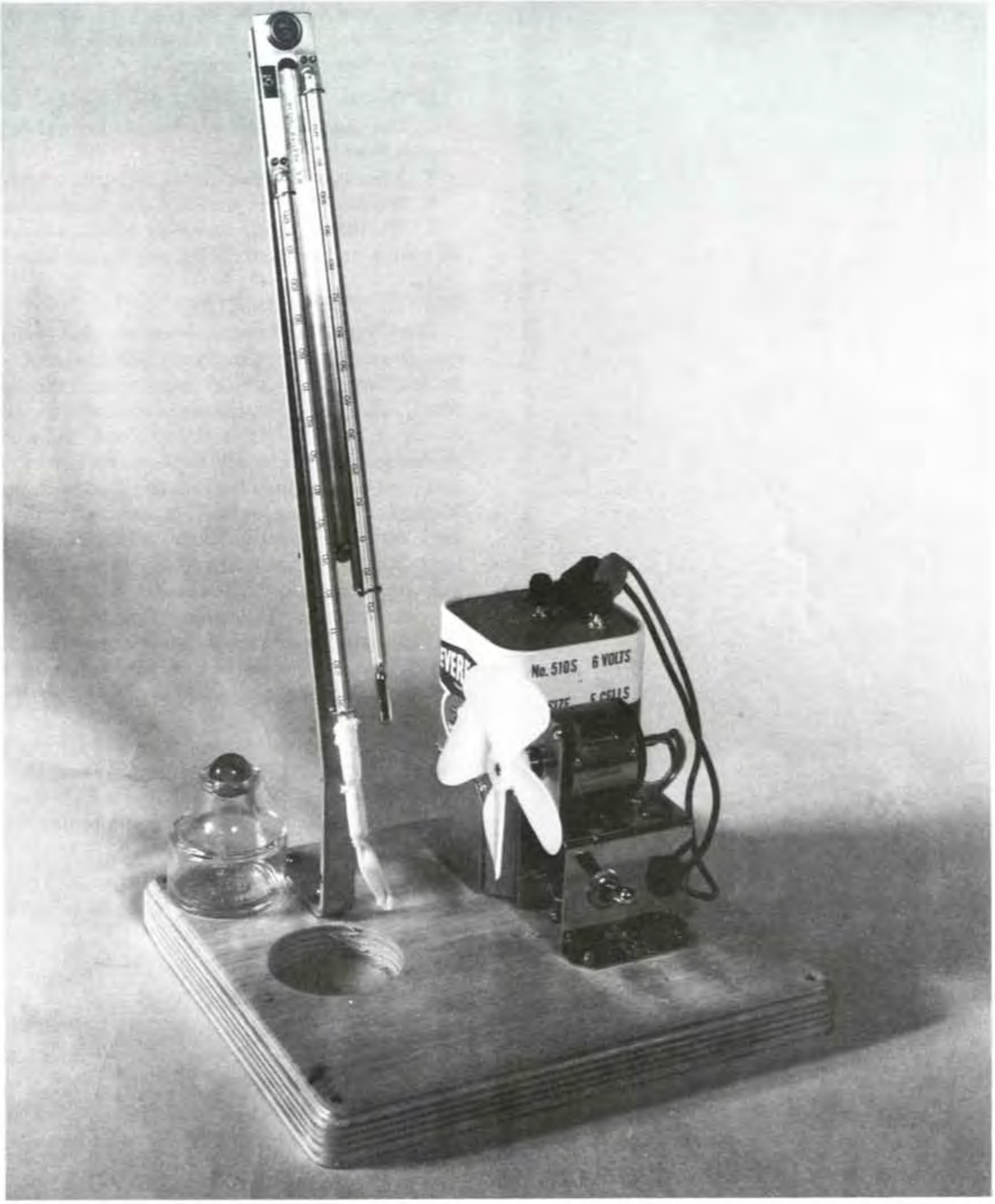


Figure 7.12—Electric fan psychrometer, Forest Service type; recommended for use at permanent manual type fire-weather stations.

HAND FAN PSYCHROMETER

Except for the method of fan operation, the hand fan psychrometer (fig. 7.13) is identical to the electric fan psychrometer. It, likewise, is designed for use in an instrument shelter. Ventilation of the thermometers is accomplished by rapidly cranking the fan. Cranking must continue without interruption until the lowest wet-bulb reading is obtained.

PORTABLE ELECTRIC FAN PSYCHROMETER

A recommended portable, battery-operated fan psychrometer is shown in figure 7.14. This type of instrument is particularly suited for spot measurements in tight spaces that do not provide clearance for a sling psychrometer (described below). Like the standard fan psychrometer, the thermometers can be read continuously during an observation. This instrument is usually supplied with a metal or plastic carrying case containing a

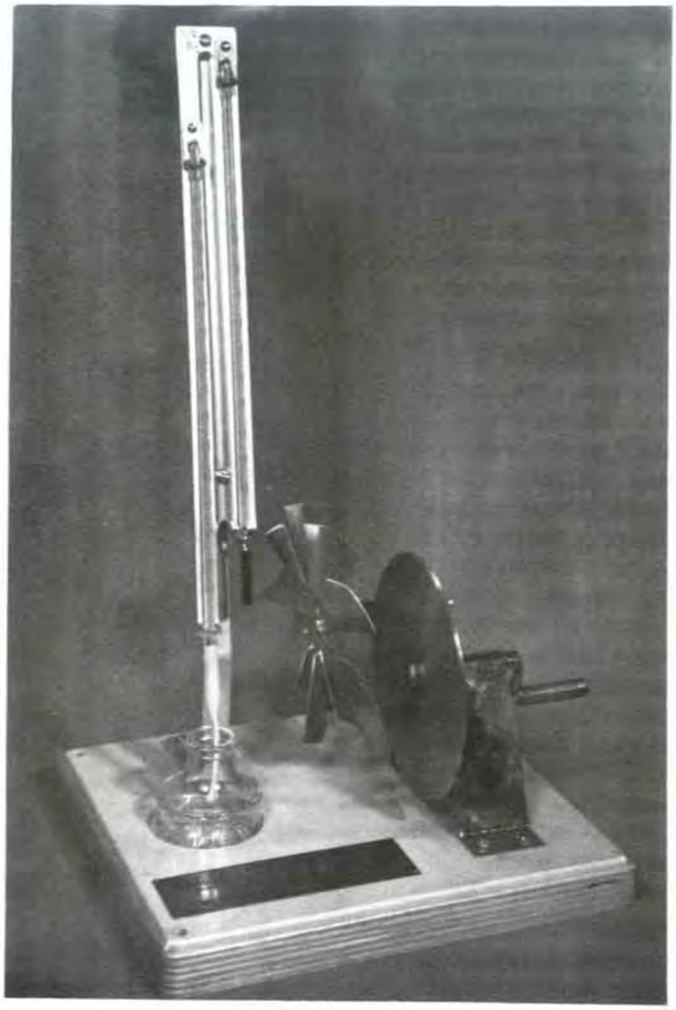


Figure 7.13—Hand fan psychrometer, Forest Service type.

foam-padded section for the psychrometer and a separate compartment for accessories and spare parts. Other features include the following:

1. The fan is powered by D-size flashlight batteries.
2. The thermometers are recessed and shock mounted with rubber fittings.
3. A built-in light facilitates nighttime readings.
4. A water bottle is stored in the psychrometer housing.
5. The thermometer assembly can be removed and used as a sling psychrometer if battery failure should occur.

SLING PSYCHROMETER

The sling psychrometer, recommended primarily for spot observations or temporary field stations, is ventilated by whirling it in a vertical circle around the observer's hand. Sling psychrometers are available in various models (fig. 7.15), differing in the size and precision of their thermometers and also in the construction of their handle and sling assembly. Most are supplied with protective storage or carrying cases. The standard model most often used at manual weather stations has 9½-inch thermometers with 1-°F graduations from –20 to +120 °F; the thermometers are identical to those in the standard electric fan psychrometer. It has a comfortable, easily gripped wooden handle. Another standard model has 9-inch, somewhat more protected thermometers with 1.0-°F graduations over a range +20 to 120 °F, together with a smaller handle.

The easily portable pocket type usually has 5½-inch thermometers with 1-°F graduations from +30 to 110 °F. This psychrometer is provided in the "belt weather kit" (USDA FS 1959); see section 8.4, under heading of Dwyer hand-held wind meter.

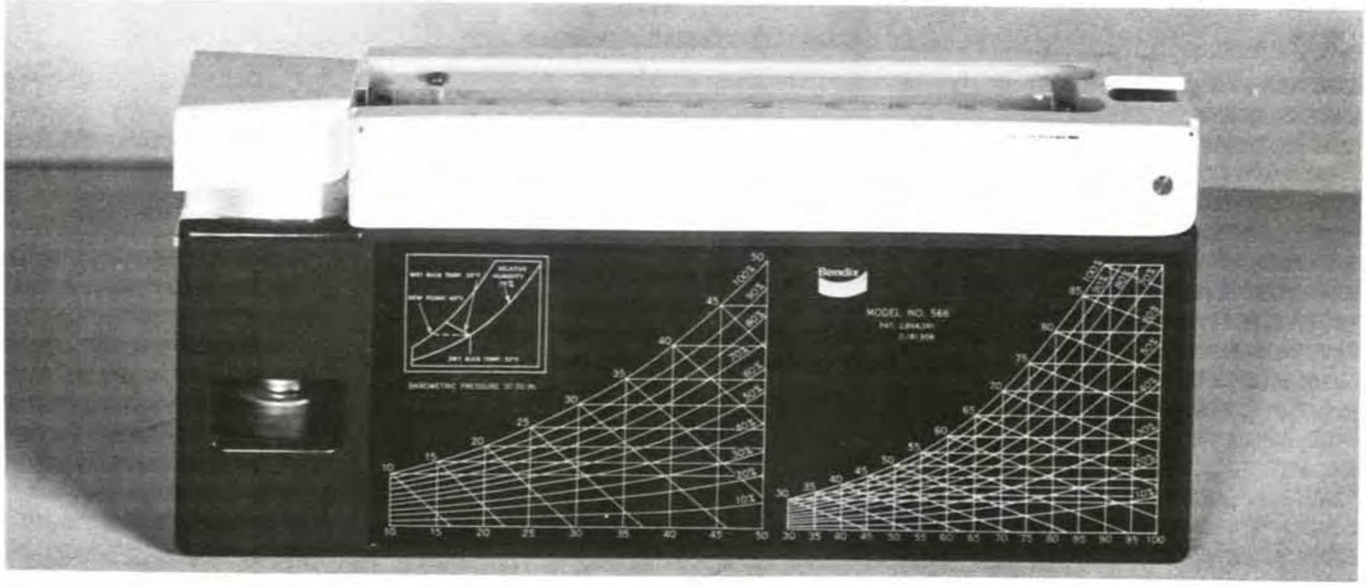


Figure 7.14—Bendix (Belfort) "Psychron" portable electric fan psychrometer. This instrument enables accurate measurement of relative humidity in both open and cramped field locations.

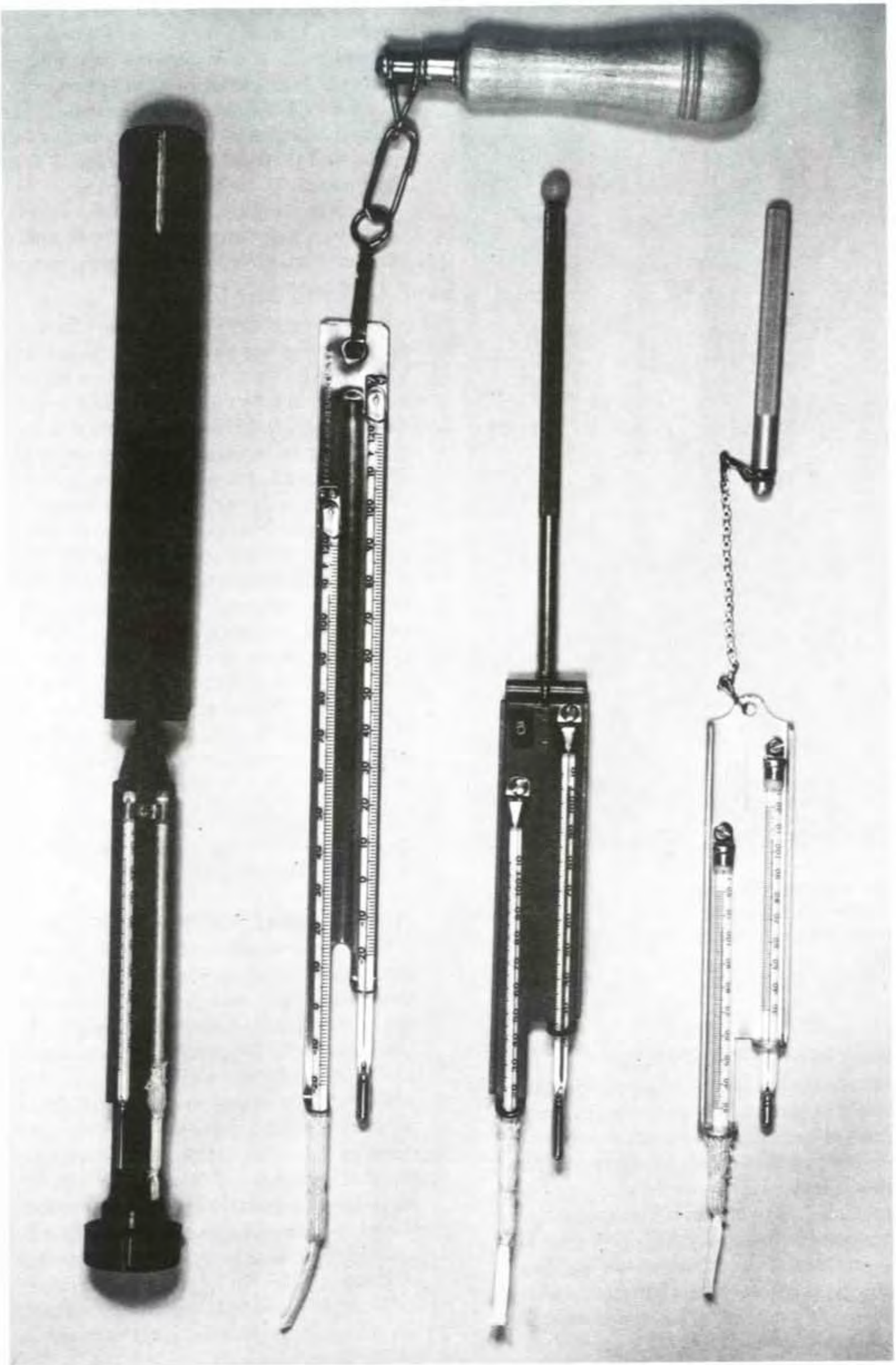


Figure 7.15—Sling psychrometers. The standard 9½-inch psychrometer (second from left) is often used for calibration checks of other temperature and humidity instruments.

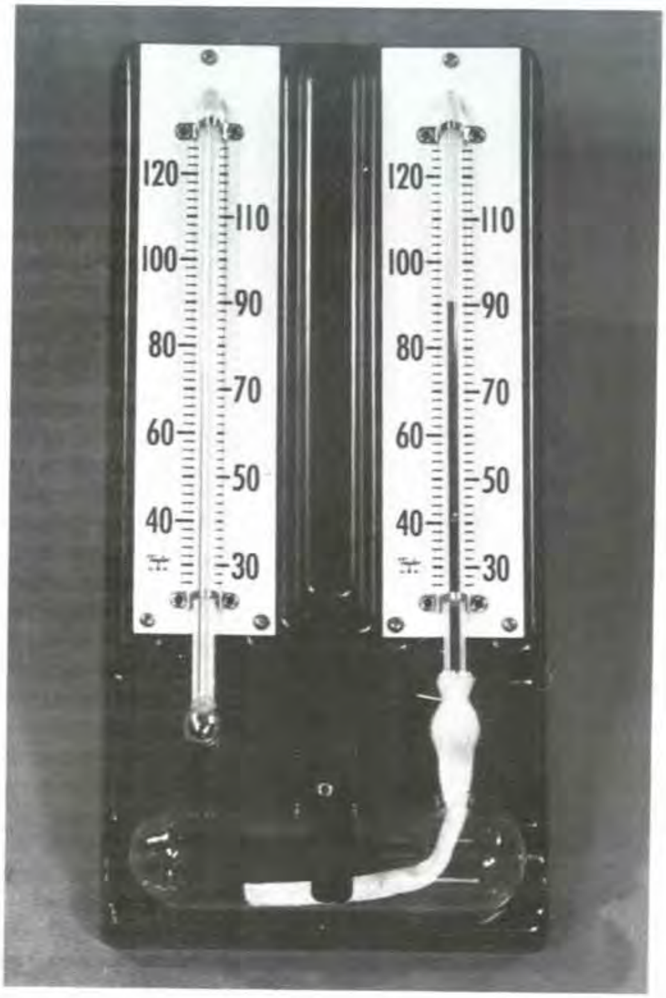


Figure 7.16—Mason hygrometer; a stationary, naturally ventilated type of psychrometer. Tail of wet bulb wick is continuously immersed in reservoir filled with water.

MASON (OR MASON'S) HYGROMETER

The Mason hygrometer (or Mason's hygrometer), actually a psychrometer, is designed for use in an instrument shelter. Unlike the preceding psychrometers, however, ventilation depends upon natural air movement or fanning with a piece of cardboard.

The instrument (fig. 7.16) consists of two easily readable mercury thermometers, usually with 2-°F graduations; these are marked on the thermometer backing rather than on the glass tubes. In the illustration, the thermometers have spherical bulbs, but thermometers with more desirable cylindrical bulbs are provided in some currently produced instruments such as those by Taylor. The wet bulb is covered by a long wick that extends into a water container, where it remains while the instrument is in service; the container must be refilled at regular intervals. The Mason hygrometer is not suited for use in below-freezing temperatures.

The model in figure 7.16 has a built-in plastic water reservoir, but another utilizes a glass jar placed beneath the wet bulb. A thin plastic oilcan with the spout cut short has been recommended as the most desirable water container (Williams 1964), because (1) the water level can be seen at a glance, (2) evaporation is reduced to a minimum, and (3) there is little chance of bursting during a light freeze.

Relative humidity and dewpoint values obtained with the Mason hygrometer generally do not have the accuracy of those from other psychrometers, because of the following reasons:

1. Thermometers with 2-°F graduations, marked on the backing, may not have a full-scale accuracy better than ±2 °F. Some thermometers will be better than others, as was found in a test of a recent Taylor unit; the uncovered thermometer bulbs were immersed in water at different temperatures. Over the range from +32 to 120 °F, error of the wet bulb thermometer varied between 0 and −0.7 °F, while the dry bulb error ranged from −1.6 to +1.6 °F. Agreement between the two thermometers was within ±1.0 °F from about +40 to 105 °F.
2. Thermometers with spherical bulbs are relatively sluggish in response to temperature changes. As previously noted, however, the thermometers in some current instruments have cylindrical bulbs.
3. Natural ventilation of the thermometers may be inadequate. This shortcoming becomes particularly important with the ambient wind less than 5 mi/h, when the affected wet bulb readings can give relative humidity values more than 5 percent too high.

During light wind conditions, to achieve greater accuracy, the thermometers should be fanned with a piece of cardboard (section 23.4).

MORTARBOARD PSYCHROMETER

The mortarboard psychrometer (fig. 7.17) was developed at the Southern Forest Fire Laboratory to provide a simple, accurate, and yet inexpensive means of obtaining dry- and wet-bulb temperature readings (Taylor 1963). Used mainly in Georgia, it consists of an upper and lower radiation shield, naturally ventilated thermometers, and supports. The radiation shields consist of three sheets of polished aluminum, supported horizontally. The two inner surfaces facing the thermometers are painted flat black to reduce possible internal reflections. The thermometers are mounted in a fixed horizontal position. Water is continuously supplied to the wet bulb by a wick running from a capped plastic cup mounted on the lower radiation shield. In light winds, the thermometers are ordinarily fanned with a piece of cardboard (as advised for the Mason hygrometer). Alternatively, an electric fan can be installed.

Figure 7.17—The mortarboard psychrometer, with self-contained aluminum radiation shield; used in southeastern area of United States.

Figure 7.18—Hygrothermograph, Bendix model, as normally exposed with case closed. The upper pen records temperature; the lower pen, relative humidity. Calibration adjustment screws are at right.

7.7 Hygrothermographs

The hygrothermograph (fig. 7.18) provides a continuous chart record of both temperature and relative humidity. Several models are in common use at fire-weather and other stations. (Separate recorders for temperature and relative humidity—thermographs and hygrographs, respectively—are also available but are less convenient where both measurements are required.) Although details of design vary according to manufacturer, general operating principles are similar. All hygrothermographs consist of four major working parts: (1) temperature element, (2) relative humidity element, (3) pen arm assemblies, and (4) chart drive mechanism.

The chart drive mechanism, which turns a cylinder (a "drum") holding the chart, most commonly employs a spring-wound or battery-operated clock movement. Newer mechanisms are now available (in Belfort instruments) that employ a stepper motor governed by a battery-operated quartz crystal oscillator. The clock is either located inside the drum (turning with it) or fixed to the base of the instrument. In the latter design, the drum revolves around the clock; the motor-type chart drive also uses this arrangement.

The pen arm assemblies are the link between the chart and the temperature and humidity elements. The pens are of two main types: (1) the barrel-type (with the two horizontal nibs extending from a small, open-sided cylindrical reservoir), furnished with Belfort and formerly manufactured Bendix-Friez hygrothermographs, and (2) the open-top V-point type, found on WeatherMeasure hygrothermographs. Cartridge-type pens are also available.

THE TEMPERATURE ELEMENT

Hygrothermographs normally used at weather stations employ a deformation-type sensing element (thermometer) for measuring temperature. This sensing element consists of either a curved Bourdon tube or a curved or coiled bimetal strip.

The Bourdon tube, slightly elliptical in cross section, is filled to capacity with an organic liquid. One end of the tube is fixed to the hygrothermograph base and the other to the temperature pen arm linkage. As the temperature of the surrounding air varies, the liquid expands or contracts and, accordingly, causes changes in the Bourdon tube curvature. These changes are transmitted to the chart through the pen arm linkage (fig. 7.19).

The bimetal strip is constructed by a welding of two different metals that have differing rates of expansion (or contraction) in response to increasing (or decreasing) temperature. As the temperature changes, this differential expansion or contraction causes the strip to change in curvature. These changes are, again, transmitted to the chart through the pen arm linkage (fig. 7.20).

THE RELATIVE HUMIDITY ELEMENT

Most hygrothermographs employ a human-hair element to measure relative humidity. This element is usually in the form of either a "banjo spread" (fig. 7.19) or a "bundle" of hairs (fig. 7.20). Whatever the arrangement may be, high humidity causes a lengthening of the hairs while low humidity causes a shortening. These hair responses are transmitted to the chart through the pen arm linkage.

Hair elements indicate the relative humidity with respect to water even at temperatures below freezing (World Meteorological Organization 1983) (see section 7.2).

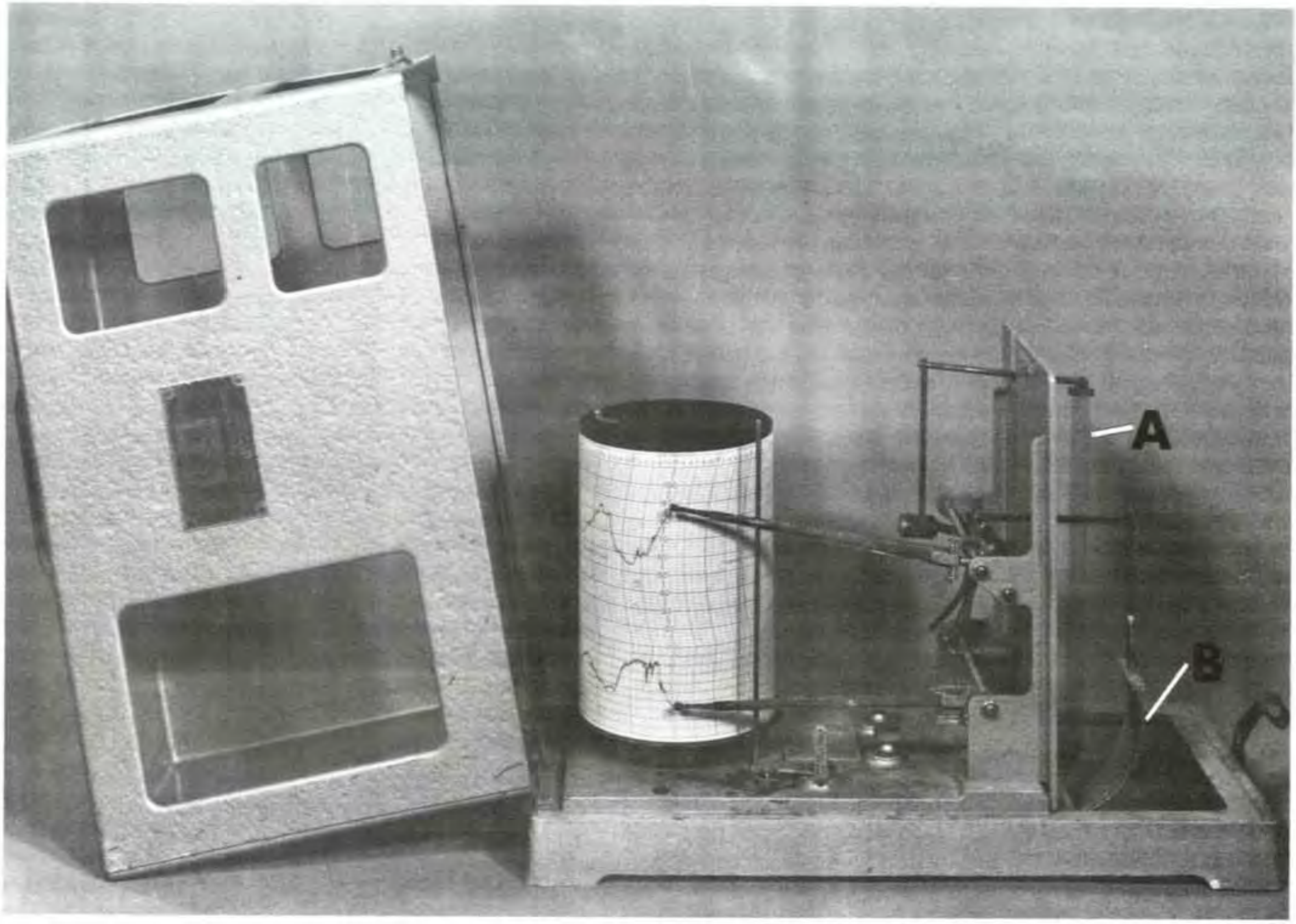


Figure 7.19—Open view of hygrothermograph, Belfort model, employing (A) banjo-spread hair element for relative humidity and (B) Bourdon tube for temperature. Calibration adjustment screws are on the base plate.

THE CHART RECORD

The temperature pen traces a record on the upper portion of the chart, while the humidity pen traces on the lower portion (fig. 7.21). Several temperature ranges are available. For Belfort and Bendix-Friez hygrothermographs (fig. 7.19), charts with the Fahrenheit scale have ranges from +10 to 110 °F for ordinary summer use; from –30 to +70 °F for winter use. WeatherMeasure (Weathertronics) instruments (fig. 7.20) use charts with a slightly larger range (from +10 to 120 °F for ordinary summer use). The relative humidity scales of all of these models cover the full range from 0 to 100 percent.

Daily, weekly, and monthly charts are available. Whatever chart is used, its time scale must be compatible with the gear ratio or drum rotation of the instrument. The gear ratio can easily be changed, as desired, by changing the gears on both the drum and base (or base-mounted clock). Weekly charts are most often used at fire-weather stations. To obtain a monthly record, instruments equipped with a spring-wound clock will require a special chart drive mechanism, in addition to the required set of gears. The long-running battery-operated chart drives have an advantage here; they can be used for either weekly or monthly charts.

Hygrothermograph charts have either square or tapered ends. Only the tapered-end charts can be used on drums that have a vertical slot in the cylinder wall. The ends of the chart are inserted into this slot and held in place by a metal retainer that presses the ends against the inside of the drum.

Both square- and tapered-end charts can be used on nonslotted drums, which are the drums usually supplied. Both types of chart are retained by a metal clip that presses the chart ends against the drum surface. The square-end charts are most commonly used, but the tapered-end charts may be advantageous, having a foldover tab that covers the retaining clip. This feature prevents loss of data (at the clip) when the drum is allowed to go beyond one complete revolution before a chart is changed. The pen traces will read slightly high, however, when the pens ride over the resulting bulge in the chart near the covered clip.

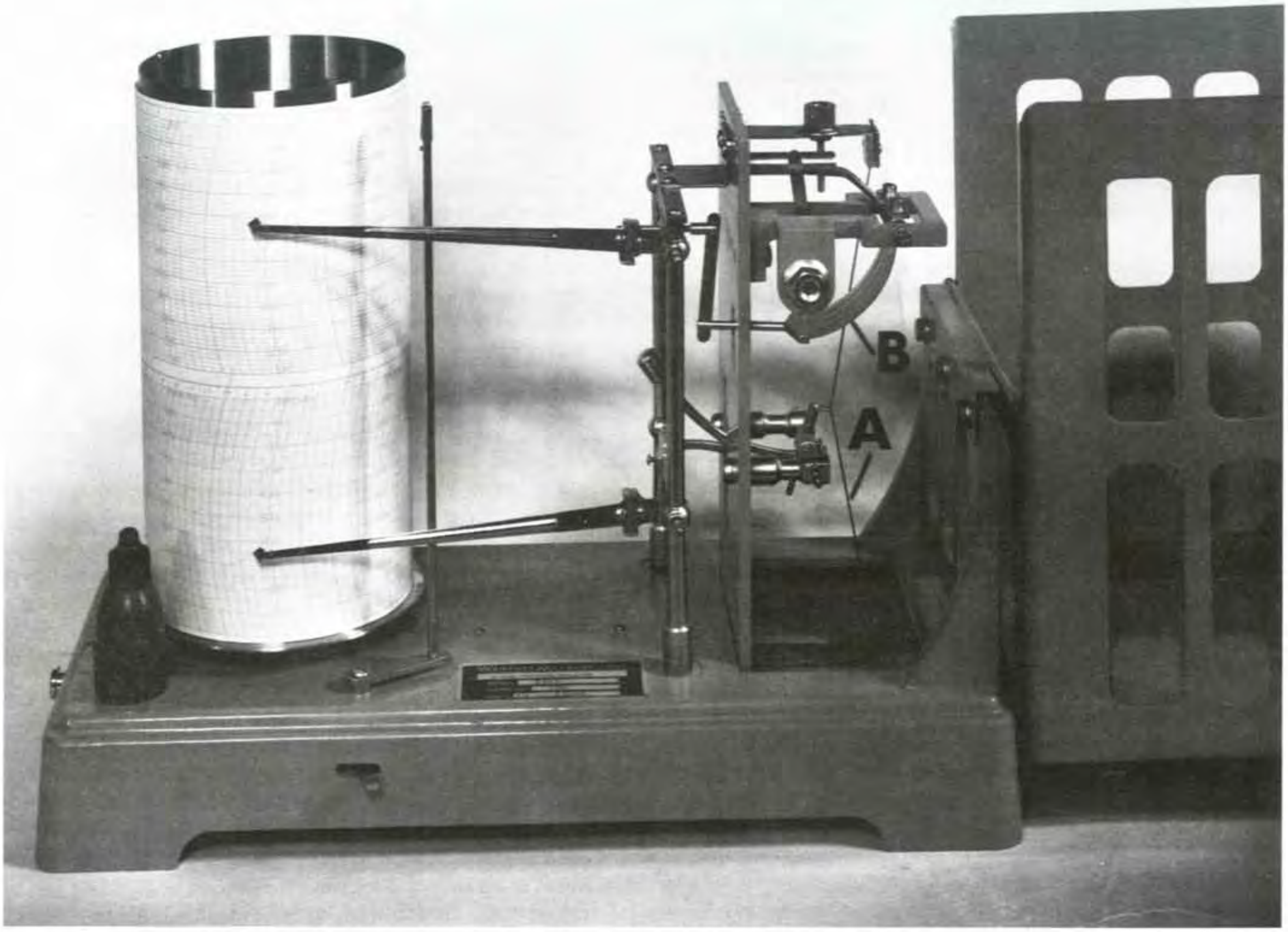


Figure 7.20—Hygrothermograph, WeatherMeasure model, employing (A) hair bundle humidity element and (B) curved bimetal strip.

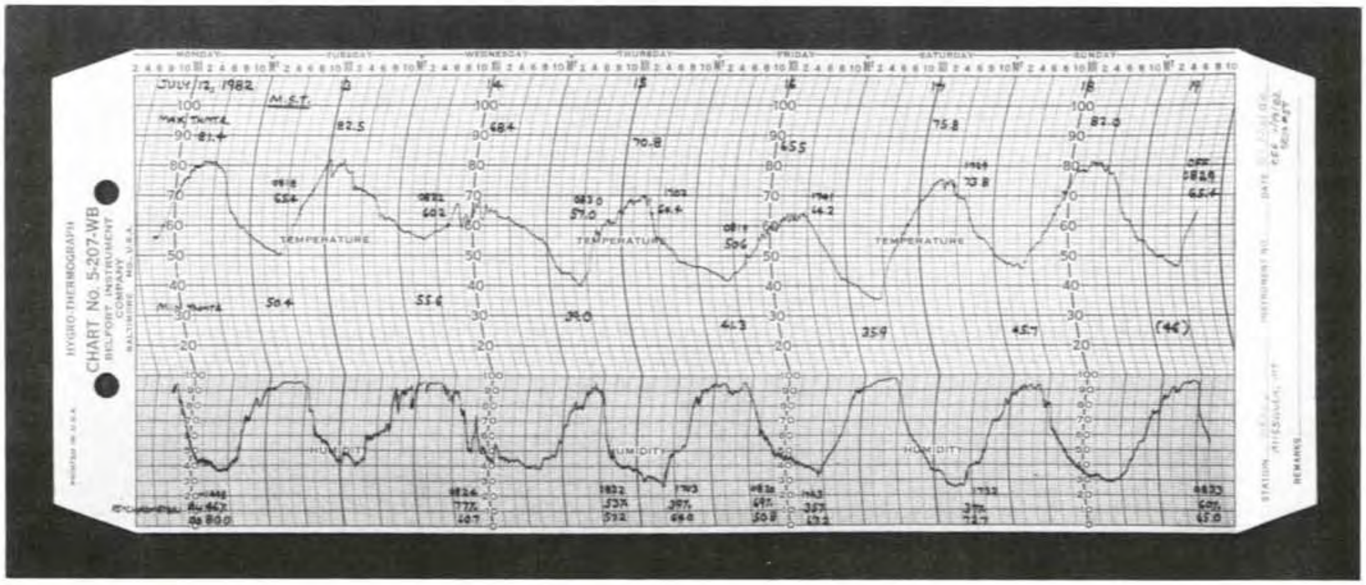


Figure 7.21—Weekly chart record from a hygrothermograph. Temperature trace is on upper portion of chart; relative humidity trace, on lower portion.

RELIABILITY

The reliability of hygrothermograph data depends greatly on the instrument's calibration and maintenance. With careful calibration and proper maintenance, an acceptable level of accuracy (within plus or minus 3 to 5 percent relative humidity and 1 °F temperature) can generally be maintained. This is particularly true for temperature data. Relative humidity readings tend to be less reliable because of calibration difficulties and certain inherent characteristics of human hair.

A test by Meeks (1968) with carefully calibrated hygrothermographs showed that characteristic "hysteresis" errors occurred. The errors varied, depending on whether the relative humidity was increasing or decreasing. The recorded values were typically too high at low relative humidities and too low at higher relative humidities.

Often the greatest loss in reliability of data occurs with calibration shifts (or "zero shifts") accompanying marked weather changes. Shifts of 10 to 15 pecent relative humidity have been observed (Hayes 1942; MacHattie 1958). Persistent dry weather causes an upward shift in calibration. Subsequent storms and saturation then bring a downward shift to near the original calibration position. If the humidity pen has been reset during the dry weather, the trace will later read too low.

CHAPTER 8. WIND

Wind is air in motion. This motion, or velocity, has two components: windspeed and wind direction.

Windspeed refers to the rate at which air passes a given point. Fire-weather measurements of windspeed are expressed in statute miles per hour (mi/h). This differs from the measurements at airport stations, which use knots (nautical miles per hour); one knot equals 1.15 statute mi/h.

Wind direction refers to the direction **from** which the air is moving. This is recorded, often in coded form, as a compass point (N, NE, E, SE, etc.); or, as at airport stations, in azimuth degrees from true north (0° to 360°).

8.1 Windspeed Instruments

Measurements of windspeed are most often obtained from cup anemometers. At standard weather stations in this country, the anemometers are exposed at a height of 20 ft above open, level ground (fig. 8.1). Particularly at fire-weather stations, it is often necessary to adjust this height to compensate for the height of ground cover, surface irregularities, and nearby obstructions (section 17.1).

Cup anemometers are calibrated to rotate at a rate proportional to the actual windspeed. Most commonly, this rotation is transferred by the main shaft to either a contacting mechanism or a generator, depending on the type of anemometer. The windspeed reading is, thus, provided by either the number of contacts made or the voltage generated. The readout device, wired to the anemometer, can be located either at the weather station or in a nearby office.

Contacting anemometers are the most widely used type at fire-weather stations, enabling easy calculation of a standard average windspeed. Generator anemometers are commonly used where instantaneous reading or continuous chart recording of windspeed is desired. Generator models that electronically accumulate the passage of wind have recently been developed and also enable an easy determination of average windspeed. Such models may find increased use, as some of the contacting models are no longer available (section 6.1).

8.2 Contacting Anemometers; Readout Devices

Contacting anemometers consist of four major parts: (1) a three- or four-cup rotor assembly, (2) a main vertical shaft or spindle, (3) a gear mechanism, and (4) an electrical contact. In addition, some contain a built-in dial or counter that records and accumulates total wind movement between settings.

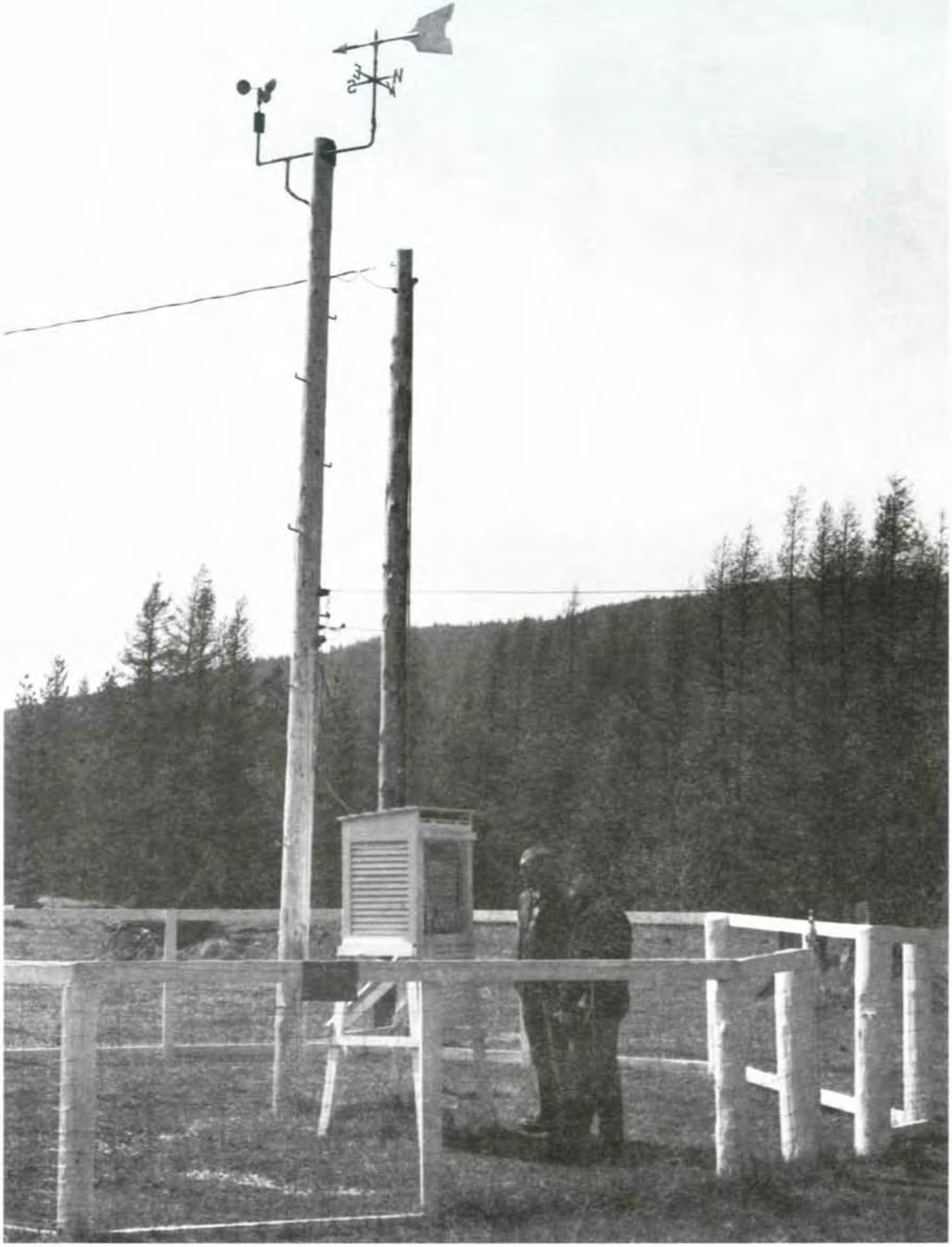


Figure 8.1—Anemometer and wind vane exposed at standard 20-ft height at a fire-weather station.

Figure 8.2—Small Airways anemometer with 1/60-mile contacts, used at many fire-weather stations.

ANEMOMETERS EQUIPPED WITH 1/60-MILE CONTACTS

The most widely used contacting anemometers are geared to close a contact after each 1/60-mile of wind has passed the cups (fig. 8.2). The number of contacts per minute, therefore, represents the windspeed in miles per hour.

Readout is obtained from a buzzer, flasher, or, more commonly, a mechanical counter. These devices are wired to the binding posts located on the anemometer housing. Each buzz, flash, or advance of the counter indicates a closure of the anemometer contact. Thus, the count per minute can be read directly as windspeed in miles per hour.

MECHANICAL COUNTERS

The mechanical counter is recommended over the buzzer or flasher because the chance of miscounting is greatly reduced, particularly when windspeed is averaged over a number of minutes. Mechanical counters are of three general types: nonreset, reset (fig. 8.3), and reset with 10-minute timer (fig. 8.4). The reset type can be zeroed at the beginning of each wind observation and, thus, can be read directly at the end of the prescribed averaging period. The reset type equipped with a timer further simplifies the observer's task because it records for only the period of time desired.

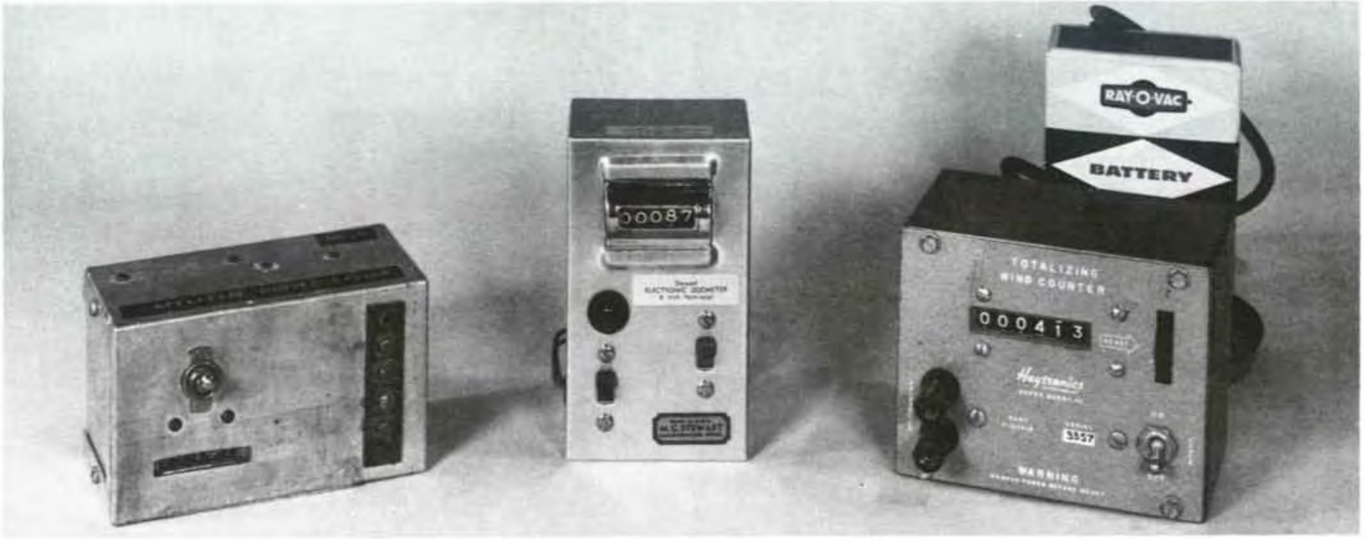
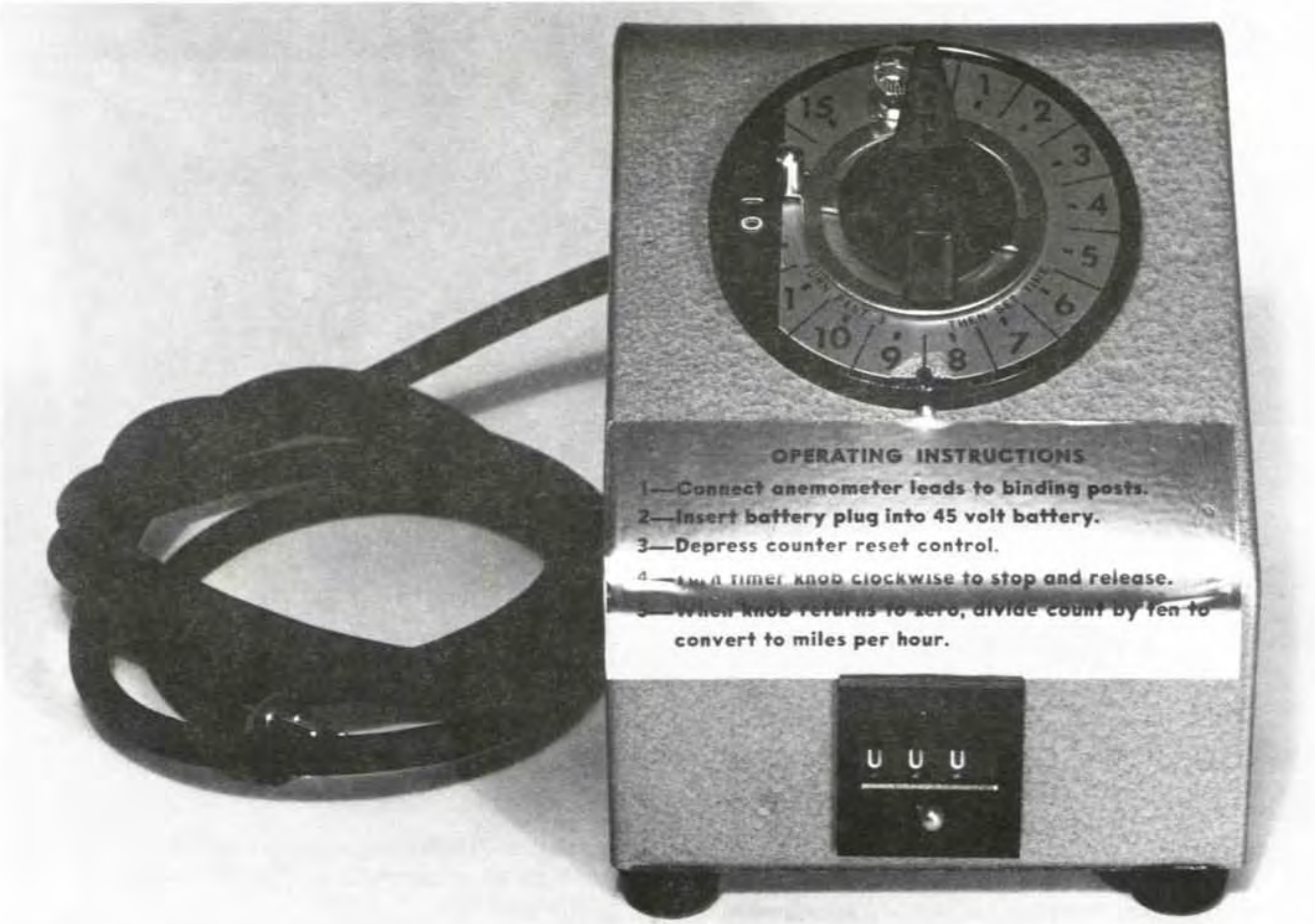


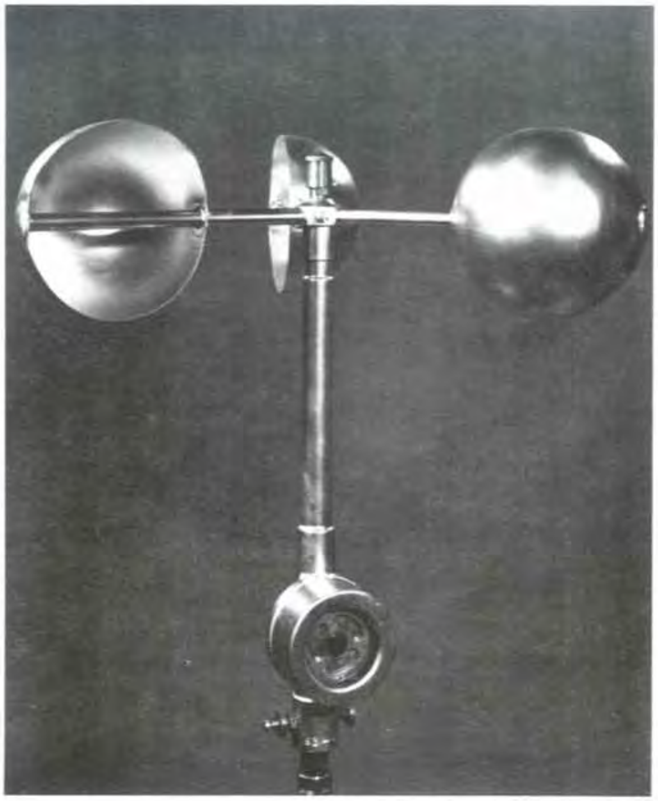
Figure 8.3—Mechanical counters in use at fire-weather stations: left and center, nonreset types; right, reset type.



OPERATING INSTRUCTIONS

1—Connect anemometer leads to binding posts.
2—Insert battery plug into 45 volt battery.
3—Depress counter reset control.
4—Turn timer knob clockwise to stop and release.
5—When knob returns to zero, divide count by ten to convert to miles per hour.

Figure 8.4—Reset type mechanical counter with timer; simplifies determination of 10-minute average windspeed.



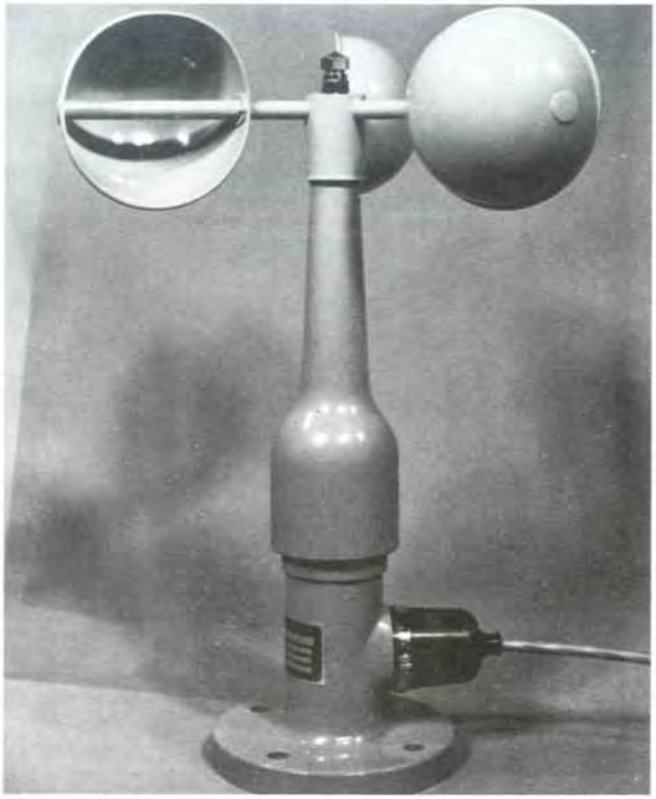


Figure 8.5—Totalizing anemometers equipped with both 1/60-mile and 1-mile contacts: top left, instrument with self-contained readout dial; top right, without self-contained readout; bottom, with self-contained readout counter.

ANEMOMETERS EQUIPPED WITH 1-MILE CONTACTS

Some anemometers have 1-mile contacts instead of, or in addition to, 1/60-mile contacts (fig. 8.5). Operation is similar to that for the 1/60-mile contacting anemometers, except that one contact is made for each 1 mile of wind passing the cups. The number of contacts per hour, therefore, gives the windspeed in miles per hour. Special totalizing counters are available for readout from these anemometers.

Usually, the ninth and tenth pins of the contact wheel are bridged to give a longer contact for each 10 miles of wind passage. One-mile contacts are often used to obtain daily or longer chart records of wind movement, in 1-mile steps accentuated every 10 miles.

THE HYGROTHERMOAEROGRAPH

Anemometers with 1-mile contacts can be used in conjunction with a hygrothermoaerograph (HTAG) to obtain a chart record of wind movement. The HTAG (fig. 8.6) is simply a conventional hygrothermograph that has been modified by the addition of a third pen arm to record each mile of wind movement (Fischer and others 1969). Tick-marks produced by each contact closure are recorded along the top portion of the chart, above the temperature trace. See appendix 5 for construction and wiring details.

ANEMOMETERS WITH SELF-CONTAINED READOUT

Some anemometers are constructed with a self-contained readout device that is driven directly, through gears, by the anemometer spindle (fig. 8.5). The readout device, indicating total wind movement (statute miles) is a four- or five-digit counter in present models; a former model uses dials. Known as totalizing anemometers, these instruments are more commonly used for obtaining 24-hour average windspeed than for 10-minute average speeds. They are standard accessory equipment, mounted near pan level, at evaporation stations.

Reading of the four- or five-digit counter is straightforward. The old dial readout device consists of two thin, concentric wheels that mesh with the same pinion gear. The inner dial is graduated in tens and hundreds of miles. The outer dial is graduated in miles and tenths of a mile (fig. 8.7).

Because the counter or dial operates accumulatively (until it reaches its limit and begins another cycle at zero), the observer must take a reading at the beginning and end of any period for which data are required. To calculate the average windspeed, the change in counter or dial reading is divided by the elapsed time (in equivalent hours).

8.3 Generator Anemometers

Generator anemometers consist of a rotor or cup assembly, a vertical shaft, a generator, and usually a windspeed-indicating device showing instantaneous values. The shaft connects the cups to a small permanent magnet generator. As the cups rotate, the voltage is generated in proportion to the windspeed. The windspeed indication is obtained from a connected voltmeter calibrated in miles per hour or other units (figs. 8.8 and 8.9). Also available are devices that electronically accumulate the total wind movement during an averaging period.

It is somewhat difficult to obtain average windspeed values from generator anemometers that give only instantaneous dial readings. Approximations may be made by observing a series of these readings, at fixed intervals

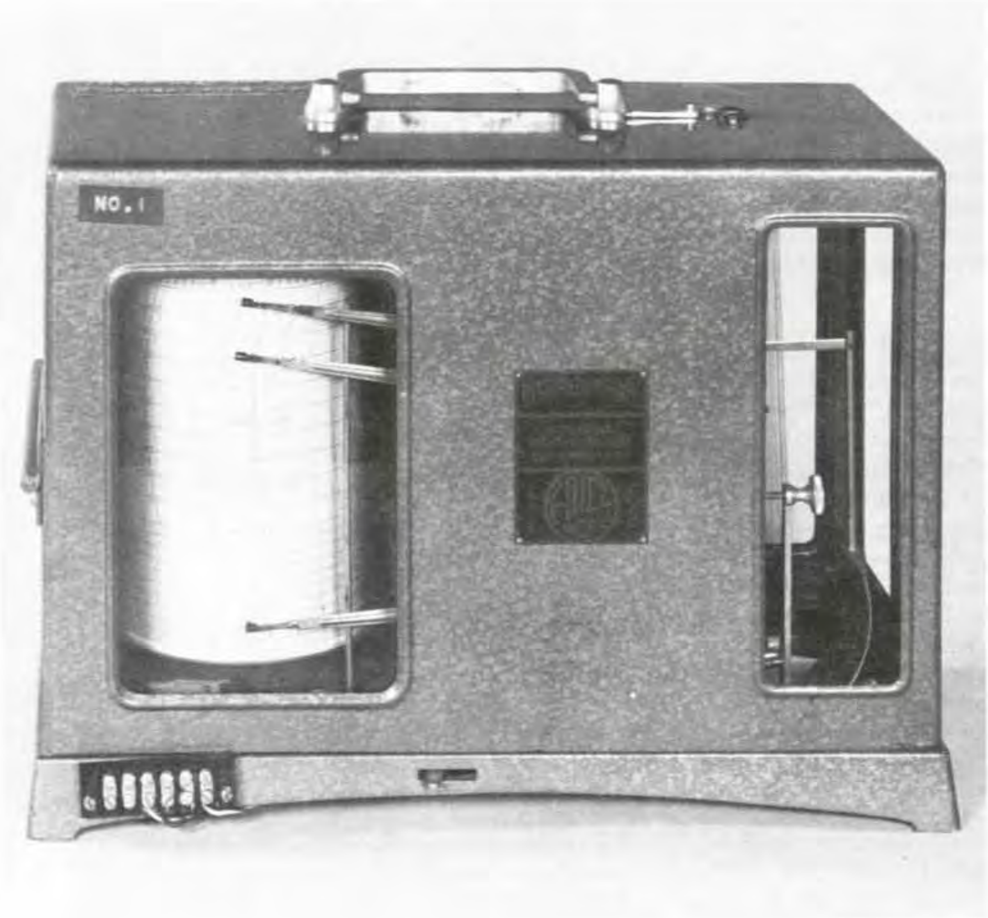


Figure 8.6—A hygrothermoaerograph. Uppermost pen arm has been installed to record each mile of wind movement.

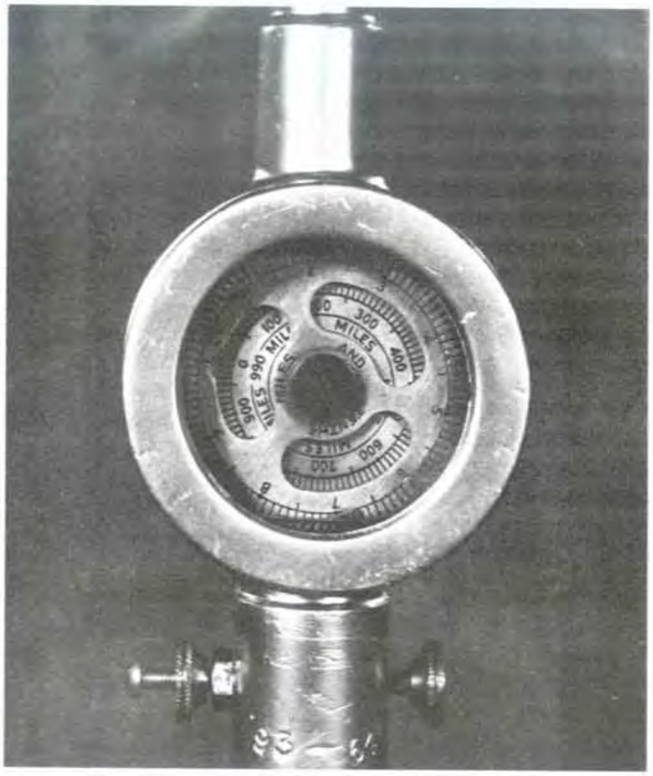


Figure 8.7—Closeup of self-contained readout dial, which accumulates total wind movement past anemometer cups.

Figure 8.8—Generator anemometer with remote readout dial is particularly useful for instantaneous windspeed measurements.

over a number of minutes, and taking an arithmetic average. Averages with greater accuracy can be obtained from traces produced on a chart recorder.

Generator anemometers are available in a design that uses a propeller, rather than cups, as the wind sensor—part of a relatively expensive system that also indicates wind direction. These are described further in Part 3 (section 44.2).

ACCUMULATING GENERATOR ANEMOMETERS

These anemometers, which electronically indicate the accumulated wind movement, have found increasing use in the northeastern United States—particularly the Natural Power Anemometer (fig. 8.10). The anemometer head sends windspeed information as a variable-frequency AC signal to the "accumulator" (a calculating and readout unit), which can be located several thousand feet away. The signal is translated into distance units equaling 1/60 mile. Upon command (in Natural Power models A21 and A22) the accumulator displays, in LED digital readout, the accumulated number of 1/60-mile units since the previous setting. Dividing that number by the elapsed number of minutes yields the average windspeed (mi/h). A newer model (A19-S6A) automatically computes a 10-minute average windspeed.

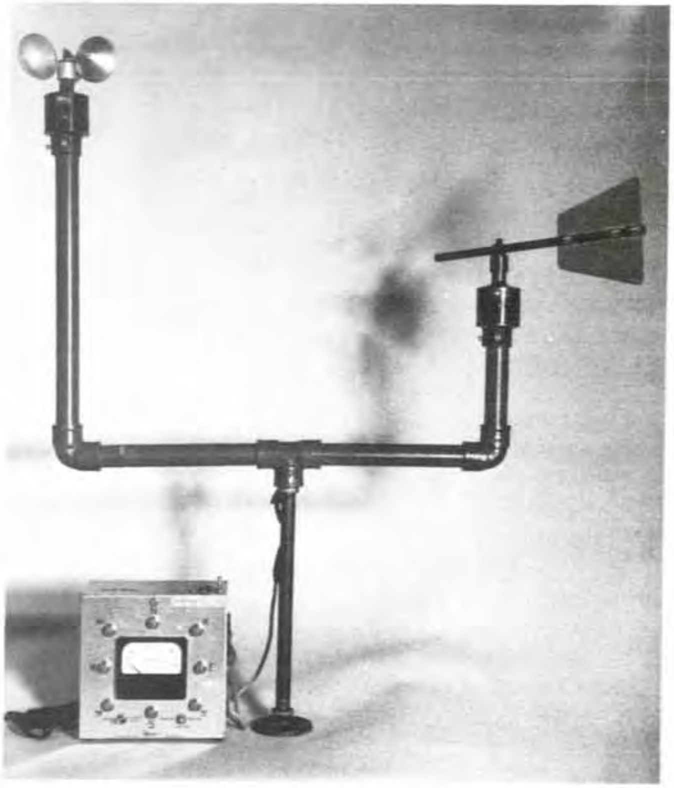


Figure 8.9—Windspeed system, with wind vane and generator anemometer. Remote readout device shows windspeed (dial) and wind direction (lights).

Figure 8.10—Accumulating-type generator anemometer, Natural Power model A19-S6A; digital readout gives 10-minute average windspeed. (Photo courtesy of Controlex, Inc.)

Both indoor and outdoor accumulator units are available. The outdoor unit, housed in a weatherproof enclosure, operates on alkaline or lithium "C"-size batteries; the indoor unit has an internal nickel-cadmium battery for backup in cases of AC power failure.

A similar device is the NRG Systems Model 2800-10M wind odometer, which displays the 10-minute average windspeed in LCD readout. The odometer interfaces with a Maximum #40 generator anemometer and counts the number of revolutions of the cups for 10 minutes. Then it displays the average speed for 10 minutes, after which the process begins again. The unit is powered by an internal, 10-year lithium battery.

8.4 Hand-Held Anemometers

Hand-held anemometers indicate windspeed directly on the instrument body, typically by means of a pointer on a dial or by a digital readout (figs. 8.11 and 8.12). Some of these are three-cup generator-type anemometers, but others operate on different principles. Anemometers with a rotating dial (and fixed pointer) employ a magnet on the rotating shaft, which sets up eddy currents that rotate a spring-loaded drum assembly in proportion to the windspeed. Lower priced generator anemometers may have somewhat high threshold windspeeds (the speed required to start the cups rotating)—as high as 5 mi/h.

Figure 8.11—Hand-held anemometer, with scale on rotating drum. (Photo courtesy of Qualimetrics, Inc.)

Figure 8.12—Hand-held anemometer with digital readout showing 2-minute or 5-minute average windspeed; Sims model DIC-3. (Photo courtesy of Simerl Instruments.)

A hand-held instrument from Sierra-Misco, Model 1039, has both a wind vane and anemometer (with dial readout); specified threshold speed of the generator anemometer is only 1 mi/h. The digital-reading "Turbo-Meter" (fig. 8.13) manufactured by Davis employs turbine blades suspended on jewel bearings and protected by the case cowling; in operation, the blades must correctly face into the wind.

To obtain average windspeed values, averaging of instantaneous readings is generally required. A digital model from Sims, however, displays the instantaneous, peak, and 2- or 5-minute average windspeeds. This instrument, Model DIC-3, employs a solid-state "Hall Effect" device.

Windspeeds obtained with hand-held instruments, at 5 to 6 ft above ground, will generally be lower than those at the standard 20-ft anemometer height, but they may be more representative for certain needs. These include actual windspeeds near flame height in ground fires.

DWYER HAND-HELD WIND METER

The Dwyer wind meter (fig. 8.14), based on pressure effects, is an inexpensive, highly portable means of obtaining approximate windspeed at observer's level. Again, averaging of instantaneous readings is necessary. The meter's slightly tapered plastic shell encloses a tube containing a small, white pith ball. Wind entering two small holes ("dynamic" ports) near the base of the shell causes a pressure difference between these ports and a "static" port at the top of the tube. This generates an air flow up the tube, varying with the windspeed, and the freely moving white ball rises and falls accordingly. Its position is read on an adjacent windspeed scale.

The meter indicates windspeeds up to 10 mi/h on its low scale and up to 60 mi/h on its high scale. When properly maintained and held (facing the wind), the meter is accurate within 1 or 2 mi/h at low speeds, but errors may exceed 5 mi/h at higher speeds (Snow and others 1989).

Belt Weather Kit—The Dwyer wind meter is a component of the belt weather kit (fig. 8.15), which also contains a small sling psychrometer (section 7.6) and accessory items fitted into a canvas carrying case. This kit is the simplest, least expensive, and most widely used portable "station" unit.

Figure 8.13—Hand-held anemometer with digital readout, employing turbine blades. (Photo courtesy of Davis Instruments.)

Figure 8.14—Dwyer hand-held wind meter, based on pressure effects; windspeed indicated by white ball rising and falling within tube.

8.5 Wind Direction Indicators

Wind direction can be obtained quite simply by facing into the wind or by observing the movement of smoke columns, blowing dust, leaves, and other vegetation. Flags make good wind direction indicators; colored plastic flagging or a wind sock fastened to an anemometer pole is also satisfactory. As closely as possible, the observer should be directly underneath the indicator; this will minimize errors due to perspective. Accuracy with any of these methods depends on correct knowledge of the cardinal directions or use of a compass. It may be helpful to establish a true-north reference at each station.

WIND VANES

The wind vane usually consists of an arrow assembly mounted on a vertical shaft or spindle that rotates freely on bearings (figs. 8.1 and 8.9). The arrowhead, pointing into the wind, is weighted sufficiently to counterbalance the larger tail section of the arrow. The tail, offering the greater air resistence, turns to the leeward. In another, generally higher priced design, a propeller serves as both anemometer and wind direction pointer.

Wind vanes at some manual weather stations are read directly through visual observation of the arrow. Other vanes transmit their indications by electrical contacts or resistance circuits to a readout device. The readout may employ a series of eight lamps (fig. 8.16), each representing a point of the compass (N, NE, E, SE, etc.), or a dial indicator (figs. 8.8 and 8.9). More-expensive chart recorders can also be used, for a continuous record of wind direction. The readout devices are usually part of a system that also shows windspeed.

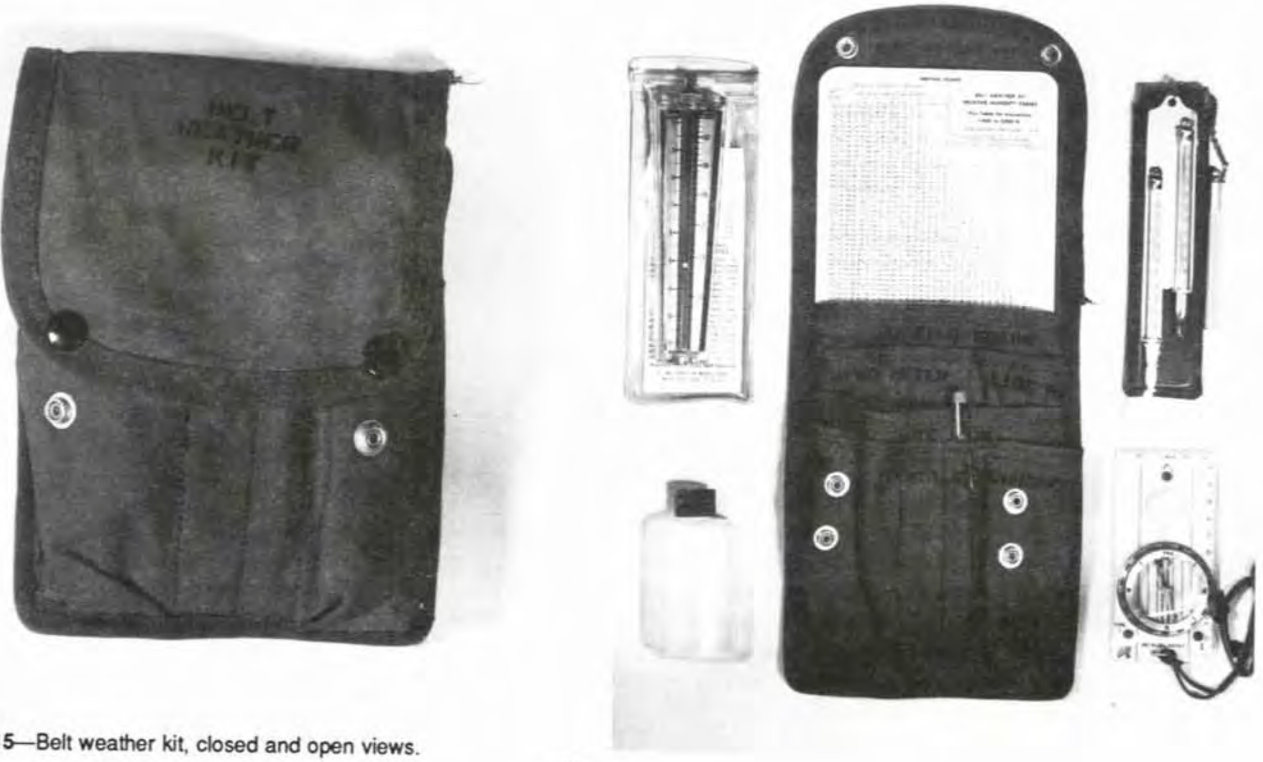


Figure 8.15—Belt weather kit, closed and open views.

Figure 8.16—Wind direction indicator; direction shown by lighted lamps.

CHAPTER 9. PRECIPITATION

Precipitation is the amount of water falling upon the earth as rain or in frozen forms such as snow, sleet, and hail. It is expressed as the depth of water that would cover a flat surface and is measured with a suitable receptacle termed a gauge. Measurement units, for fire-weather and standard climatological observations in this country, are in inches. Amounts are recorded to the nearest hundredth of an inch (for example, 0.47 inch).

There are three general categories of precipitation gauges (also called rain gauges, for brevity): (1) ordinary (nonrecording) gauges, such as dipstick (or "stick") gauges, (2) recording gauges, and (3) storage gauges. These gauges are available in various designs and sizes; standard designs have a circular cross section. The standard nonrecording gauge has an 8-inch diameter.

9.1 Nonrecording Gauges

STANDARD 8-INCH RAIN GAUGE

Components of the standard 8-inch "stick" gauge are shown in figure 9.1. Precipitation is caught within the collector (the funnel), or top section; this has a knife-edge rim with an 8-inch inside diameter. The water is funneled into the measuring tube set within the outer cylinder, which is also termed the overflow can. The top section, seated on the overflow can, also acts as a shield in curtailing evaporation of the collected water.

The cross-sectional area of the measuring tube is one-tenth that of the collector. Therefore, the depth of water standing in the tube is ten times the depth that has actually fallen. This magnification enables easy measurement of precipitation to the nearest hundredth of an inch.

The measuring stick is graduated at one-tenth inch (0.10-inch) linear intervals, each representing 0.01 inch of precipitation. An actual length of 1.00 inch on the stick represents 0.10 inch precipitation.

Large and Lower Capacity Gauges—The standard 8-inch gauge is available in two types: the traditional, large-capacity rain and snow gauge (fig. 9.2) and the less expensive but lower capacity Forest Service gauge (fig. 9.1). The traditional type, used by the National Weather Service (NWS) at year-round climatological stations, can hold 2.00 inches precipitation in its measuring tube and a total of 20 inches in the overflow can. The Forest Service type holds only 0.50 inch in its measuring tube and a total of 7 inches in the overflow can. This gauge was designed to provide an economical instrument for use in areas where 24-hour precipitation rarely exceeds a few inches.

For collecting snowfall, which is later melted to obtain its water content, these gauges are exposed with only the outer can in place (the top section would block the downward passage of snow). The shallow Forest Service gauge is, of course, limited in its snowfall capacity, particularly under windy conditions when snow may be swirled out of the can.

Measuring Sticks—Measuring sticks of laminated plastic are now widely used for both types of standard gauges, replacing wooden (cedar) sticks. The plastic stick has several advantages over the wooden stick: (1) water will not creep up the stick, (2) the plastic stick and its white, easy-to-read markings are more durable, and (3) the plastic stick can be easily washed clean of oil, dirt, or grease. On the other hand, the waterline is often much easier to see on the wooden stick than on the plastic stick.

The waterline, also, may be displaced slightly upward on the nonabsorbant plastic stick, but this error can be considered negligible, considering possible errors in gauge catch of precipitation. Also, close to 0.005 inch precipitation—one-half the increment between stick markings—

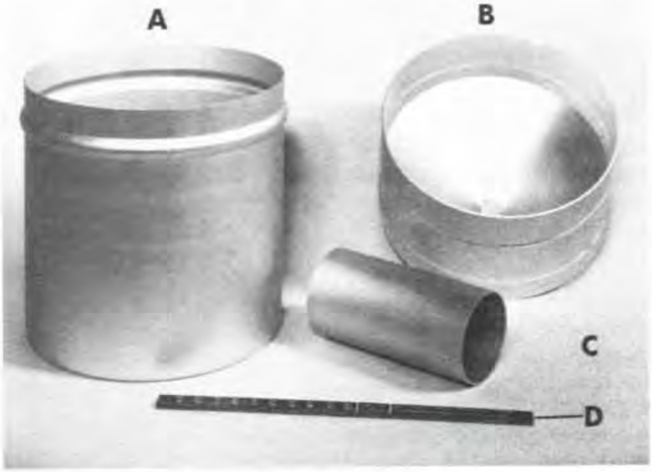


Figure 9.1—Components of small-capacity standard 8-inch rain gauge, Forest Service type: A, overflow can; B, collector; C, measuring tube; D, measuring stick.

Figure 9.2—Large-capacity standard 8-inch rain gauge, National Weather Service type.

may be required to wet a previously dry funnel before water will flow into the measuring tube.

Gauge Mounts—The large-capacity 8-inch gauges are mounted in either a steel or aluminum tripod stand or in a wooden stand. The wooden stand, less common in newer installations, was in the past constructed from a box in which the gauge was shipped (fig. 9.2). The shorter, Forest Service rain gauge is usually mounted in a specially-constructed wooden stand (section 18.2).

Weighing Scales—Spring-type weighing scales (fig. 9.3) provide a convenient means of measuring the water content of snowfall collected in the standard, large-capacity 8-inch gauge overflow can—an alternative to the method described in section 25.1. The scale is particularly suited where the 8-inch can, charged with antifreeze solution (section 9.3), is used as a storage precipitation gauge. The can and scales are also used for determining the total water content of snow on the ground, from snow cores (section 25.1), at locations with snow depths less than 2 ft. A small hole is usually drilled near the rim of the overflow can for suspending it from a hook on the scale. The scale in figure 9.3, with graduations in 0.05-inch increments, can measure 11 inches water (or water plus antifreeze) content in one revolution of the pointer; 22 inches in two revolutions.

SMALL-ORIFICE RAIN GAUGES

Rain gauges designed with small collection areas (orifices) and reduced capacities are often used to obtain supplemental rainfall data at locations away from the main or permanent weather station. Most of these gauges are constructed of durable plastic and have the advantage of lower cost and easy portability. A survey of literature

Figure 9.3—Weighing scales, used with overflow can of large-capacitiy 8-inch rain gauge; a convenient means of measuring water content of snow. (Photo from U.S. Department of Commerce 1972.)

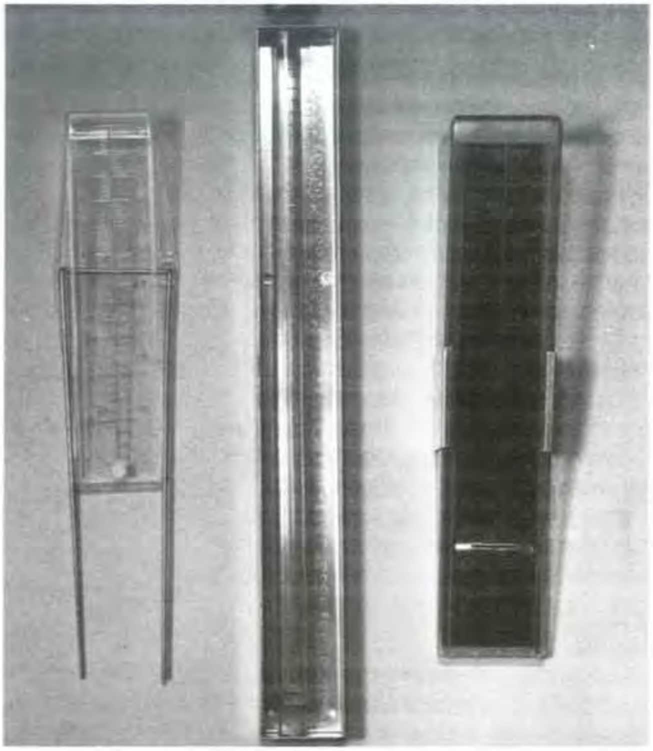


Figure 9.4—Several types of direct-reading, small-orifice rain gauges.

examining small-orifice gauges (Corbett 1967) showed them to have the following characteristics:

1. Accuracy of some gauges compares favorably with the standard 8-inch gauge.
2. Under certain conditions, a more accurate catch of rainfall can be obtained because these gauges do not obstruct the airflow (and thus create eddies) as greatly as a large gauge.
3. Most are unsuitable for snowfall collection.
4. Use is not recommended during freezing weather.
5. Evaporation loss is relatively high; hence, these gauges should be read as soon as possible after precipitation has ended.

Most small-orifice rain gauges are designed as direct reading instruments and do not require a measuring stick. Several of the more common types are shown in figures 9.4 and 9.5. Two models considered suitable for supplementary or temporary field use are described below.

Four-Inch Clear Plastic Gauge—This gauge (fig. 9.5) is modeled after the traditional 8-inch-diameter gauge; all parts are durable plastic. It consists of a 4-inch-diameter knife-edge collector with funnel, an outer (overflow) cylinder, and a direct-reading measuring tube. The measuring tube has 0.01-inch graduations and holds 1.00 inch

Figure 9.5—Four-inch clear plastic direct-reading rain gauge.

of rain; the overflow cylinder holds an additional 10 inches. The gauge is supplied with a stainless steel bracket for mounting on a post or other suitable support that does not block precipitation.

Wedge-Shaped (Fencepost) Gauge—This flat-sided, one-piece plastic gauge consists of a wedge-shaped well on which a scale is embossed (fig. 9.4). Rectangular in cross section, its knife-edge orifice measures 2.5 by 2.3 inches. The gauge has a capacity of 7.00 inches, with the scale graduated in units of 0.01 inch for rainfall up to 0.30 inch; 0.02 inch for rainfall between 0.30 inch and 1.00 inch; 0.05 inch for rainfall above 1.00 inch. Measurement is by direct observation of the water level. The gauge is supplied with a mounting bracket.

Evaporation loss can be quite high in this gauge. Contributing to this loss is the open top and also the tendency for small amounts of water to cling to the sides; the small gauge and its contents can also heat up rapidly in the sun, providing energy for the evaporation process. The gauge must be read very soon after rainfall has ended.

9.2 Recording Precipitation Gauges

Recording gauges provide a chart record or other readout that can be used to determine the time, duration, intensity, and amount of precipitation for each occurrence. They also show the accumulation during a specified time period.

Two basic types of recording gauges are in common use: the weighing type and the tipping bucket type. The traditional ("Universal" type) weighing gauge uses an ink trace on a rotating chart. A newer, digital type weighing gauge employs punched tape.

Recording gauges consist of four basic parts: a collector, measuring mechanism, recording mechanism (or transmitting device), and housing.

UNIVERSAL WEIGHING GAUGE

The Universal weighing gauge (fig. 9.6), also known as the Fergusson weighing gauge, continues as the standard recording gauge in use at manual fire-weather stations and at the NWS primary (airport) stations. But the punched-tape gauge, described below, has replaced the Universal gauge in the NWS cooperative recording-gauge network.

The Universal gauge's operating principle is relatively simple. In the standard model, the collector has an 8-inch (inside diameter) orifice and "chimney," together with a removable funnel. As precipitation enters the chimney, it is funneled or directly deposited into a 12-quart bucket resting on a spring-scale weighing platform. The funnel is removed during the snow season, when, also, a charge of antifreeze is added to the bucket. A high-capacity model is also available. To inhibit snow bridging across the orifice, its collector measures 11.3 inches in diameter and is coated with teflon.

The weight of precipitation in the bucket, converted to inches, is transmitted through a linkage system to the pen arm and onto the rotating chart (fig. 9.7). A dashpot is provided in the linkage system to dampen pen arm oscillations caused by wind or other sources of vibration.

The standard model can be supplied calibrated to record, on appropriate charts, a total of either 2.4 inches, 4.8 inches, 6 inches, 12 inches, or 20 inches precipitation. Some of these ranges include dual traverses of the pen arm. The high-capacity model will record 30 inches, dual-traverse (including antifreeze charge). Standard range is 12 inches. In this case, a 1-inch vertical spacing on the chart equals 1 inch of precipitation. The first 6 inches are recorded on the ordinary upward traverse of the pen; the second 6 inches, on a downward traverse.

The chart drives are similar to those available for the Belfort-type hygrothermograph—spring-wound or battery-operated (sections 3.1 and 7.7). Likewise, the chart rotation period can be varied by gear selection. Daily, weekly, and monthly charts are available.

The housing encloses the entire operating mechanism and the collector-funnel assembly serves as the top. A vertically sliding door is provided at the bottom of the housing for access to the chart, chart drive, and pen arm assembly.

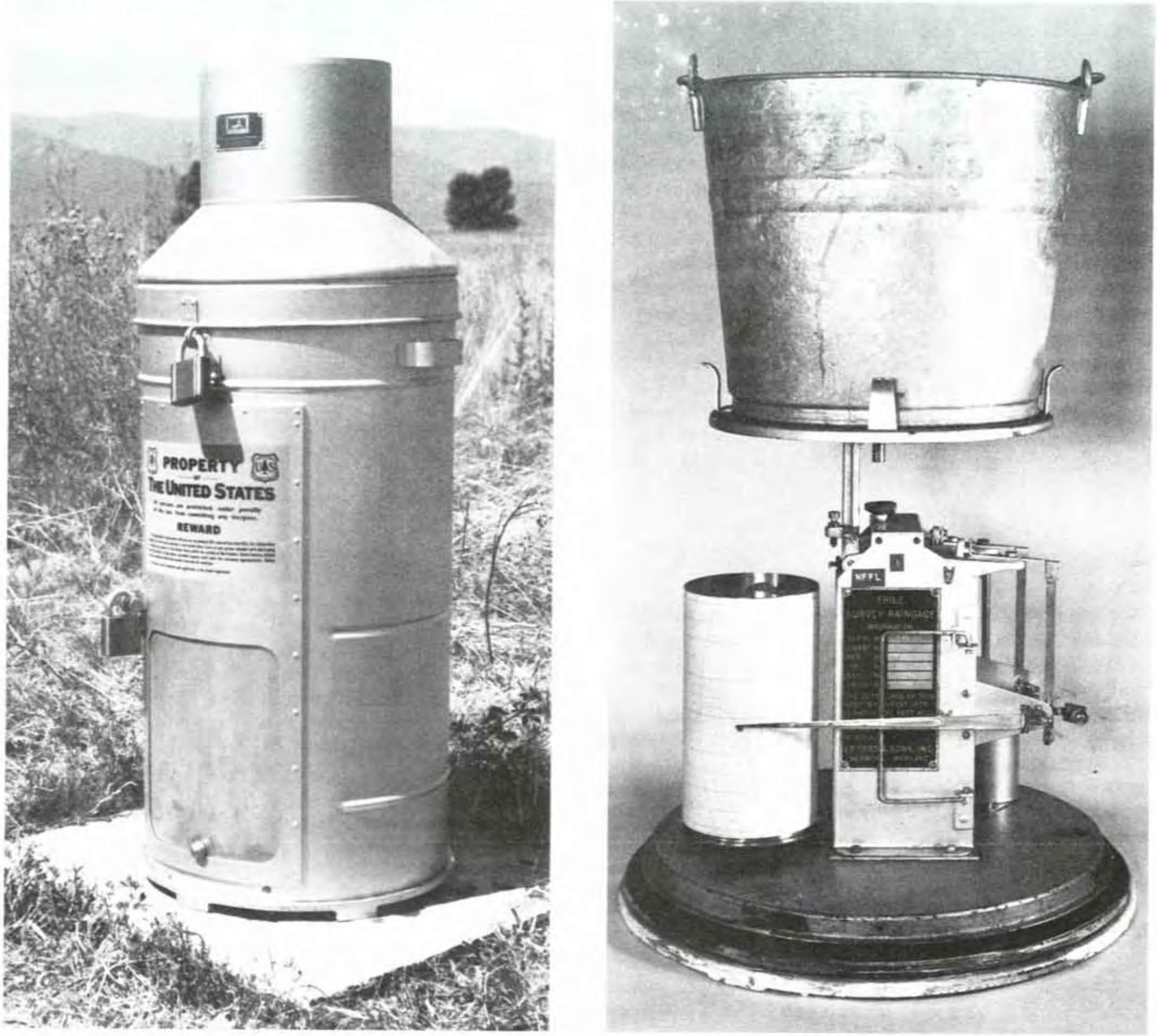


Figure 9.6—Universal weighing-type precipitation gauge: left, assembled gauge; right, weighing and recording mechanisms.

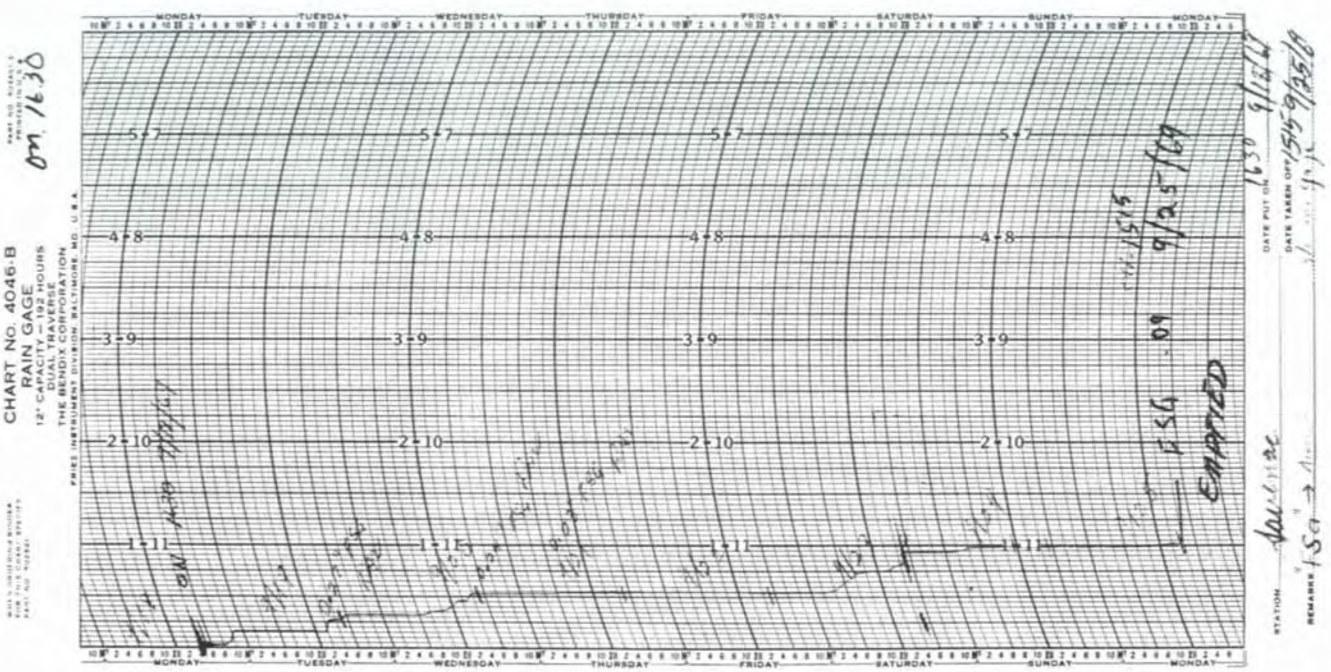


Figure 9.7—Weighing gauge chart record. The first 6 inches of precipitation are recorded on the upper traverse of pen.

PUNCHED-TAPE RECORDER

This type of weighing gauge (fig. 9.8), also known as the Fischer & Porter gauge, has replaced the Universal gauge in the NWS cooperative recording-gauge network. It operates on the same principle as the Universal gauge, though the recording mechanism is quite different. The instrument is electrically powered, usually with a 7½-volt VDC battery. Recording capacity is 20 inches.

The weight of precipitation entering the collector and deposited in a bucket is translated into a binary-decimal code and punched on paper tape. Precipitation is recorded only in 0.1-inch increments, compared with the 0.01-inch resolution that is possible from the Universal weighing gauge.

The punched-tape record can be read visually, translated manually by using a desk reader, or converted to computer inputs. An interval timer controls the frequency of data collection. By changing a cam, the punch or printout interval can be varied between 5 and 60 minutes. At the 5-minute interval, 3 months of record can be obtained from a roll of tape.

With added antenna equipment, data from this gauge can be transmitted via satellite to distant offices requiring real-time information. The NWS, for example, receives such data for hydrological forecasting.

Figure 9.8—Punched-tape recording precipitation gauge, a digitally recording type of weighing gauge.

TIPPING BUCKET GAUGE

Tipping bucket rain gauges are used for remote recording or readout of precipitation amounts, as in an office at manual stations. Such gauges are also widely used in automatic weather station systems. Both 8- and 12-inch-diameter models are available (figs. 9.9 and 9.10).

In these gauges, precipitation is funneled from the collector through a small spout to a tipping-bucket mechanism. This mechanism consists of a pivoted container, or bucket, divided into two compartments, each having a capacity of 0.01 inch precipitation. The compartment under the spout fills to capacity, overbalances the other compartment, and tips the bucket. The tipping action closes a mercury or reed switch, sending an electrical impulse representing 0.01 inch precipitation to the recording unit. As the bucket tips, the second compartment is positioned under the spout, ready to fill and repeat the cycle.

In some models, water from the tipping bucket is emptied into a reservoir for later drainage and stick measurement. In other models, the water drains immediately, giving unlimited recording capacity. As usually supplied, the tipping bucket gauge will not function in the case of snowfall and freezing temperatures. But heated, insulated models (fig. 9.11), with either electric or propane heaters, may be operated down to about –10 to –20 °F.

Several types of recorders can be used with tipping bucket gauges. The most commonly used is the spring-wound or battery-operated, clock-driven event recorder. The chart record shows precipitation by a stepped trace, each step representing 0.01 inch (one tip of the bucket). After 1.00 inch of precipitation has been recorded, the pen returns to the bottom of the chart and starts a new upward cycle. Some event recorders are equipped with a digital counter, which shows total accumulated precipitation at a glance.

Figure 9.9—Tipping bucket rain gauge containing reservoir, with tube for stick measurements; standard NWS design with 12-inch-diameter orifice. (Photo courtesy of Belfort Instrument Company.)

Figure 9.10—Self-draining tipping bucket rain gauge; model with 8-inch-diameter orifice. (Photo courtesy of Sierra-Misco, Inc.)

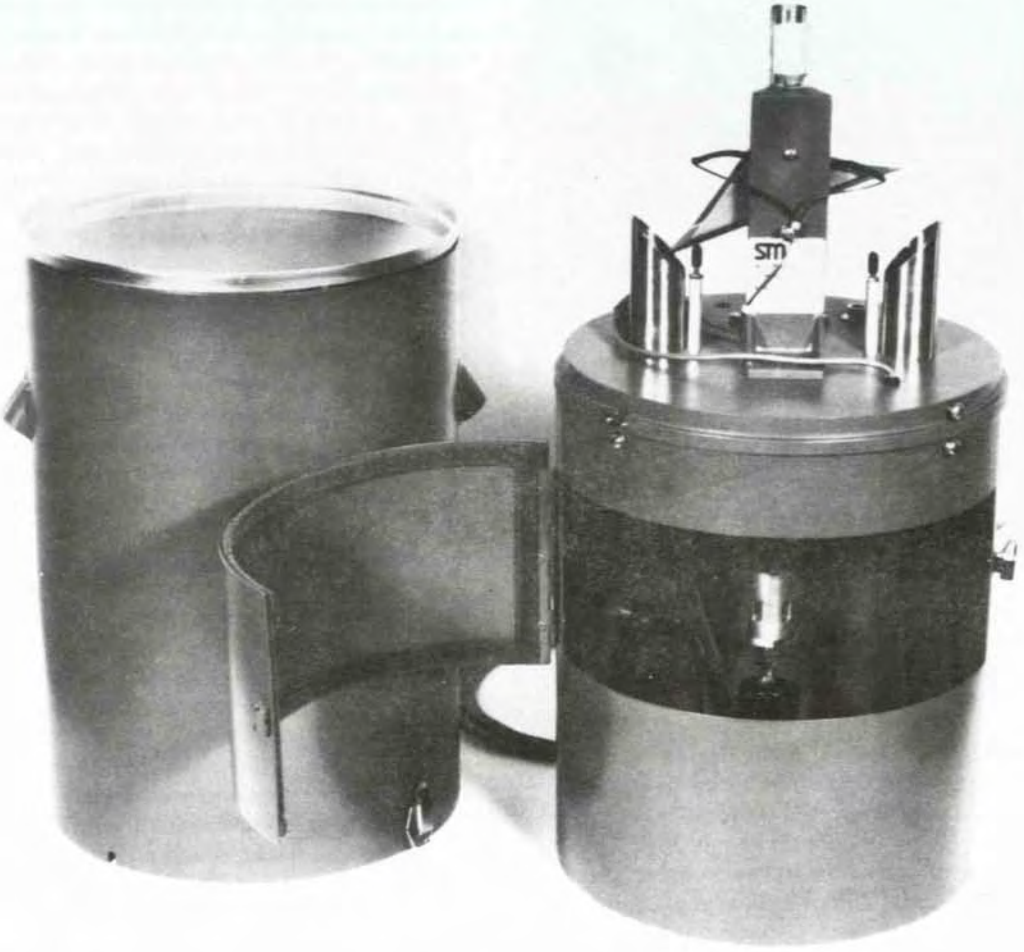


Figure 9.11—Tipping bucket gauge, as in figure 9.10, with propane heater for measurement of both rain and snow (water content). (Photo courtesy of Sierra-Misco, Inc.)

Figure 9.12—Electronic rain gauge, self-draining tipping-bucket type, with digital counter. (Photo courtesty of RainWise Inc.)

Remote-Reading Electronic Rain Gauge—An inexpensive tipping-bucket gauge manufactured by RainWise (fig. 9.12) provides a digital readout on a battery-operated indicator. The gauge, usable only for rain or melting snow, has a standard 8-inch-diameter collector and is self-emptying. The indicator will accumulate rainfall up to 99.99 inches or can be reset for daily readings.

RELIABILITY OF RECORDING RAIN GAUGES

Observers may often encounter differences in catch between a recording rain gauge and a nearby nonrecording gauge. Such differences are, in fact, typical.

Studies by Jones (1969) showed that recording gauges with sloping shoulders below the orifice—such as the Universal gauge—collected 2 to 6 percent less rain than standard nonrecording gauges, which have a straight profile. The slope can induce upward wind currents that carry away some of the raindrops. Larger errors typically occur with snowfall.

In addition, the tipping bucket gauge has characteristics that can produce errors in recorded precipitation. During light rains in warm weather, water can accumulate in the bucket slowly enough to allow losses from evaporation before the bucket is tipped. During intense rainfall, some error will result as water continues to pour into the already filled compartments during the tipping motion. With an actual rainfall rate of 5 in/h, the recorded rate in gauges with a mercury switch may be 5 percent too low (Parsons 1941). The error should be about one-half this in models employing a magnetic reed switch.

9.3 Storage Precipitation Gauges

Storage precipitation gauges are employed in remote, usually mountainous areas, where frequent attendance by an observer is impractical; access is commonly limited by deep snow cover. Many such gauges are read only once or twice per year. Storage gauges at Soil Conservation Service (USDA SCS) snow survey courses, however, are now part of a SNOTEL (snow telemetry) system that provides data on a daily basis, via radio transmissions bounced off ionized trails of meteors (Barton 1977).

Storage gauges are usually mounted on a platform or tower, or are in the form of a standpipe, at a height that maintains the gauge orifice above the location's maximum expected snowpack depth. Clearance of at least 2 ft above the snow surface is advisable. Except at well-sheltered sites, wind shields (section 9.4) are usually installed. Many gauges employ a collector that is tapered toward the top to prevent wet snow from adhering to the inside walls and clogging the orifice. The recommended storage-gauge type and capacity (or dimensions) depend largely on the depth of snow that may accumulate between visits—not on the equivalent water depth—and on the characteristic type of snow that falls (dry snow versus heavy wet snow) (USDA SCS 1972).

Storage gauges are charged with an antifreeze solution. Glycometh—a solution of 40 percent ethylene glycol and 60 percent methyl alcohol—is now preferred over ethylene glycol or calcium chloride (USDA SCS 1972); ethylene glycol has been recommended over calcium chloride (Kidd 1960). Only glycometh, with a specific gravity between that of ice and water, is self-mixing, preventing an ice layer from forming at the top of the solution (diluted by melted snow). When such a layer forms, in other solutions, snow builds up on the ice and, if the gauge has inadequate capacity, the gauge caps over; excess snow may blow away. Particular caution is required, however, in preparing glycometh, as methyl alcohol (methanol) is toxic and flammable; avoid skin contact and inhalation, taking care to protect the eyes with goggles.

The antifreeze charge is covered with a film of light oil such as transformer oil, mineral oil, or refrigerant oil, at least 0.3 inch thick, to prevent loss of water by evaporation. Light motor oil such as SAE 10 has been found unsatisfactory at low temperatures (Farnes 1988).

Gauges with an orifice 12 inches in diameter are recommended over those with an 8-inch orifice in areas where heavy wet snow is likely to bridge the smaller orifice. Heat absorption for melting snow buildups can be increased by painting the outside of the gauge with flat black or brown paint.

TYPES OF STORAGE GAUGES

Storage gauges most commonly used in the United States fall into two general categories, having either constant diameter or variable diameter, and these comprise four basic designs: the Sacramento gauge (which has a truncated cone shape), the straight-sided can, the can-cone (straight-sided can with truncated cone top), and the standpipe. The first three gauges are mounted on towers (USDA SCS 1972), while the standpipe gauge rises from its base at the ground. Most of the gauges are equipped

Figure 9.13—Sacramento storage precipitation gauge.

with a drain cock to release their contents for weighout measurement of the seasonal precipitation. Interim measurements of the precipitation catch are made by stick or tape readings inside the gauge.

The Sacramento gauge (fig. 9.13) usually has an 8-inch orifice. Its conical shape increases the gauge's capacity to well above that of a straight-sided gauge of equal height. Capacity is typically 100 or 200 inches liquid (water plus antifreeze charge).

Straight-sided cans are usually 8 inches in diameter and either 24 or 42 inches in length. Their relatively low capacity makes them suited mainly for drier locations or for locations that can be visited often (for example, at monthly intervals). The shorter can is not equipped with a drain.

The can-cone gauge (fig. 9.14) usually has a 12-inch-diameter can, with the cone on top reducing the orifice to a diameter of 8 inches. Capacity is thus somewhat greater than that of a straight-sided can of equal height.

The standpipe gauge (fig. 9.15) has in the past been constructed from 5-ft sections of 12-inch-diameter thin-walled pipe, commonly 10-gauge steel. A one-piece aluminum standpipe gauge is now favored by the Soil Conservation Service at its SNOTEL stations. A truncated cone 18 inches long, forming the top of the traditional standpipe gauge, reduces the orifice to a diameter of 8 inches. The SNOTEL standpipe gauges have a 12-inch diameter throughout, including the orifice.

A modified standpipe gauge described by DeByle and Haupt (1965) consisted of a 40-inch-tall, 12-inch-diameter tank of 12-gauge or heavier steel, together with a truncated cone top section, mounted on a single 3½-inch support pipe. This gauge was recommended as a rugged, vandalproof gauge suitable for sites receiving 60 inches or less precipitation during the storage season. Standpipe gauges may also be fashioned from PVC pipe used in sewer lines (Farnes 1988).

9.4 Wind Shields

Precipitation gauges are sometimes installed in locations where wind effects, reducing the gauge catch, cannot be minimized by site-selection efforts (section 18.1). In such cases, use of a wind shield may be advisable, particularly at stations subject to much snowfall.

Two types of shield have had wide use in the United States: (1) the Nipher shield, a flared metal device that attaches to the precipitation gauge, and (2) the Alter type

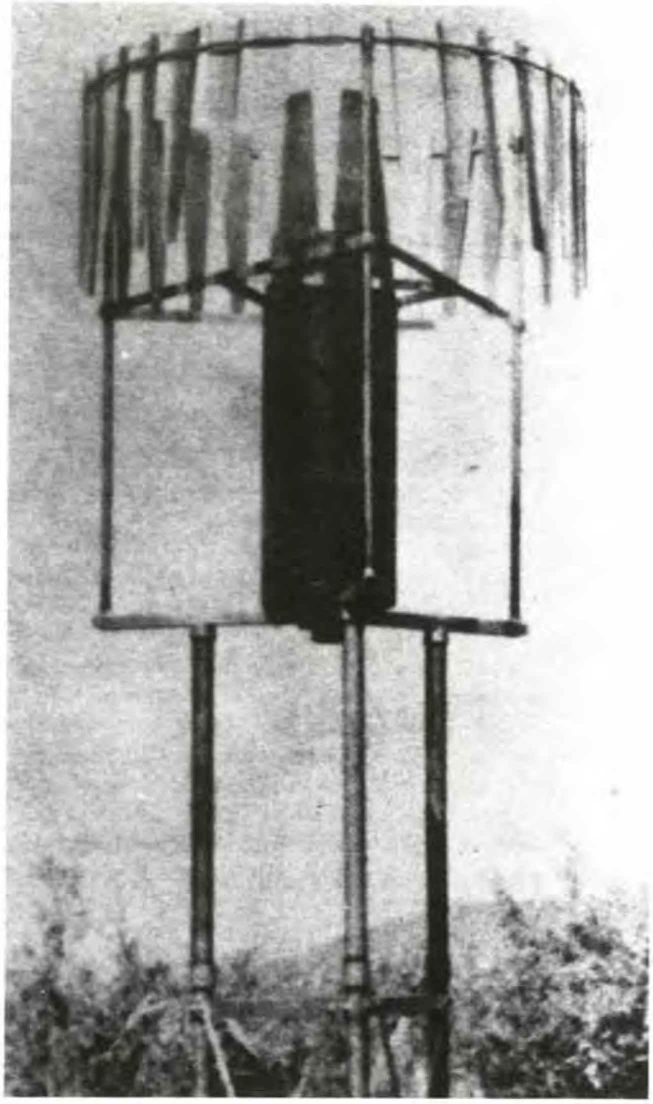


Figure 9.14—Can-cone storage precipitation gauge, with Alter wind shield. (Photo from USDA SCS 1972.)

Figure 9.15—Standpipe storage precipitation gauge, with Alter shield. (Photo from National Weather Service.)

(figs. 9.15 and 9.16), which consists of 32 free-swinging galvanized metal leaves, or baffles, attached to a steel ring 4 ft in diameter. At ground level, the Alter shield is supported on three or four galvanized pipe legs installed around the precipitation gauge. In the standard design, with four support pipes, one of the shield quadrants is hinged and swings outward for easy access to the gauge.

Although deficiencies in precipitation catch may still be large at very windy sites, overall both types of shield can greatly improve the catch. At gauges that are not frequently attended, however, snow can often build up on the Nipher shield and bridge the gauge orifice. The Alter shield has thus become the standard shield in the United States for storage and other gauges. Nevertheless, heavy wet snow can also cause buildup problems with the Alter shield, particularly when the shield is used with the sloping-walled Sacramento storage gauge (Garstka and others 1958). In this regard, the present Alter shield configuration (figs. 9.15 and 9.16) is an improvement over the previous configuration, which had angled, constrained baffles (fig. 9.17).

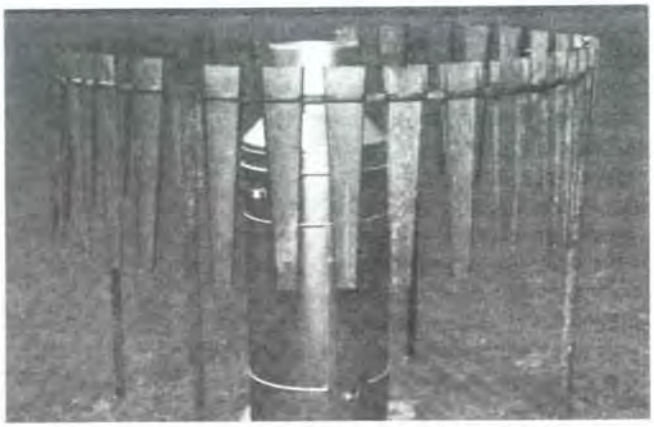


Figure 9.16—Alter wind shield, installed around weighing gauge.

The use of wind shields at fire-weather stations would improve the accuracy of precipitation data, particularly at openly exposed, windy locations. As indicated earlier, however, their main benefit occurs during the snow season (Brown and Peck 1962).

9.5 Snowfall and Snow Depth Indicators

SNOWFALL

Snowfall is the depth of new snow that has fallen and accumulated during the measurement period (usually 24 hours); it is recorded in inches and tenths. The snowfall water content is also measured, as described later. Although snowfall is collected in the standard 8-inch precipitation gauge (with only the open, outer can exposed), its depth is ordinarily measured outside the gauge on nearby ground—on a short grassy surface away from pavements, buildings, and trees. The rain gauge measuring stick is commonly used for this purpose, but sturdier sticks are advised where the snow has become deep or crusty.

Snow Boards—Snow boards provide a cleared surface for determining new snow accumulation (and its water content). They can be particularly convenient where snow often falls on previous snow cover that has not formed a distinguishable, harder surface (or crust). A snow board is made of thin, white-painted wood or plastic. It should be about 2 ft square, with the surface somewhat rough or covered with a layer of white cotton flannel. In use, the board is set flush with the existing snow surface; a stick with red-painted top is inserted nearby to mark the board location.

The board should be set in a location that usually has representative snowfall accumulation and is also sheltered from the wind. Otherwise, snow could blow off or drift onto the board, making it unreliable for measurements.

Figure 9.17—Snow buildup that may occur between Alter shield and sloping wall of Sacramento storage gauge, particularly with shield of previously used configuration (see text). (Photo from National Weather Service.)

SNOW DEPTH

Snow depth, as distinguished from snowfall, is the total snow (and ice) cover on the ground. This may include the contribution of many individual snowfalls, or it may be derived entirely from a single snowfall, past or present. The depth is recorded to the nearest whole inch; its water content may also be measured, as described later.

Snow depth measurements should be made over a representative grass surface. The rain gauge measuring stick will often be adequate if handled carefully, but deeper and coarser snow will require a longer and stronger stick. A stick with a sharp metal end may be necessary to break through ice layers near the snow-ground interface. The snow depth is read in several sampling spots to obtain an average value.

Snow Stakes—Snow stakes provide the simplest means of measuring snow depth in areas of deep snow accumulation. Recommended stakes (U.S. Department of Commerce 1972) are made from wood $1^3/_4$ inches square, of appropriate length, and painted white to minimize undue melting of the immediately surrounding snow. The entire length is graduated at 1-inch intervals, using small black edge markings and numerals. Stakes are usually anchored against the ground surface with angle iron supports. Location should be at a carefully selected, representative site that allows easy reading from a distance if necessary. Where a single snow stake is not consistently representative, several stakes should be installed and an average depth taken.

Snow Sampling Tubes—Snowpack depth and water content may also be measured with sampling tubes and a spring scale. The federal snow sampler, widely used in the Western United States, consists of 30-inch sections of duraluminum tube with an inside diameter of $1^{11}/_{16}$ inches. A steel cutter bit is fitted to the bottom section. Measurements, usually taken monthly or semimonthly along marked snow courses for water supply forecasts, are outside the scope of this handbook. These measurements are described in detail by the USDA Soil Conservation Service (1972). Snow pillows, which automatically record the snowpack water content, are also described.

9.6 Supplemental Information

In addition to the amount of precipitation that is measured, the following supplemental information is part of a complete precipitation record, such as that required for fire-weather observations (Deeming and others 1977):

1. Kind of precipitation.
2. Time precipitation began.
3. Time precipitation ended.
4. Duration of precipitation.

KIND OF PRECIPITATION

The kind of precipitation specifies whether it was rain, drizzle, snow, ice pellets (sleet), or hail. Further distinctions include freezing rain and drizzle (glaze), and also snow pellets and snow grains (U.S. Department of Commerce 1972). This information is often entered in coded form.

TIME PRECIPITATION BEGAN AND ENDED

The beginning and ending times of each continuous precipitation occurrence should be noted, to the nearest half hour if possible. A recording rain gauge, either the Universal or tipping bucket type, is a ready source for this information (except when amounts are less than 0.01 inch).

DURATION

The duration of precipitation is the elapsed time from beginning to ending of each occurrence. Usually, the sum of the elapsed times for all occurrences during the reporting period is entered. Just 1-hour total duration, however, is recorded in fire-weather observations when only trace amounts of precipitation (amounts less than 0.01 inch) have occurred.

CHAPTER 10. FUEL MOISTURE

10.1 Fuel Moisture Sticks

Since Gisborne (1933) first developed the idea in 1924, fuel moisture indicator sticks have been widely used to estimate the moisture content of small-diameter (10-hour timelag) forest fuels. A fuel moisture indicator stick is ". . . a specially prepared stick or set of sticks of known dry weight continuously exposed to the weather and periodically weighed to determine changes in moisture content as an indication of moisture changes in forest fuels" (Society of American Foresters 1958).

Unlike conventional weather instruments, indicator sticks do not measure any single weather variable but, rather, they ". . . measure the net effect of climatic factors affecting flammability in terms of the most significant item, the fuel itself" (Davis 1959). For this reason, the practice of using fuel moisture indicator sticks is common at fire-weather stations, both in conjunction with fire-danger rating systems and prescribed burning operations. Also, in some areas the fuel moisture stick readings during critically dry periods serve as a basis for initiating fire protection measures, such as restrictions on logging operations, camping, and open burning.

STANDARD FUEL MOISTURE STICK

A standard fuel moisture indicator stick consists of four $\frac{1}{2}$-inch ponderosa pine sapwood dowels space one-fourth inch apart on two $\frac{5}{16}$-inch-diameter hardwood pins. The dowels are held in place on the pins by wire brads at each intersection. The resulting stick (fig. 10.1) is $2\frac{3}{4}$ inches wide, about 20 inches long, and has an ovendry weight of 100 grams. A screw hook is inserted in the end of one of the dowels, and the notation, "This end NORTH, this side up," is stamped on the dowel surface just below the screw hook (Hardy 1953).

The wooden fuel moisture stick has several shortcomings as a fuel moisture analog (Fosberg 1971). Specifically:

1. The response characteristics of wood are highly variable. Dowels cut from the same board will sometimes give different fuel moisture values when exposed side by side in the same environment.
2. Exposure and aging will change both the response characteristics and the calibration of a wooden stick. Discoloration with age changes the radiation characteristics of the stick. If the dowels check and split, as they often will, more surface area is exposed to the air and the calibration of the stick is changed. The actual weight or mass of the stick can be reduced if splitting and checking are severe.

Efforts to develop an improved, more consistent analog for indicating fuel moisture, utilizing inorganic material, have, at present, been unsuccessful. Thus, the NFDRS 10-hour fuel moisture continues to be estimated with the wooden sticks at manual fire-weather stations. Corrections for aging changes in these sticks (Haines and Frost 1978) are, however, incorporated in the NFDRS (Deeming and others 1977). As a further step, these corrections are now adjusted, based on NFDRS climate class. For example (Harrington 1983), the weathering rate (average monthly weight loss) of fuel moisture sticks in a dry Southwest climate is about one-half that in a wet climate.

Figure 10.1—Standard fuel moisture stick, consisting of $\frac{1}{2}$-inch ponderosa pine dowels, and wire mounting rack (two rack sections are required for installation).

10.2 Fuel Moisture Scales

Using a properly exposed stick, analog fuel moisture is measured by weighing the stick on a suitable scale. The fuel moisture is represented by the stick weight in excess of ovendry weight (100 grams for a set of $\frac{1}{2}$-inch ponderosa pine dowels). Several scales in common use at fire-weather stations are described below. These include scales designed specifically to weigh fuel moisture sticks, either at permanent stations or in the field. Such scales are recommended over the laboratory balances.

THE FORESTER FUEL MOISTURE SCALE

This scale (fig. 10.2), traditionally known as the Appalachian Fuel Moisture Scale, is recommended as the standard scale at permanent stations. It was designed by Byram (1940)—originally for weighing basswood slats, which were similar in purpose to the present fuel moisture stick but had variable ovendry weights. The scale consists of a pivoted balance arm mounted on a 10- by 10-inch metal back. A sliding weight on the arm is used to adjust the scale for the ovendry weight of the stick. When weighed, the stick is hung on a small hook

Figure 10.2—Forester (Appalachian) fuel moisture scale mounted in Appalachian scale shelter.

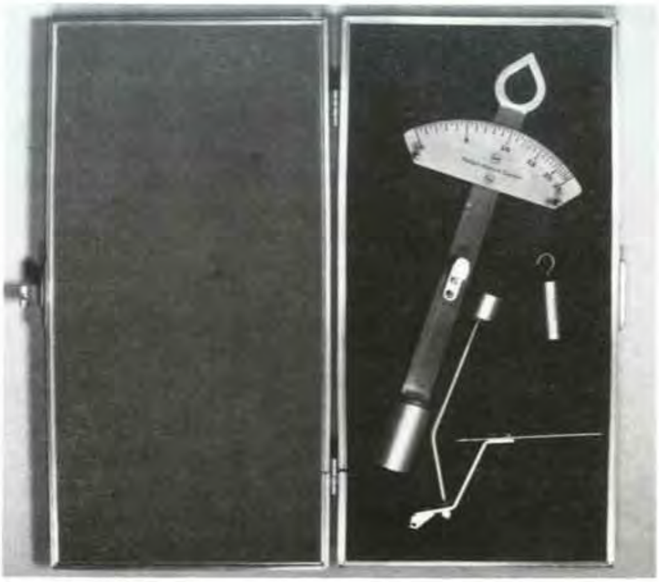


Figure 10.3—Forester (Chisholm) portable fuel moisture scale.

at the left end of the balance arm. The pointed right end of the balance arm indicates the analog moisture content on a curved scale graduated from 0 to 50 percent. A standard 100-gram weight is provided to level and zero the scale.

Appalachian Shelter—The Forester scale should be mounted in a specially designed shelter known as the Appalachian shelter. This shelter (Barney 1962) facilitates correct leveling of the scale and also the weighing process (affording protection from moisture and wind). It provides leveling adjustment in two planes, adequate space, and ample viewing through a large window in the door (fig. 10.2). Construction details are shown in appendix 5.

FORESTER PORTABLE FUEL MOISTURE SCALE

The Forester portable scale (fig. 10.3), also known as the Chisholm Portable Fuel Moisture Scale, operates in the same manner as the previously described Forester (Appalachian) scale, except that it has no adjustment for a range of ovendry weights. It is calibrated for weighing the standard 100-gram ponderosa pine stick. Although the Forester portable scale can be hand held, it is much easier to use when hung on a post, tree, truck, or similar support. A 100-gram test weight is provided with the scale.

WILLIAMS POCKET FIRESTICK MOISTURE SCALE

The Williams scale (fig. 10.4) is a portable, accurate, and durable scale. Measuring 1½ inches in diameter and less than 5 inches long, it weighs only 14 ounces. Its case weighs 100 grams and doubles as a calibration weight. Micrometer graduations are read as direct percentages of the amount of moisture in 100 grams of wood; the upper limit is 25 percent. Scale sensitivity is one-fourth gram.

TRIPLE BEAM AND HARVARD BALANCES

These are standard laboratory balances. The triple beam balance (fig. 10.5) has a single pan; the Harvard balance (fig. 10.6), a double pan. Fuel stick weight is read from the scales after balance has been achieved.

When used at fire-weather stations, triple beam and Harvard balances are installed in a scale shelter similar to that shown in figure 10.7. It is important that the shelter is watertight, firmly mounted, and exactly level and plumb.

Figure 10.4—Williams pocket scale: left, assembled for storage; right, assembled for use.

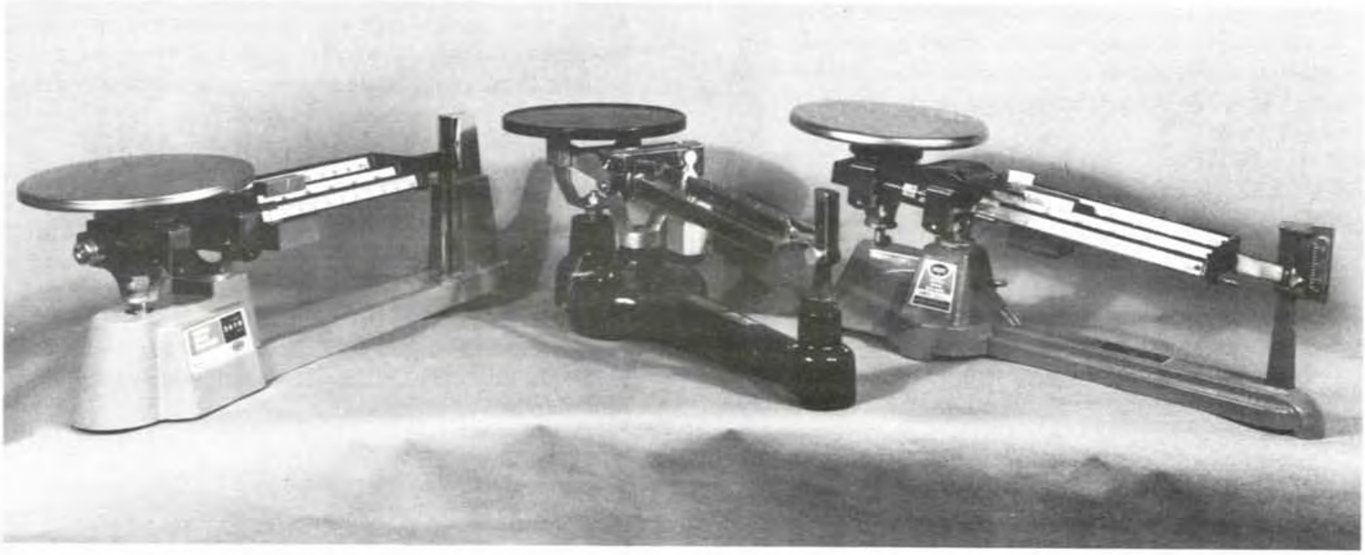


Figure 10.5—Triple beam balance, three models.

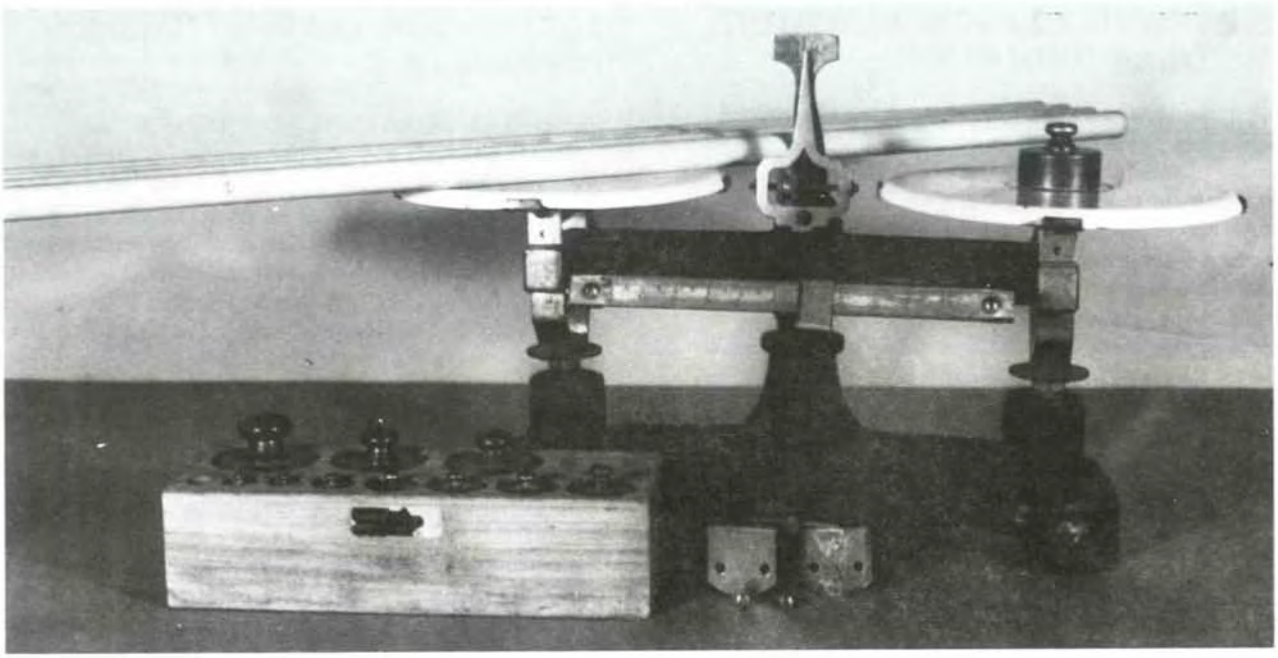


Figure 10.6—Harvard balance.

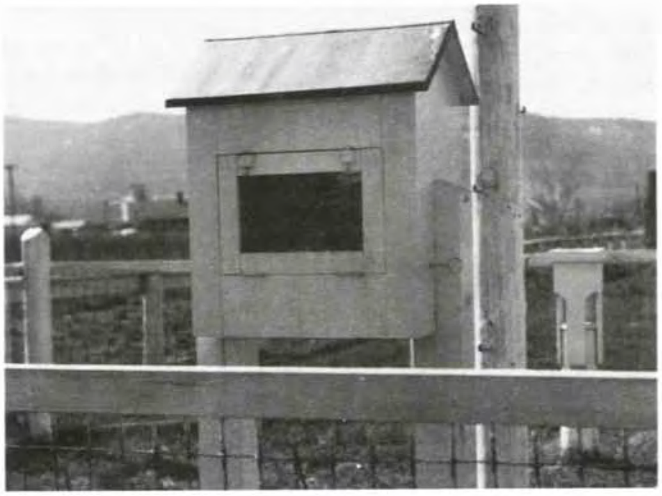


Figure 10.7—Scale shelter for triple beam balance or Harvard balance.

CHAPTER 11. CLOUDS, SUNSHINE, AND SOLAR RADIATION

The amounts of solar radiation reaching the ground or vegetative cover have an important influence on fuel moisture. Depending on the time of season and available moisture, solar energy can promote both growth and drying. The amount of cloud cover (or state of weather), as routinely observed at fire-weather stations, serves largely as an indicator of solar radiation and related changes in fuel moisture.

Relatively few weather stations in the United States routinely measure incoming solar radiation (or other radiation parameters). Only a few hundred, mostly National Weather Service airport stations, measure sunshine duration, which is a better indicator of the radiation received than is the amount of cloud cover. Observations at fire-weather stations do not distinguish between low, opaque clouds and the higher, thin types through which greater solar radiation can pass.

11.1 Clouds

Unlike the other weather and environmental measurements covered in this handbook, the cloud observations are visual, employing no instruments.

CLOUD FORMS

Details concerning cloud types, or forms, are helpful for various purposes. This is particularly true with clouds that have vertical development, because of their importance as potential lightning producers. These clouds, and "stratiform" types, also serve as indicators of atmospheric stability or instability.

A cloud is a visible aggregate of water or ice particles, or both, that is based above the ground surface (such an aggregate lying on the surface is known as fog). Clouds, varying greatly in their origin and appearance, have been classified into certain basic, characteristic forms. The "International System" for cloud classification lists 10 major cloud forms (genera) within three height classes (families), together with recognized species and subspecies.

A simplified cloud classification is presented in figure A3.1, appendix 3. Some clouds forms are illustrated in figures A3.2 through A3.10, appendix 3.

CLOUD COVER

Cloud cover refers to the fraction of the sky (in tenths) that is covered by clouds or obscured by phenomena such as fog or smoke. The following cloud cover classification, together with code numbers, is used in fire-weather observations (Deeming and others 1977):

Clear (code 0)—Cloud cover less than $^1/_{10}$.
Scattered clouds (code 1)—Cloud cover $^1/_{10}$ to $^5/_{10}$.
Broken clouds (code 2)—Cloud cover $^6/_{10}$ to $^9/_{10}$.
Overcast (code 3)—Cloud cover more than $^9/_{10}$ (completely overcast or overcast with small breaks).
Obscured by fog (code 4).

11.2 Sunshine and Solar Radiation Instruments

SUNSHINE DURATION RECORDERS

Two main types of sunshine duration recorders are in use in the United States: (1) the Campbell-Stokes recorder, which focuses radiation from the sun to burn a trace in a card, and (2) the Foster photoelectric sunshine switch, a remote recording instrument used at primary (airport) stations of the National Weather Service. The Foster sunshine switch (Foster and Foskett 1953) is a successor to the Marvin electrical sunshine recorder (Middleton and Spilhaus 1953; World Meteorological Organization 1971). The Foster instrument consists of a pair of electrically connected selenium photocells, one exposed to direct sunshine and the other shielded; direct radiation produces a signal that activates a recorder or counter.

Sensitivity differs between these two instruments and thus their recorded sunshine durations are not comparable. Only the Foster switch allows reliable measurements when the sun is near the horizon (near sunrise and sunset). The Campbell-Stokes recorder, however, may more closely measure the duration of "bright" sunshine. It is more commercially available and is relatively simple in operation, acting as a sundial. A disadvantage of the Campbell-Stokes recorder is the variation of its sensitivity threshold (Mazzarella 1985). Sunshine recorders require very careful installation and adjustment to minimize errors (chapter 20).

Campbell-Stokes Sunshine Recorder—The Campbell-Stokes sunshine recorder (fig. 11.1) consists basically of a "glass sphere about 4 inches in diameter mounted concentrically in a section of a spherical bowl, the diameter of which is such that the sun's rays are focused sharply on a card held in grooves in the bowl" (World Meteorological Organization 1983). Three different cards are used during the year—for defined summer, winter, and equinoctial periods. The radiant heat of the sun, concentrated by the sphere, burns a track in the card; the cards are graduated in $^1/_2$-hour increments. The width and depth of the burn depend on the sun's brightness. Specific rules are provided for evaluating the traces (above reference). Precautions must be taken in cold weather to keep the sphere free of frost or snow. This can be accomplished by use of a heating element and fan or the application of deicing fluid.

PYRANOMETERS

There are various types of instruments available for measuring solar radiation (Fritschen and Gay 1979; Szeicz 1975). The type most often employed for general climatological and weather monitoring purposes is termed a pyranometer. Such an instrument measures the total, or global, radiation (both the direct beam radiation and the diffuse, or sky radiation) received on a horizontal surface. The sensor usually employs a thermopile (a series of very closely spaced differential thermocouples) or, in less expensive and less precise models, a silicon photovoltaic cell.

Figure 11.1—Campbell-Stokes sunshine recorder. (Photo courtesy of Qualimetrics, Inc.)

Figure 11.2—Black and white pyranometers: Eppley model (top, photo courtesy of Sierra-Misco, Inc.); star pyranometer (bottom, photo courtesy of Qualimetrics, Inc.).

Eppley Pyranometer—One of the most precise pyranometers, adopted as a standard reference instrument in the United States, is the Eppley black and white pyranometer (fig. 11.2, top). (A similar instrument is shown in figure 11.2, bottom.) Its glass cover, or dome, is transparent to most of the solar radiation spectrum. The black and white areas, differing greatly in their absorption or reflection of radiation, develop a temperature difference that increases with radiation intensity. This difference, sensed by the thermopile, produces an output voltage proportional to the radiation. Instrument response time for a 66 percent change in radiation is 3 to 4 seconds. The output, converted to radiation units, can be read either from a strip chart recorder or an electronic integrator that displays or prints the cumulative count between settings.

Bimetallic Pyranograph—The bimellatic recording pyranometer, or pyranograph (fig. 11.3), is a relatively simple, self-contained and mechanically operated instrument. Also termed an actinograph, it is slower responding and less precise than either the thermopile or silicon-cell pyranometer. Its dome transmits about 90 percent of the solar radiation within a somewhat restricted spectrum. Radiation intensity is measured by the temperature difference between black and white bimetallic strips. The recording chart is fastened to a rotating drum, as in a hygrothermograph (section 7.7). Overall accuracy is within 5 to 10 percent.

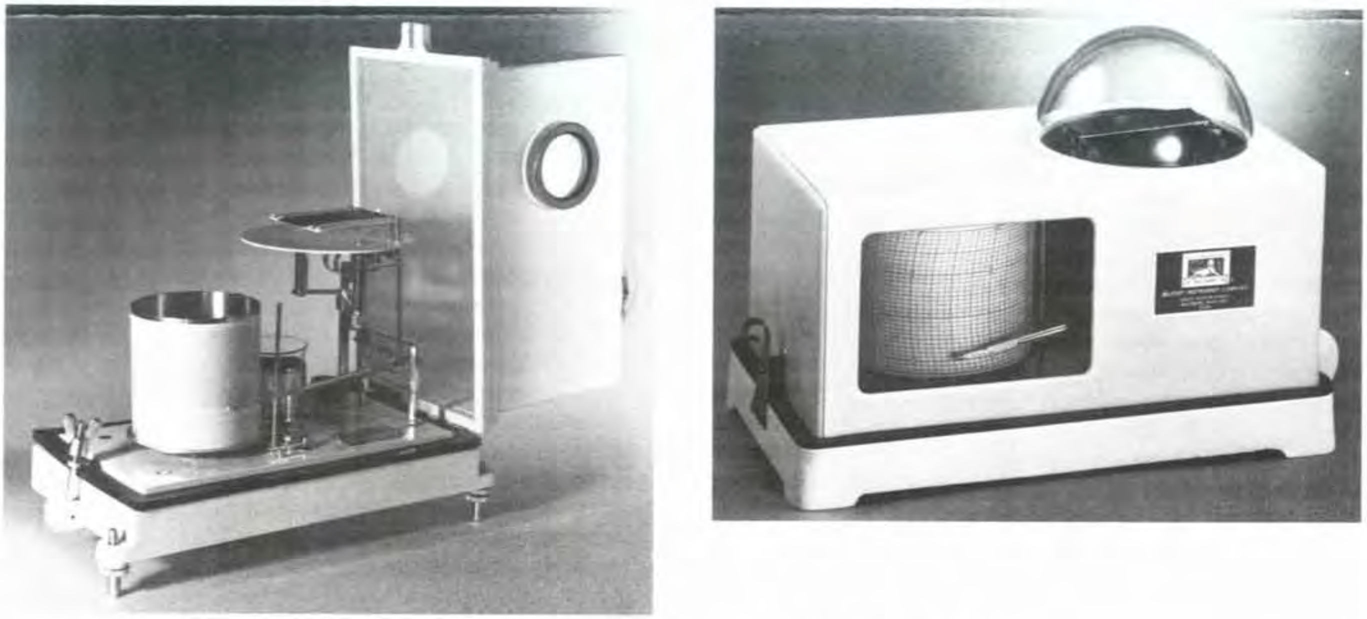


Figure 11.3—Bimetallic pyranograph, two models. (Photos courtesy of Qualimetrics, Inc., left, and Belfort Instrument Company, right.)

CHAPTER 12. EVAPORATION

Measurements of evaporation provide an estimate or index of the actual evaporation from free water surfaces and the soil. The measurements may also indicate the potential water use (transpiration) by vegetation. The amount of evaporation, given the available water, integrates the effects of variables such as solar radiation, air and water surface temperatures, relative humidity, and windspeed.

12.1 Evaporation Pans

The most widely used evaporation indicator in the United States is a large pan filled with water. Observations measure the change in water-surface level, correcting for precipitation. Some pans are sunken (installed below ground level) or mounted on anchored floating platforms on lakes, but the most practical exposure is at a small height above ground (World Meteorological Organization 1983). The aboveground exposure allows some objectionable boundary effects, however, such as radiation on the side walls and heat exchanges with the pan material. These effects tend to increase the evaporation. The measured amounts are thus multiplied by a coefficent, such as 0.70 or 0.80, to more closely estimate the evaporation from naturally existing surfaces. The standard pan in the United States, mounted aboveground, is termed the "Class A" evaporation pan.

12.2 Evaporation Station Equipment

Standard, daily measurements at evaporation stations in the United States include (1) the 24-hour evaporation from a Class A evaporation pan, (2) precipitation (for which the pan water level reading is adjusted to obtain the actual evaporation), (3) wind movement near the rim of the pan, and (4) maximum and minimum water temperatures in the pan. Soil temperatures may also be measured (chapter 13).

CLASS A EVAPORATION PAN AND ACCESSORIES

The standard Class A evaporation pan (fig. 12.1) is constructed of noncorrosive metal—galvanized iron,

Figure 12.1—Class A evaporation pan on wooden support, with installed accessory equipment: stilling well (containing fixed-point gauge), submerged-mount Six's thermometer, and totalizing anemometer. (Photo from National Weather Service.)

Figure 12.2—Stilling well with hook gauge installed; leveling screws in base plate. (Photo from U.S. Department of Commerce 1972.)

stainless steel, copper, or Monel—and normally left unpainted. It is cylindrical, with an inside depth of 10 inches and diameter of 47½ inches. It is supported on an open wooden frame, constructed of 2- by 4-inch or heavier lumber that is either rot resistant or treated with a wood preservative. The pan is filled with water to a depth of 8 inches (2 inches below the rim). The water-surface level is measured by either a hook gauge or fixed-point gauge supported or mounted in a stilling well. The well provides a water surface that is undisturbed by possible ripples. Changes in water level between observations, adjusted for precipitation, represent the evaporation.

Stilling Well for Hook Gauge—The stilling well used with the hook gauge (fig. 12.2) consists of a cylinder made of brass, Monel, or other noncorrosive metal. To minimize electrolytic action, the metal should be the same as that used in the pan. The cylinder is about 9 inches high and 3½ inches in outside diameter. It is mounted on a triangular or three-legged base plate of the same material, resting on the bottom of the evaporation pan. The top of the stilling well is leveled by three screws provided in the base plate. A small tube or pipe through the center of the base plate allows only slow movement of water to and from the well, thus preventing possible rippling of the water surface within the well.

Hook Gauge—The hook gauge (fig. 12.3), also termed a micrometer hook gauge, can measure changes in the pan water level to the nearest thousandth of an inch, but actual observations are recorded to the nearest hundredth of an inch. The gauge consists of a hook in the end of a stem that is graduated to tenths of inches over a range of several inches. A three-legged "spider" and adjusting-nut assembly supports the hook inside the stilling well and provides for height adjustment of the hook to measure the water level (U.S. Department of Commerce 1972). A circular hundredths scale is situated within the spider.

Fixed-Point Gauge—The fixed-point gauge (fig. 12.4) consists of a pointed ⅛-inch rod affixed within a stilling well to the center of the base. The tip is located 7½ inches above the bottom of the pan (2½ inches below the rim). Two small openings in opposite sides of the well, near the base, allow movement of water to or from the well while preventing possible rippling of the surface.

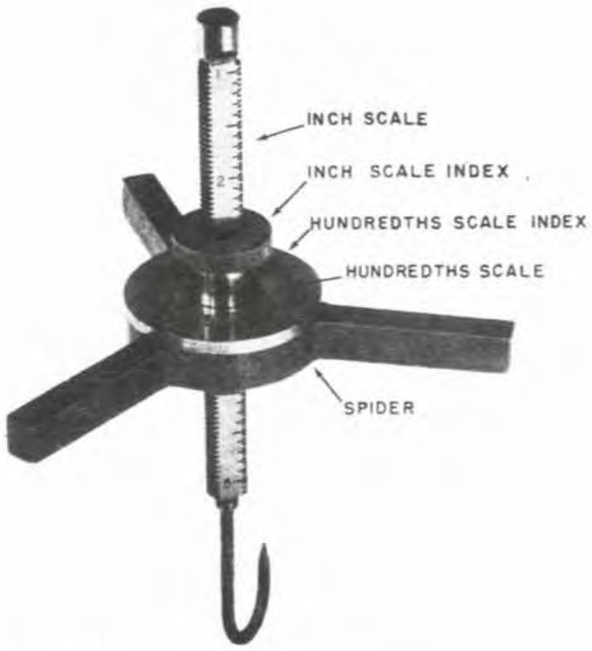


Figure 12.3—Detailed view of hook gauge, showing a reading of 2.53 inches. (Photo from U.S. Department of Commerce 1972.)

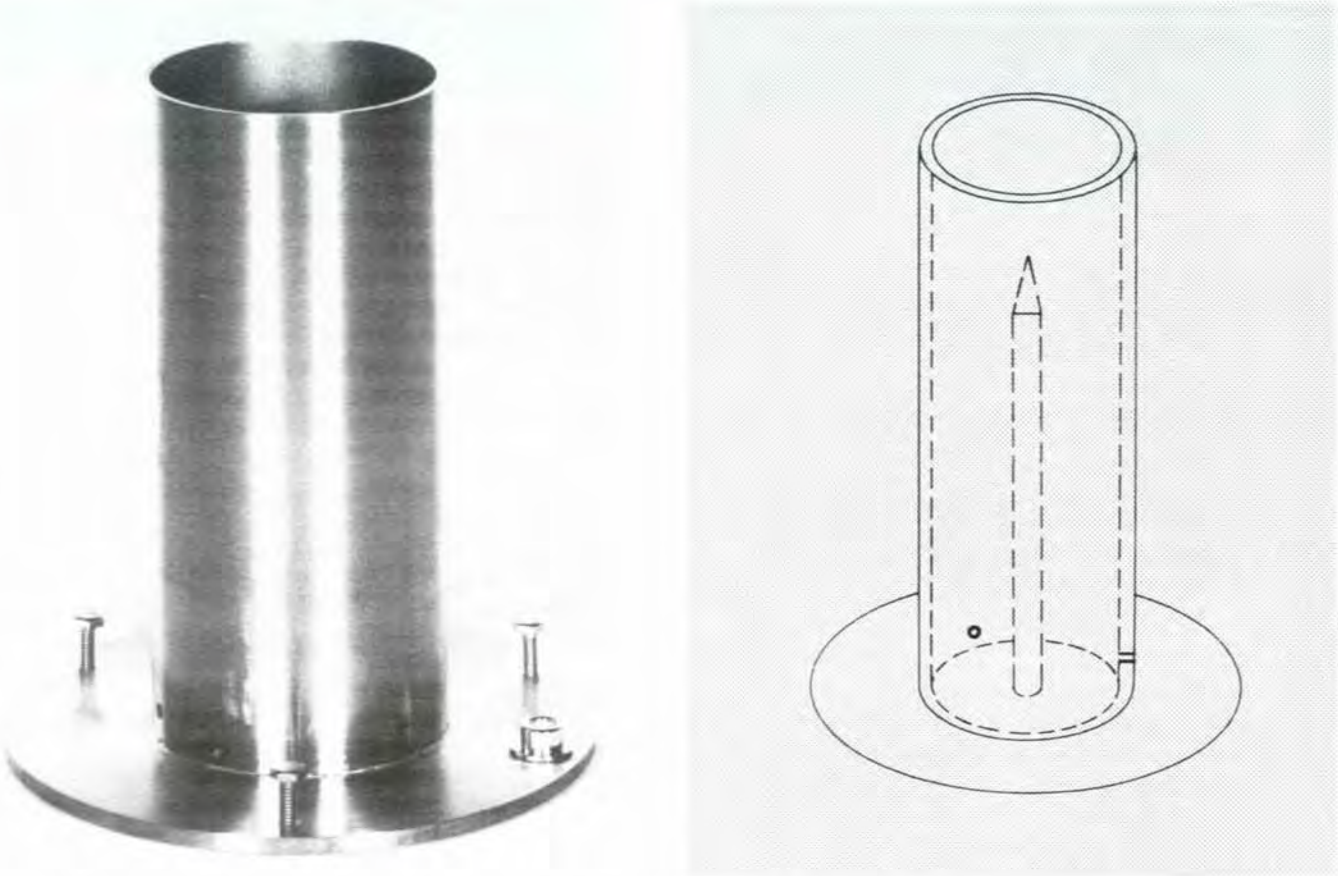


Figure 12.4—Stilling well for fixed-point gauge (photo courtesy of Sierra-Misco, Inc.); the gauge is affixed inside, as shown in drawing at right (from U.S. Department of Commerce 1972).

A transparent plastic measuring tube (fig. 12.5) is used to add or remove water at each observation until the water surface coincides with the tip of the fixed point. The tube is 15 inches deep and has a cross sectional area one hundredth that of the evaporation pan; the inside diameter, thus, will be 4.75 inches for a 47.5-inch pan. Graduations on the tube are at 1-inch intervals, corresponding to 0.01-inch increments of water level in the pan.

Water Storage Tank—At stations some distance from a water source, a water storage tank at the site will provide a convenient supply of water for refilling the evaporation pan. Tank capacity should be at least 30 gallons. In the absence of rainfall, this amount will last only 2 weeks during a month with 8 inches evaporation. The water placed in the tank should be free of oil.

SUPPLEMENTAL INSTRUMENTS

Precipitation Gauge—The basic precipitation gauge used at an evaporation station is the standard, large-capacity, 8-inch nonrecording gauge. A Universal recording (weighing) gauge may be added. These two gauges have been described in sections 9.1 and 9.2.

Pan-Level Totalizing Anemometer—The anemometer for measuring wind movement over the evaporation pan is mounted on the wooden pan support, with the center of the cups about 6 to 8 inches above the rim of the pan. A 3-cup contacting anemometer is usually employed; it has both 1-mile and 1/10- or 1/60-mile contacts and self-contained readout, as previously described in section 8.2 (fig. 8.5). Most widely used among these anemometers is the 5-digit odometer type, which is replacing the older, circular-dial type.

Water Temperature Thermometer—Maximum and minimum pan-water temperatures are usually measured with a Six's thermometer (section 7.4); however, a recording thermometer (such as an electrical resistance or mercury-in-steel type) having a sensing element suitable for immersion in water may also be used (U.S. Department of Commerce 1972). The recommended Six's model has its scale markings on the glass tube; the range is from +20 to 110 °F, in 1-°F divisions. The thermometer is provided with a white, reflective shield over its bulb for protection and shading. Two types of mount have been employed—a float mount and a submerged mount (fig. 12.6), with the submerged mount now favored by the National Weather Service.

In the float mount, the thermometer is mounted horizontally on a plastic (acrylic) frame supported by a float at each end. The thermometer rides about one-fourth inch

Figure 12.5—Plastic measuring tube used with fixed-point gauge. (Photo courtesy of Sierra-Misco, Inc.)

below the water surface. Flexible lines of proper length are attached between the two floats and an anchor to keep the thermometer in place, 1 ft from the edge of the pan and the stilling well.

In the submerged mount, the thermometer is mounted horizontally on a plastic frame that rests on the bottom of the pan. A nonmagnetic metal handle is fastened to the bulb end of the frame and hooked over the south rim of the pan.

CHAPTER 13. SOIL TEMPERATURE

Soil temperatures are measured at one or more standard depths (section 13.2) in nonirrigated, representative plots (section 22.1). Depending on location, the plot may have sod cover, natural cover, or only bare soil.

13.1 Instruments

Soil temperatures at manual stations are generally measured by either mercury-in-glass thermometers or dial-type thermometers. The dial type preferred by the National Weather Service (U.S. Department of Commerce 1972) is actuated by a mercury-in-steel sensing element, rather than a bimetallic element (section 7.5). Sensors employing thermistors or thermocouples may also be used (Fritschen and Gay 1979; Mazzarella 1985).

MERCURY-IN-STEEL THERMOMETERS

The thermometer shown in figure 13.1, similar to that in figure 7.10, will indicate maximum and minimum soil temperatures. Its mercury-in-steel sensor is connected to a Bourdon-spring drive by flexible, 5-ft stainless steel capillary tubing.

LIQUID-IN-GLASS THERMOMETERS

The most convenient liquid-in-glass (usually mercury) soil thermometers are made with stems bent at approximately right angles; these are suitable for soil depths down to about 8 inches. The scales thus face upward, enabling easy reading without disturbance of the instrument. Such thermometers might not be readable, however, when there is snow cover, which should not be disturbed.

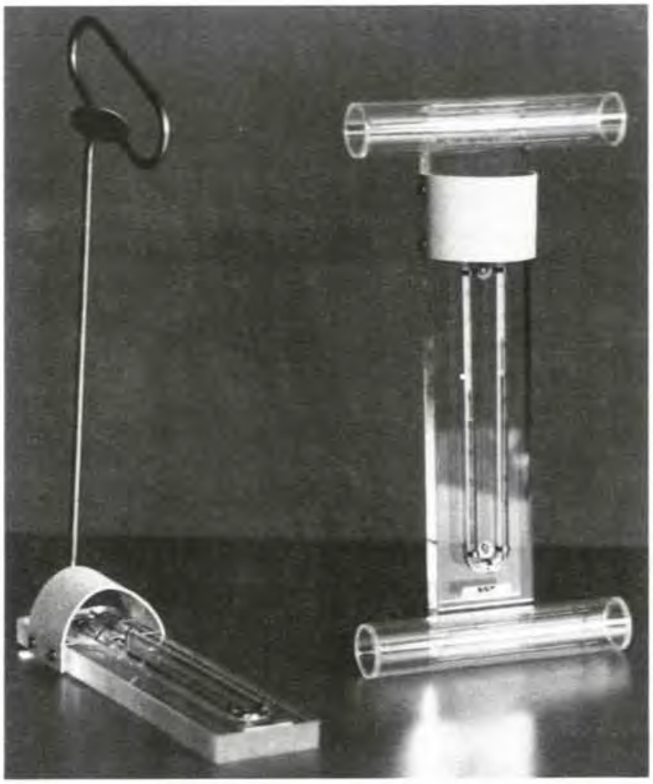


Figure 12.6—Six's water-temperature thermometers, with shields: left, thermometer in submerged mount; right, in float mount. (Photo courtesty of Qualimetrics, Inc.)

Figure 13.1—Soil maximum-minimum thermometer, similar to thermometer in figure 7.10 but with 5-ft flexible armor capillary tubing connected to mercury-in-steel sensing probe. (Photo courtesy of Palmer Instruments, Inc.)

For greater soil depths, mercury-in-glass thermometers should be suspended in thin metal or plastic tubes (World Meteorological Organization 1983); the tops of these tubes should extend above the expected depth of snow cover. The thermometers, themselves, should be mounted in wooden, glass, or plastic tubes, with their bulbs embedded in wax to provide sufficient temperature lag when they are raised for reading.

Special liquid-in-glass, bent-stem thermometers are available for measuring maximum and minimum soil temperatures. These are either of the U-tube (Six's) type or pairs of individual thermometers. The separate maximum thermometer uses a steel index set by a magnet; the minimum thermometer uses a glass index.

THERMOMETER HEAD SHELTER

Thermometer dials (or "heads") must be protected from rain and other elements by a shelter. Several shelter designs, for either mercury-in-steel or electrical instruments, are illustrated by the U.S. Department of Commerce (1972); the dimensions will depend on the number of thermometers installed.

13.2 Measurement Depths

Standard, recommended soil temperature measurement depths (U.S. Department of Commerce 1972) are 4, 8, and 20 inches, in that order of priority. Where the equipment is available, additional depths, in recommended order of priority, are 40, 2, 60, and 120 inches.

CHAPTER 14. SOIL MOISTURE

14.1 Measurement Methods

The accurate measurement of soil moisture has been a difficult instrumentation and sampling problem (World Meteorological Organization 1983). Of the presently available measurement techniques, the direct gravimetric method appears to be one of the most accurate and is commonly used as a calibration control for other methods (though laboratory calibration is preferred where feasible). The gravimetric method, however, wherein a soil sample is weighed before and after drying in an oven, is cumbersome and precludes repeated monitoring of a fixed soil mass. The direct but nondestructive lysimeter method, in which a container is filled with soil and weighed, is very costly; it cannot be used for obtaining soil moisture profiles.

The neutron method (World Meteorological Organization 1983) is considered to be the most accurate and efficient of the indirect methods. The USDA Soil Conservation Service (1972) indicates that both the electrical resistance method and neutron method can give reasonably satisfactory results. These methods, however, may be best suited for determining soil-moisture profiles or changes rather than the actual soil moisture (World Meteorological Organization 1983); careful calibration is necessary (Mazzarella 1985). The tensiometer method, used to indicate soil moisture suction, has limited application because of the instrument's small range of sensitivity. Its main use is in agriculture, for irrigation control.

ELECTRICAL RESISTANCE METHOD

In the electrical resistance method, two electrodes carefully spaced in a block of water-absorbant material are buried in the soil. The block comes into equilibrium with the soil, responding to moisture changes. The electrical resistance of the block, varying with the amount of moisture, is measured by means of a meter connected to the electrodes. The moisture blocks are usually composed of gypsum (plaster of Paris), nylon, or fiberglass, or combinations of these materials. Nylon and fiberglass units (World Meteorological Organization 1983) are more suitable than gypsum for higher soil moisture contents and have greater durability, but they exhibit greater calibration shifts. Gypsum blocks have been combined with fiberglass or nylon, and further modified, to give improved performance.

The resistance method's main advantages are its relatively low cost and the fast speed at which readings can be made. The method is particularly suited for automated, remote recording. For manual type readings, the Bouyoucos and Colman soil moisture meters have had field use by the USDA Soil Conservation Service (1972), which presents operational details. These two instruments employ nylon-reinforced gypsum blocks and fiberglass-mesh blocks, respectively.

NEUTRON METHOD

The neutron method, also termed neutron scattering, employs a fast neutron source and detector combined in an instrument called a neutron probe. The neutrons are slowed down in the presence of hydrogen atoms. Because water is the most significant source of hydrogen in soil, a count of the slowed neutrons as provided by the detector is proportional to the nearby soil water content per unit volume. Although portable, the neutron probe is heavy because of the need for radiation shielding, and it is relatively expensive. Improved, more compact, and automated neutron equipment is being developed. The neutron method is not reliable at shallow soil depths (about 10 inches or less) because some of the neutrons will pass into the air instead of the soil.

In use, the neutron probe is lowered into a noncorrosive access tube that has been installed in the soil (section 22.1); further operational details are given in the preceding two references. It is necessary to follow all instructions for protection against possible radiation hazards.

PART 2B. MANUAL WEATHER STATIONS: INSTALLATION AND EXPOSURE OF EQUIPMENT

Certain standards were presented in Part 1, sections 2.5 and 3.2, concerning weather station location and instrument accuracy. The objective of these and other standards is to obtain reliable data that represent, as much as possible, the weather occurring in the station vicinity. The data should be comparable with past data at the same station and also with similar data collected at other stations in an observing network.

Part 2B presents both guidelines and details for station and equipment setup, with specific attention given to two standard types of manual stations—fire-weather stations and evaporation stations. The information will pertain to other manual station configurations, which, in their equipment, may be subsets or combinations of the stations described. For example, standard climatological substations in the National Weather Service network, reporting only daily precipitation and maximum and minimum temperatures, would be subsets operating on a year-round basis.

Standards covering station siting, instruments, and the installation and exposure of the instruments apply to all of these stations.

CHAPTER 15. STANDARD WEATHER STATIONS

15.1 Standard Fire-Weather Station

The term "standard fire-weather station" as used here refers primarily to a permanent, manually operated station. Such stations are part of a network maintained for purposes of routine fire-danger rating and fire-weather forecasting. Many of these stations also serve as National Weather Service climatological stations.

The standard or recommended fire-weather station equipment has been listed in section 6.1. Station checklists that summarize equipment installation and maintenance standards are presented in appendix 4.

LOCATION

The standard fire-weather station should be located in a large opening, away from obstructions and local sources of dust and surface moisture. The station should be on level ground with only low vegetative cover. The station should be exposed to full sunshine throughout the day, or as much as possible, during the fire season. If the station is located on a slope, a southerly or westerly exposure is required to meet fire-danger rating specifications (Deeming and others 1977). (See section 2.5 for detailed location and exposure guidelines.)

LAYOUT

Arrangement of Equipment—A recommended ground plan for a standard fire-weather station is shown in figure 15.1. This particular arrangement of equipment allows a free flow of air and full exposure to sunshine. Plot size should be based on the individual station requirements. Ideally, the size should be large enough to accommodate instruments that may be added in the future. Recommended dimensions (fig. 15.1) are 24 by 24 ft. Plots should be at least 15 by 15 ft for proper exposure of minimum instrumentation.

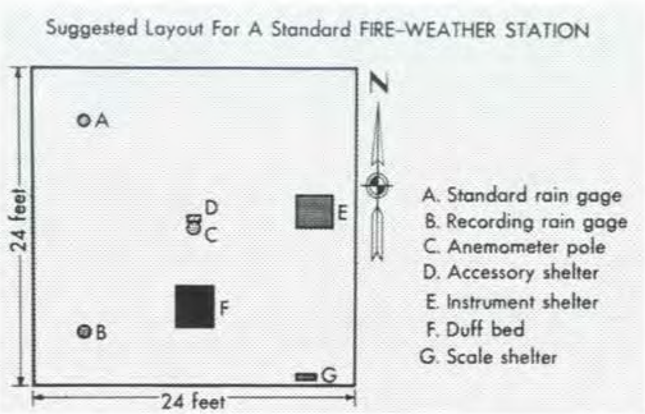


Figure 15.1—Ground plan for a standard manual fire-weather station.

Grounds—The station grounds, and a surrounding 20-ft radius, should be free of tall vegetation. Brush and trees beyond this area should not interfere with exposure. A ground cover of native perennial grass is ideal, provided it is kept well clipped (to about 3 inches height) and is not irrigated. Graveled paths to the various instrument locations are desirable to avoid dust or mud problems.

Fence—A fence around the station plot is not essential unless there is danger that instruments will be upset or otherwise damaged by animals or human intruders. A fence, however, often improves the appearance of a station and discourages unauthorized entry.

A fence should be no higher than 4 ft and constructed of open material such as woven wire. Picket fences and other types that would restrict airflow across the plot are unacceptable.

15.2 Standard Evaporation Station

The standard or recommended evaporation station equipment has been listed in section 6.2.

LOCATION

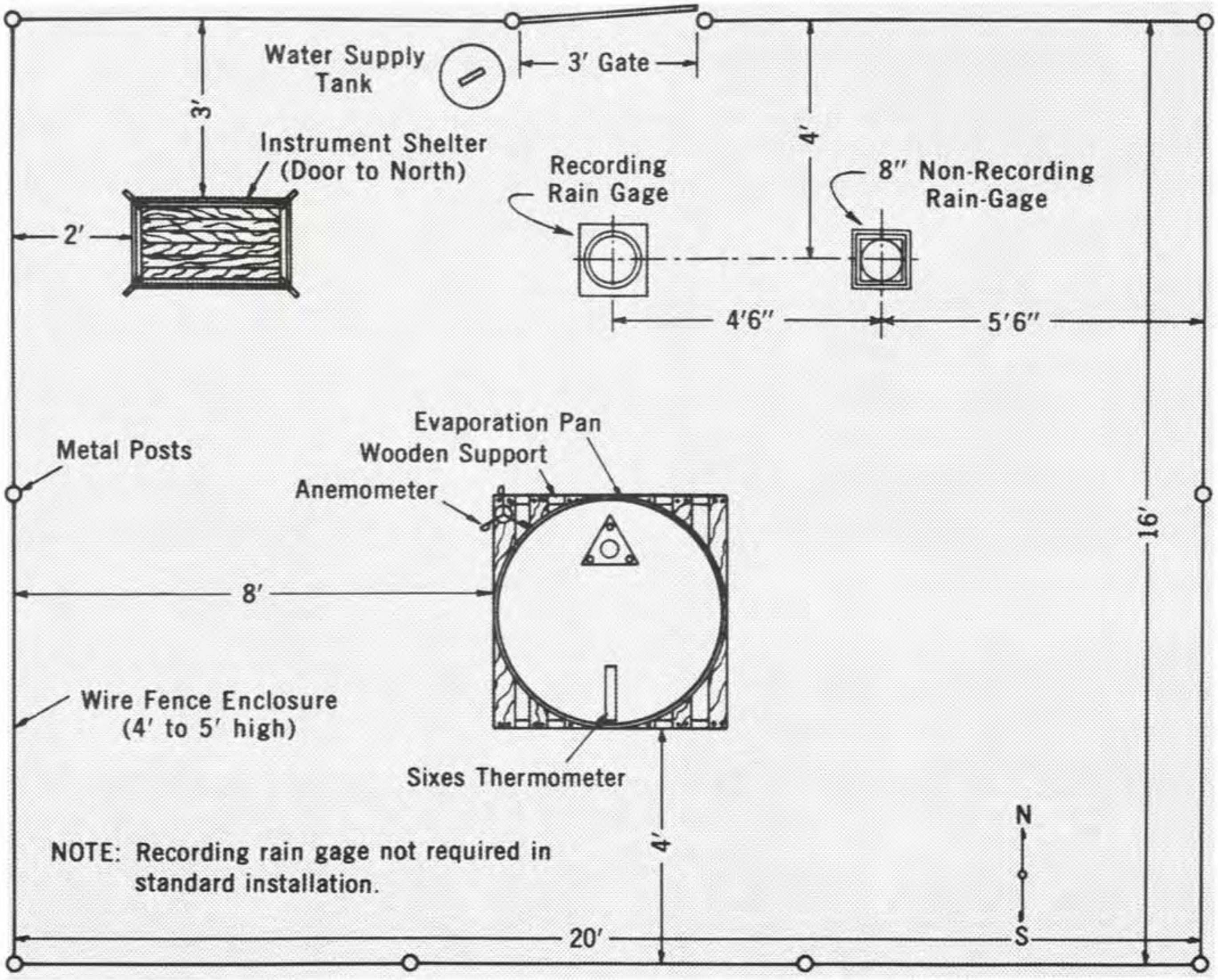
Location requirements for a standard evaporation station largely follow those given in section 15.1. In general (U.S. Department of Commerce 1972), the site should be fairly level and free from obstructions that cast shadows over the evaporation pan during any part of the day, other than brief periods near sunrise and sunset. The site should be representative of the natural soils and ground cover common to the area. Locations with nearby sprinkling, or subject to flooding, should be avoided.

LAYOUT

A recommended ground plan for a standard evaporation station is shown in figure 15.2. The layout is designed to eliminate shadows over the evaporation pan from adjacent instruments or structures. The plot dimensions, 16 by 20 ft, and the indicated spacings within are the minimum for the equipment shown. To accommodate additional equipment or accessory equipment (such as a wind shield for the precipitation gauge), the plot should be 20 by 20 ft or larger.

The ground cover should be sod where its maintenance is permitted by the climate and soil conditions—without irrigation. Grass and weeds about the plot should be kept mowed below the evaporation pan level.

The plot should be enclosed by a fence to protect the equipment from possible interference by animals, who may drink water from the evaporation pan, and humans. A chain link fence, of 9 or 11 gauge steel and at least 4 ft high, is recommended, with access through a 3-ft-wide locking gate. Additional precautions such as low chicken mesh barriers may be needed to exclude rodents or other small animals.



NOTE: Recording rain gage not required in standard installation.

Figure 15.2—Ground plan for a standard evaporation station. (From U.S. Department of Commerce 1972.)

CHAPTER 16. TEMPERATURE AND HUMIDITY EQUIPMENT

16.1 Instrument Shelter

COTTON REGION SHELTER

A properly installed instrument shelter will meet the following requirements:

1. Shelter is open to the free movement of air.
2. Shelter is located over low vegetative cover, such as grass, or other ground surface representative of the surrounding area. It should be at least 100 ft from any extensive paved surfaces.
3. Door faces north, so that sun cannot shine on the thermometers when the door is opened for observations during the day.
4. Floor is level and 4 ft above ground, except higher in areas of heavy snowfall accumulation.
5. Shelter is firmly mounted on its support, and the support legs are firmly anchored to the ground. This is required to prevent blowdown by wind and also to minimize vibrations that could displace the index of liquid-in-glass minimum thermometers. Likewise, the door should close firmly to prevent possible wind vibration, but it should not rub against its frame during opening and closing.

At a permanent station, it is recommended that the shelter support legs are fastened to concrete footings; the legs are buried, however, only if they are constructed of metal. Wooden support legs may alternatively be fastened to metal or treated-wood stakes. Metal mounting pins of the type shown in figure 16.1 can aid in obtaining proper, level installation of the shelter (fig. 16.2).

In windy areas where shelter vibration causes erroneous minimum-thermometer readings, the maximum and minimum thermometers should be mounted on a separate post, which enters the shelter through a hole cut in the bottom.

The instrument shelter should be used only for the exposure of temperature and humidity instruments (fig. 16.3). Storage should be limited to related small items that do not block ventilation of the instruments.

Figure 16.1—Instrument shelter mounting pin. (See appendix 5 for details.)

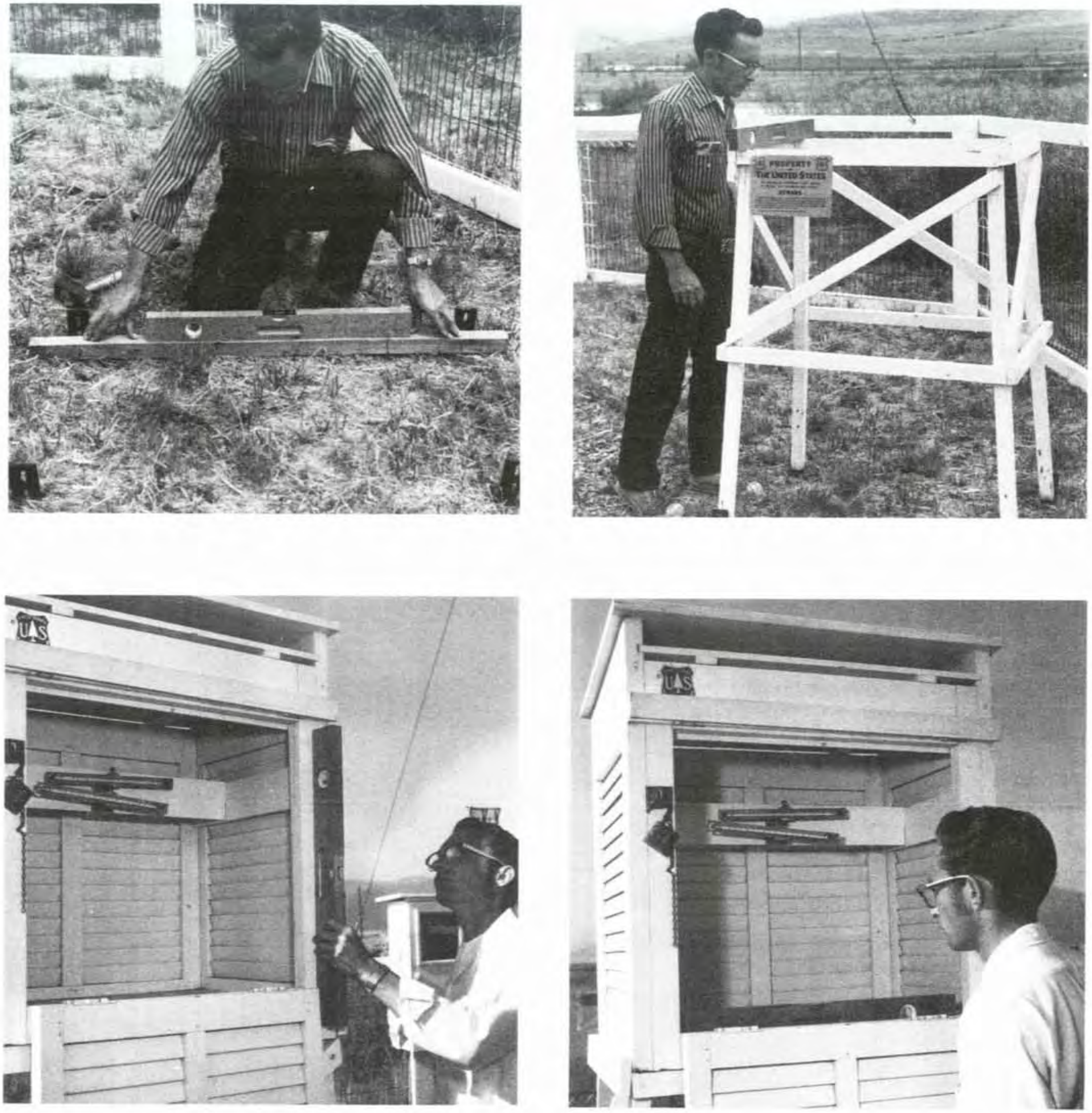


Figure 16.2—Installing and leveling instrument shelter using mounting pins.

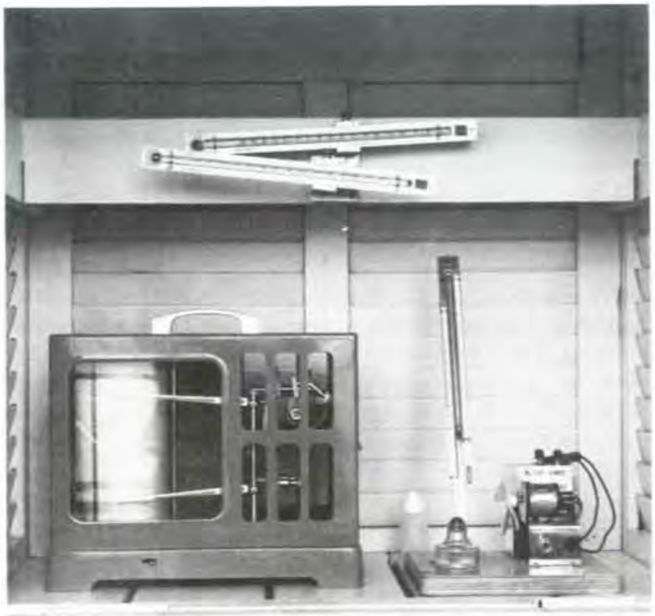


Figure 16.3—Suggested arrangement of instruments in a cotton region shelter. Only temperature and humidity instruments should be installed in this shelter.

16.2 Maximum and Minimum Thermometers

STANDARD LIQUID-IN-GLASS THERMOMETERS

The standard maximum and minimum thermometers with Townsend support are mounted in an instrument shelter, as follows:

Townsend Support—Attach the Townsend support with screws at the center of the instrument shelter crossboard. Be sure that the support is positioned with the spinning clamp (for the maximum thermometer) at the bottom (fig. 16.3).

Maximum Thermometer—With the clamp in locked ("set") position, mount the maximum thermometer, bulb end to the left, in the spinning (lower) clamp of the Townsend support. Mount at about two-thirds distance up the thermometer stem (near the 80° mark on a –20 to +120 °F-range thermometer). If the thermometer is mounted too near its midpoint, the mercury column is apt to separate during spinning, and part of it may become lodged at the top of the stem.

Tighten the thumbscrew on the bracket securely to prevent thermometer slippage during spinning. When properly mounted, the bulb end of the maximum thermometer is inclined about 5 degrees above the horizontal. This position facilitates the movement of mercury as the temperature rises and minimizes the chance of mercury retreating through the constriction as the temperature falls.

Minimum Thermometer—Mount the minimum thermometer, bulb end to the left, in the upper clamp, slightly beyond the middle of the stem (near the 60° mark on a –40 to +120 °F-range thermometer).

Tighten the thumbscrew on the clamp to hold the thermometer in place. Gently push the bulb end downward to its limiting position. When properly mounted, the bulb end is inclined about 5 degrees below the horizontal. This position facilitates the downward movement of the index when the temperature falls. It also tends to prevent accumulation of vaporized liquid above the alcohol column and resulting bubble formation (section 30.2). The minimum thermometer, however, must be protected against vibration that would slide the index downward (section 16.1).

OTHER MAXIMUM-MINIMUM THERMOMETERS

The Six's and dial types of maximum-minimum thermometer can also be mounted in an instrument shelter, using the crossboard or a vertical post. The Six's thermometer should be mounted rigidly in a vertical position. Its index rods ordinarily remain in place until reset by a magnet, but movement is possible from wind vibration. In mounting a dial-type thermometer, the end of the sensor stem should be near the standard thermometer height and position, at least several inches from the shelter louvers.

The sensor of a remote-reading digital maximum-minimum thermometer likewise can be mounted in an instrument shelter (particularly when this shelter is required for housing other temperature and humidity instruments). The digital thermometers employed by the National Weather Service have their sensors mounted in a small radiation shield (section 7.3).

16.3 Psychrometers

STANDARD ELECTRIC FAN PSYCHROMETER

Locate the psychrometer in the right front portion of the instrument shelter, fastening it to the floor board (fig. 16.3). Be sure that the position of the psychrometer does not interfere with the spinning of the maximum thermometer. To obtain the proper ventilation, observe the polarity of the battery wires when connecting the fan to the battery.

OTHER PSYCHROMETERS

The above instructions concerning location also apply to a hand fan psychrometer. A Mason hygrometer if used should be mounted in an instrument shelter, on a hook or screw near the right end of the crossboard, clear of the maximum and minimum thermometers.

16.4 Hygrothermograph

Set the hygrothermograph in the left front portion of the instrument shelter (fig. 16.3). It is ordinarily set on the floor, but it may be raised slightly on 2- by 4-inch wooden blocks (broad side up) at year-round stations where snow blows into the shelter and covers the floor. Be sure that the hygrothermograph is placed far enough forward to be clear of the spinning maximum thermometer.

CHAPTER 17. WIND EQUIPMENT

17.1 Anemometers

Anemometers should be exposed 20 ft above open, level ground (fig. 17.1). This standard height must be adjusted, however, to compensate for height of ground cover, uneven ground, and nearby obstructions. To obtain a suitable, representative exposure, the anemometer can, if necessary, be located one-quarter mile or farther away from the main weather station plot.

HEIGHT ADJUSTMENT

Uneven Ground—In rolling country or over rough ground characterized by depressions and ridges, mount the anemometer 20 ft above a representative high spot. If the anemometer is mounted over a low spot, increase the height by the average depth of the depression in relation to the surrounding higher ground.

Ground Cover—Adjustment of anemometer height will depend on the density and height of the ground cover. If the ground is densely covered with rocks, brush, or small trees, increase the height of the anemometer by the average height of the ground cover. If the ground cover is scattered, increase the height of the anemometer by one-half the average height of the ground cover. If the ground cover is sparse, increase the height of the anemometer by one-third the height of the ground cover.

Nearby Obstacles—No adjustment of anemometer height is necessary if the distance of an obstacle from the anemometer is more than seven times the height of the obstacle. If the distance is less than seven times the height of the obstacle (fig. 17.2), table 17.1 can be used to determine the adjusted anemometer height (USDA FS 1964b).

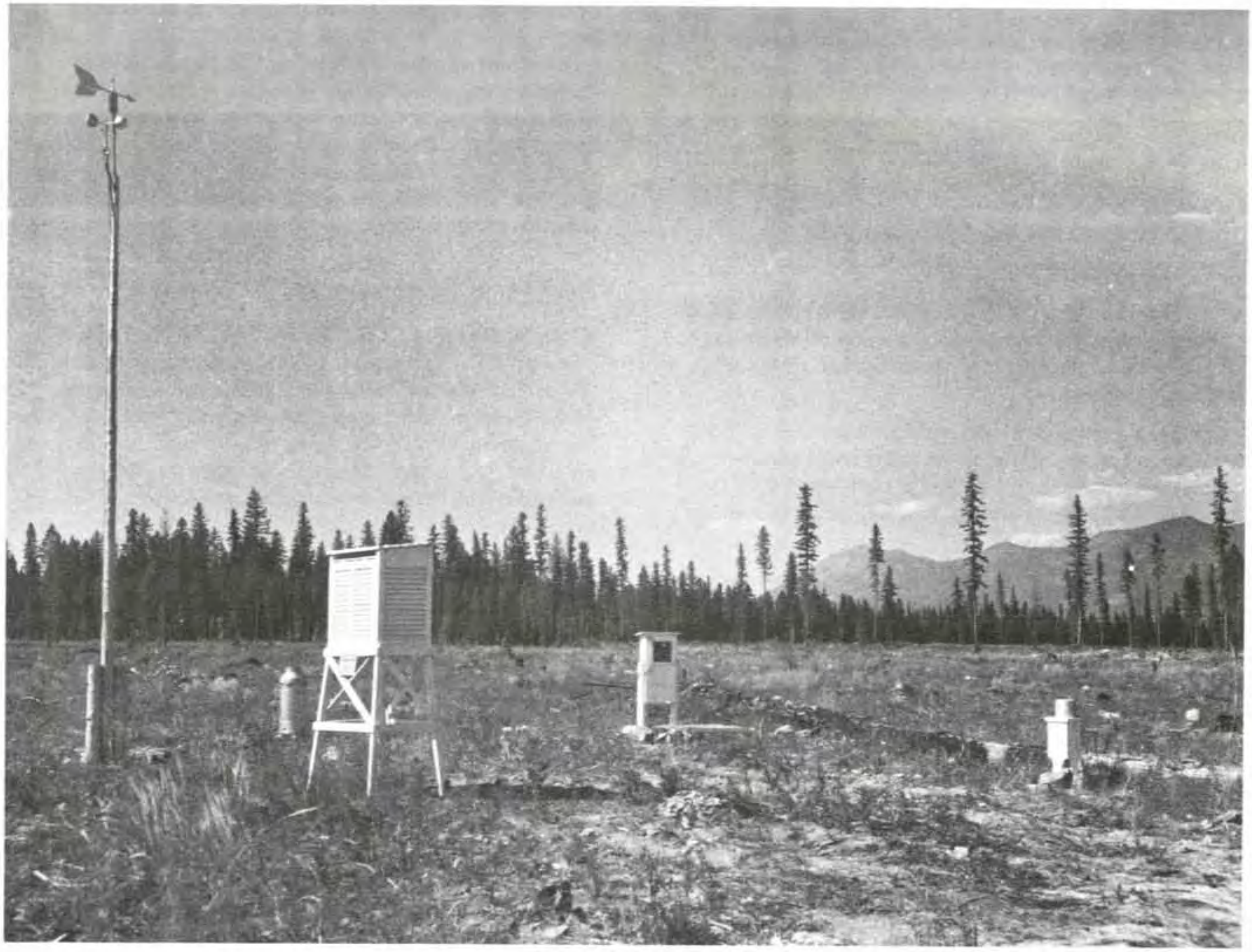


Figure 17.1—A standard anemometer installation 20 ft above open, level ground.

Table 17.1—Anemometer height (20-ft standard)[1] correction table

Distance to obstacle	Height of obstacle (feet)														
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**	**150**
Feet							*[2]Feet*								
10	27	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20	25	34	—	—	—	—	—	—	—	—	—	—	—	—	—
30	24	32	41	—	—	—	—	—	—	—	—	—	—	—	—
40	22	30	39	48	—	—	—	—	—	—	—	—	—	—	—
50	21	29	37	46	55	—	—	—	—	—	—	—	—	—	—
60	21	27	35	44	53	62	—	—	—	—	—	—	—	—	—
70	20	26	34	42	51	60	69	—	—	—	—	—	—	—	—
80	20	24	32	40	49	58	67	76	—	—	—	—	—	—	—
90	20	23	31	38	47	56	65	74	83	—	—	—	—	—	—
100	20	22	29	37	45	54	63	72	81	90	—	—	—	—	—
120	20	21	26	34	42	50	59	68	77	86	95	104	—	—	—
140	20	20	24	31	39	47	55	64	73	82	92	100	109	118	—
160	20	20	23	28	36	44	52	60	69	78	87	96	105	114	123
180	20	20	22	26	33	41	49	57	65	74	83	92	101	110	119
200	20	20	20	24	30	38	46	54	62	70	79	88	97	106	115
220	20	20	20	23	28	35	43	51	59	67	75	84	93	103	112
240	20	20	20	22	26	32	40	48	56	64	72	80	89	98	107
260	20	20	20	21	25	30	37	45	53	61	69	77	85	94	103
280	20	20	20	20	24	28	34	42	50	58	66	74	82	90	99
300	20	20	20	20	23	26	32	39	47	55	63	71	79	87	95
350	20	20	20	20	20	23	27	33	39	48	55	64	71	80	88
400	20	20	20	20	20	21	25	28	34	40	48	56	64	72	80
450	20	20	20	20	20	20	22	26	29	35	41	48	56	65	73
500	20	20	20	20	20	20	20	23	27	30	36	42	49	56	65
600	20	20	20	20	20	20	20	20	21	25	28	32	38	44	50
700	20	20	20	20	20	20	20	20	20	20	23	27	31	34	40
800	20	20	20	20	20	20	20	20	20	20	20	22	26	29	33
900	20	20	20	20	20	20	20	20	20	20	20	20	20	24	28
1,000	20	20	20	20	20	20	20	20	20	20	20	20	20	20	22
1,100	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20

[1] The computed anemometer heights do not include an adjustment for uneven ground or ground cover. These adjustments must be added to table values.

[2] For distances less than height of obstruction, place anemometer 20 ft above the obstruction.

INSTALLATION

Anemometers have been most commonly installed on wooden poles at fire-weather stations (figs. 8.1, 17.1, and 17.2A), but installations on metal poles and towers are also used (figs. 17.2B, 17.3, and 17.4).

Metal towers (fig. 17.2B) are especially favored where adjusted anemometer heights in excess of 25 to 30 ft are required; also, at temporary field stations, where equipment portability is a major consideration. The towers are available in a variety of forms: (1) one-piece towers of a specified height, (2) stacked 10-ft sections that are extended and bolted together, (3) telescoping sections that crank up and down, and (4) foldover models equipped with a hand winch for raising and lowering the upper half of the tower.

Regardless of the type used, and whether at temporary or permanent stations, anemometer installations should have the following features: (1) remain firm during windy conditions, (2) allow easy access to the anemometer, (3) accommodate a readout device, (4) provide for periodic adjustment of anemometer height, and (5) be compatible with any existing lightning protection system.

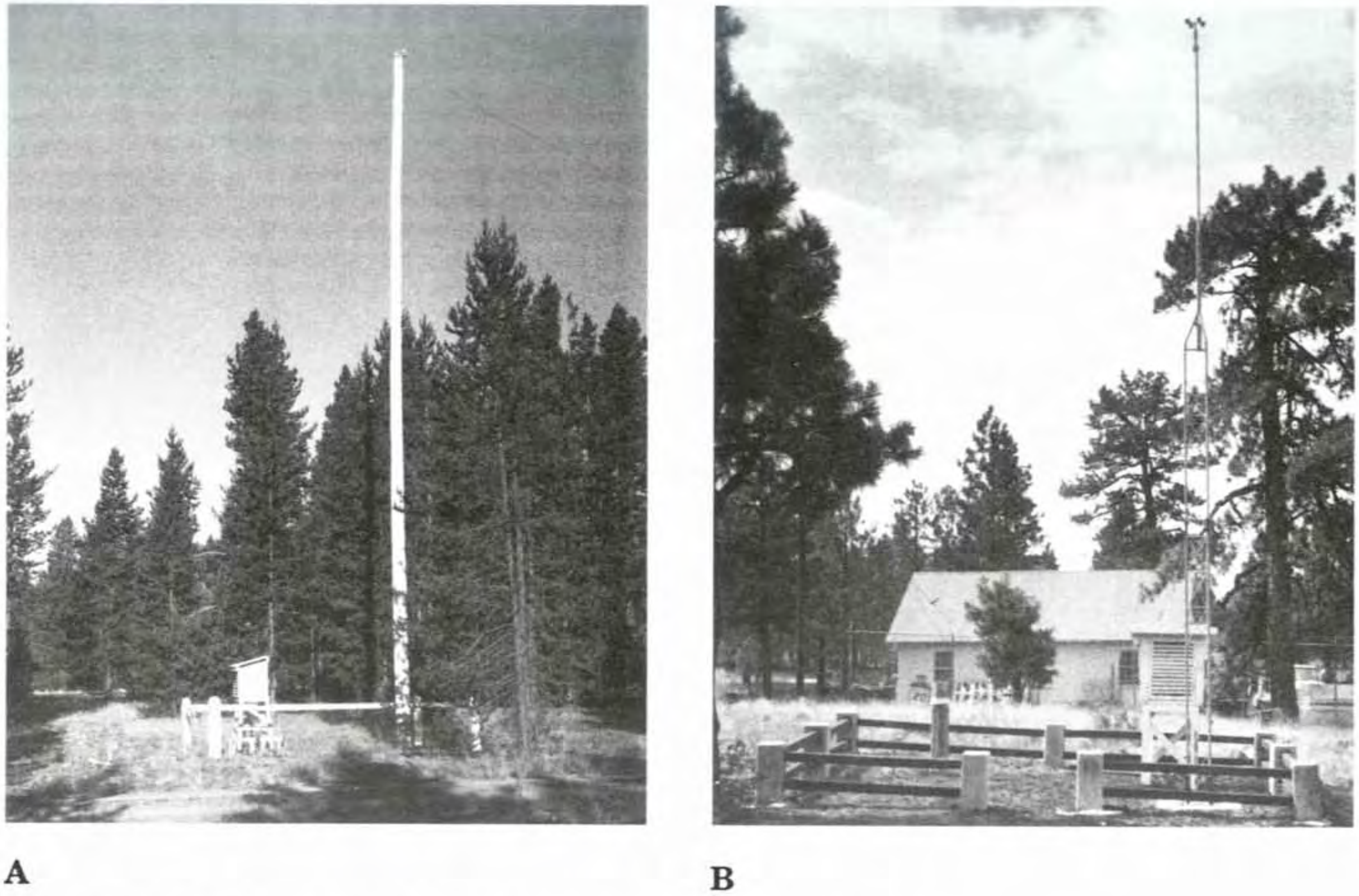


Figure 17.2(A and B)—Anemometer installations with height adjusted upward because of nearby trees.

Figure 17.3—Anemometer installation employing metal pole fastened to wooden pole. This installation allows easy access to the anemometer and provides for periodic height adjustment. The wire to right of metal pole connects the anemometer to a wind counter located inside the fire dispatcher's office.

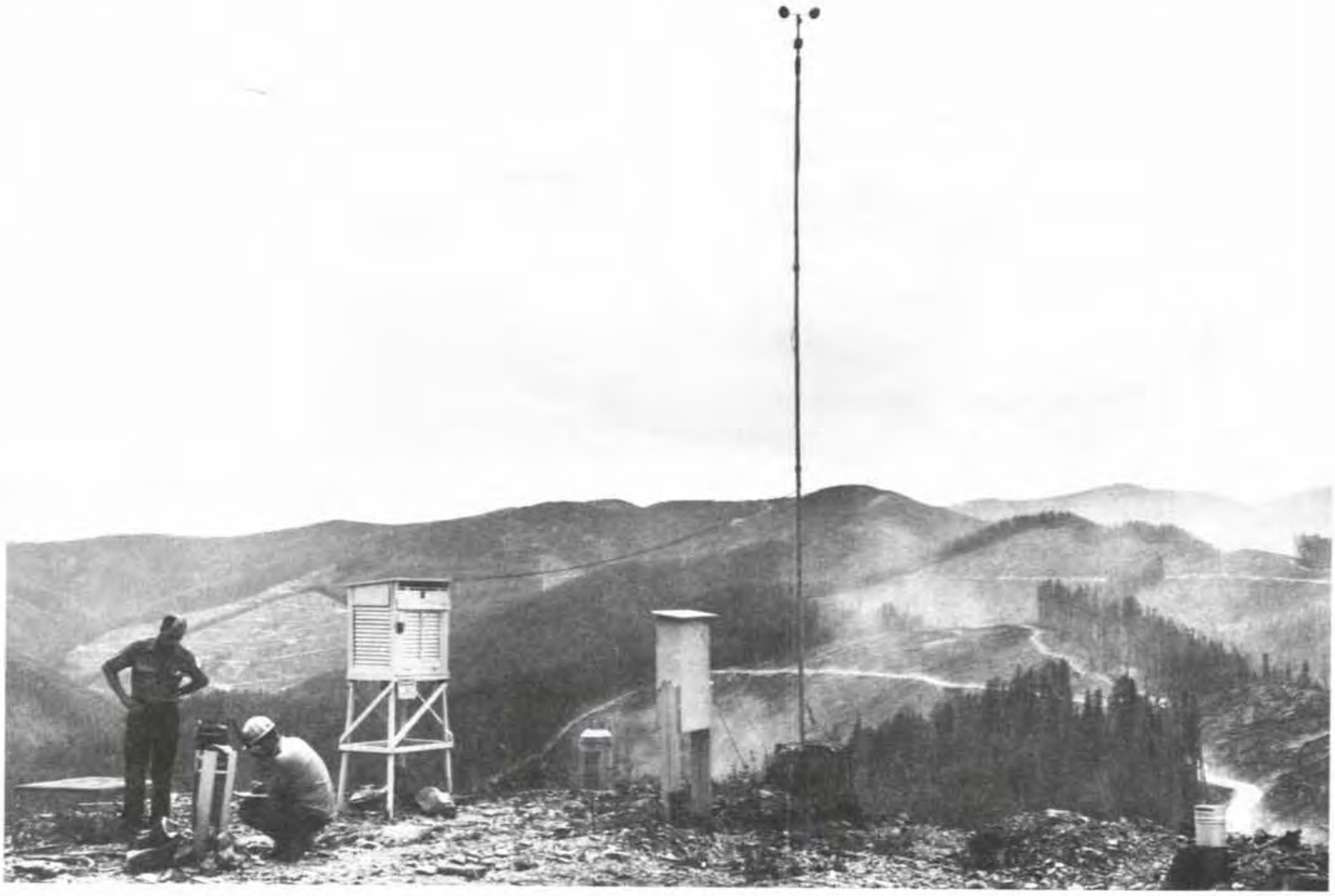


Figure 17.4—Metal pole used in anemometer installation at a temporary station, established to monitor weather for prescribed burning.

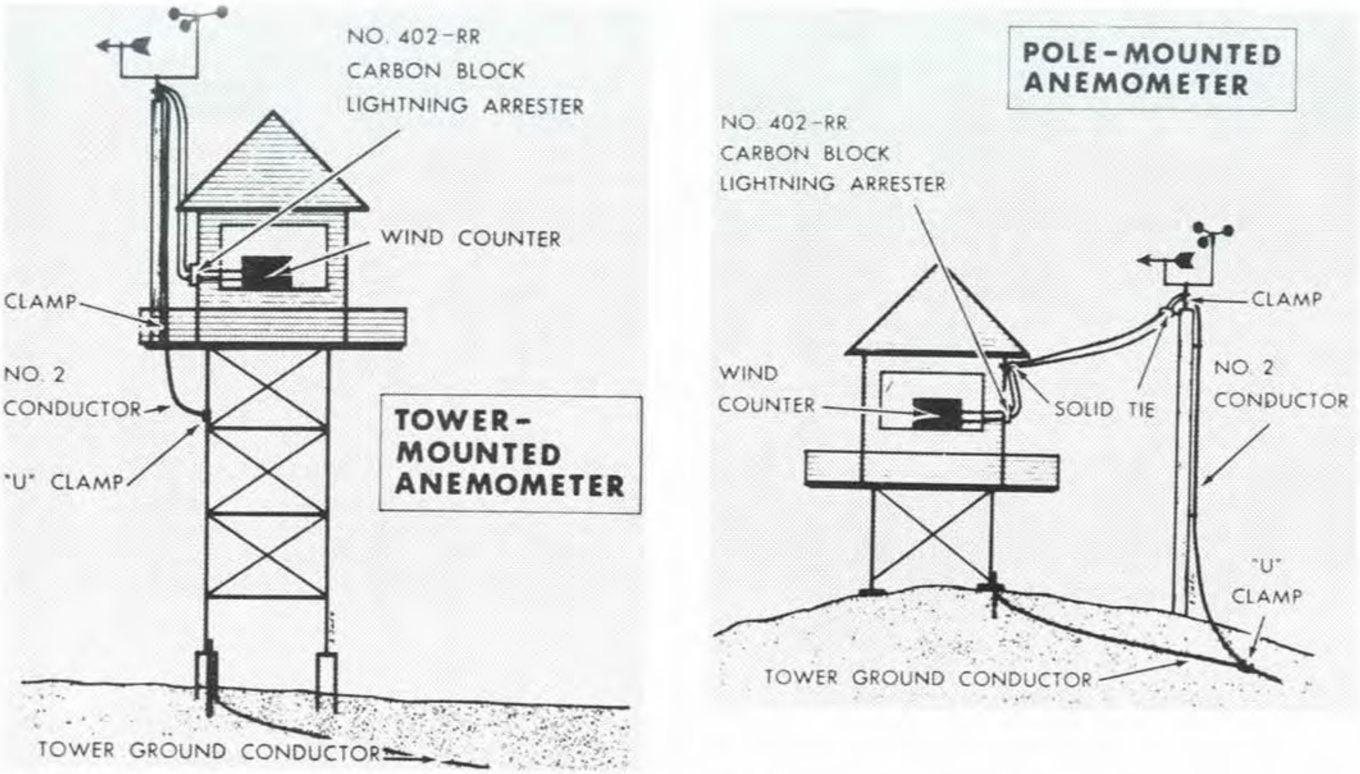


Figure 17.5—Suggested method for obtaining adequate lightning protection at lookout anemometer installations: left, anemometer pole on tower; right, anemometer pole on ground.

LIGHTNING PROTECTION

In many areas, good safety practice requires adequate lightning protection on both the anemometer and the wires leading to the indoors reading device.

Lookout Tower Installation—If the anemometer is mounted on a lookout tower (fig. 17.5), follow these procedures for lightning protection:

1. Clamp a length of #2 copper-wire conductor onto the anemometer pole (if metal) or the anemometer itself (if the pole is wooden).
2. Run the conductor underneath the catwalk of the lookout cab and clamp it to the existing lightning protection system.
3. Install a carbon block lightning arrester (#402-RR, or equivalent) on the tower leg. The wire connecting the anemometer to the readout device must pass through the arrester before it is run into the lookout cab. Be sure that this wire is tightly connected to both the anemometer pole and the tower.

Ground Installation—The following procedures apply if the anemometer is mounted on a pole set into the ground, either at a lookout station (fig. 17.5) or at a valley bottom station (fig. 17.6):

1. Clamp a length of #2 copper-wire conductor onto the pole (if metal) or to the anemometer itself (if the pole is wooden).
2. If a ground wire from an existing lightning protection system is available nearby, run the conductor down the pole and clamp onto the ground wire.
3. If an existing ground wire is not available, install a ground rod near the pole and run the conductor down to it.
4. Install a carbon block lightning arrester (#402-RR, or equivalent) on the tower leg or exterior of the building where the readout device is located. The wire connecting the anemometer to the readout device must pass through the arrester before it enters the building. Again, be sure that this wire is tightly connected to both the anemometer pole and the tower or building that it enters.

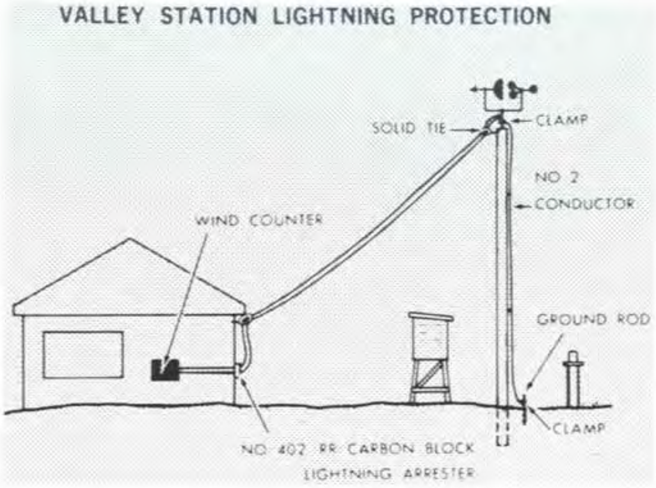


Figure 17.6—Suggested method for obtaining adequate lightning protection at valley-bottom anemometer installations.

17.2 Wind Counters

LOCATION

The location of a wind counter is largely a matter of observer convenience. An office installation (fig. 17.7) may be desirable if windspeed observations are required periodically throughout the day or if the observation duration is relatively long. When making an office readout installation, be sure that the appropriate lightning protection is also installed.

If the wind counter is located at the weather station plot, its position must not interfere with exposure requirements of other instruments. Recommended as a housing for the wind counter is a small, weatherproof cabinet, located about 4½ ft above the ground near the anemometer pole. Construction plans for this cabinet (fig. 17.8) are provided in appendix 5. The counter should not be placed in the station's instrument shelter, which should contain only temperature and humidity instruments.

INSTALLATION

Moistureproof insulated copper lead-in wire should be used to connect the wind counter to the anemometer. When connecting the battery to the counter, be sure to observe the polarity of the battery wires.

An important consideration when installing a wind counter is the relationship between length and diameter of wire, electrical resistance, and battery voltage. As the linear distance between anemometer and counter increases, the resistance increases; thus, additional voltage may be needed for very long distances. The diameter of the wire can be a modifying factor, since resistance decreases as the diameter of the wire increases. A final consideration is the fact that too much voltage can burn the anemometer contacts.

The wind counter can be located up to 1 mile away from the anemometer, without increased voltage, provided that #20 or #22 copperweld twin-conductor wire is used for the anemometer-battery connection (USDA FS 1969).

Because of the above factors, it is recommended that an electronics technician check the proposed installation before the actual work and operation proceed.

17.3 Indicator Dials and Chart Recorders

These readout devices, as used with generator-type anemometers, are typically installed inside an office near the weather station. Such devices should be installed by a qualified technician, following manufacturer's instructions. Proper lightning protection should be provided.

17.4 Wind Vanes

LOCATION

The wind vane can be mounted on the same pole as the anemometer. A connected wind-direction readout device is recommended at the standard fire-weather station.

The readout device can be located either in the the office (fig. 17.7)—with required lightning protection—or at the weather station plot, depending on available facilities and observer convenience. If located at the station plot, the readout device can be installed in the same cabinet as the wind counter (fig. 17.8).

Figure 17.7—Wind counter and wind direction indicator installed in an office.

Figure 17.8—Accessory cabinet for on-site installation of wind counter and wind direction readout device. The upper shelf can be used for tools and supplies.

INSTALLATION

Two matters requiring particular attention during installation of a wind direction system are:

1. Proper orientation of the wind vane in relation to true north.
2. Careful wiring of the readout device so that the indicated wind direction agrees with the direction shown by the vane.

Use insulated, moistureproof cable to connect the readout device with the wind vane. A 10-lead cable is required for the wind direction indicator in figure 17.9.

True North Orientation—The following procedure is useful for obtaining proper orientation of the Stewart and other makes of wind vanes:

1. Remove the front cover from the wind vane housing.
2. Rotate the wind vane arrow until the north contact is closed, causing the "north" indicator lamp to light.
3. Draw a chalk line on top of the wind vane housing directly under and parallel with the shaft of the arrow.
4. Replace the front cover and extend the chalk line down the face of the housing.
5. Paint the line, or install a strip of plastic tape, so that it is visible when the wind vane is on the pole (fig. 17.10).
6. With the wind vane in operating position, drive a stake so that it is directly under the center of the wind vane housing. Use a compass and sight a line from this stake (designated point A) to true north, correcting for magnetic declination.
7. Drive a second stake (designated point B) about 100 ft from point A along the sighted line to true north.
8. Backsight a line from point B to the painted line on the wind vane housing.
9. Adjust the position of the wind vane housing until the line backsighted in step 8 is along that obtained in step 6; corrected compass reading should be exactly south (180°).

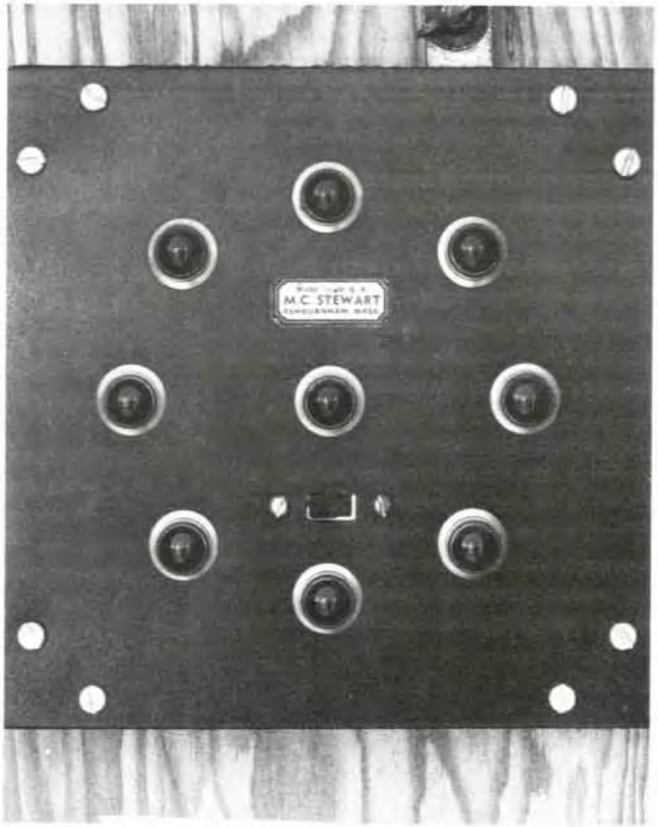


Figure 17.9—Wind direction indicator. Lighted lamps indicate the direction.

Figure 17.10—Wind vane with marking to assist in true north orientation.

CHAPTER 18. PRECIPITATION EQUIPMENT

18.1 Exposure Guidelines

Accuracy of precipitation measurements (the gauge catch) is affected by wind and also the presence and height of adjacent objects. Thus, although an exposure that is open to wind is recommended for a weather station in general (section 2.5), the action of wind on a precipitation gauge results in eddy currents (increasing with windspeed) that tend to carry away the precipitation and cause a deficient gauge catch. With a windspeed of 10 mi/h at gaugetop level, the catch deficiency may average about 15 percent for rain and 40 percent for snow (Linsley and others 1958). Unrepresentative windy sites should therefore be avoided; likewise, exposures on roofs or near corners of buildings.

Equipping gauges with wind shields (section 18.3) will improve the catch in open areas, but further improvement can be obtained by using suitable low objects, bushes, or trees as a windbreak. Gauge installations at lookouts or other mountaintop stations should take advantage of available sheltering terrain, away from the windy crest. In seeking wind protection, it may be advisable to locate the precipitation gauge some distance from the other weather instruments. The bushes, trees, and other objects should not be so close as to create additional eddy effects or block precipitation from the gauge. As a general rule (U.S. Department of Commerce 1972; World Meteorological Organization 1983), their distance from the gauge should not be closer than twice their height above the gauge orifice.

18.2 Precipitation Gauges

Installation instructions are given for only two specific, standard-type precipitation gauges. For other gauges, the same basic principles apply with respect to level mounting and proper exposure height. Consult the manufacturer's instruction manual for further details, particularly where mechanism assembly and electrical connections are required for recording gauges.

Additional installation procedures particularly helpful where gauges are operated in snowy, windswept areas are described by Winter and Sturges (1989).

STANDARD 8-INCH GAUGE

Wooden or metal stands for the large- and small-capacity 8-inch gauges must be firmly anchored to the ground; stakes may be used or the stands fastened to a wooden or concrete base set into the ground. During the procedure, set the gauge in the stand and use a spirit level in several positions across the gauge top (collector properly seated), to be sure that the installation is perfectly level (fig. 18.1). Ordinarily, the gauge top should be 3 ft above the ground. A greater height will be required if the gauge is to be used throughout the year in a heavy snowfall area.

UNIVERSAL WEIGHING GAUGE

Mount the gauge securely onto a heavy, raised wooden or concrete base set into the ground. Fasten with a metal anchor base, if this has been provided, and bolts through the three 3/8-inch-diameter holes in the base of the gauge. The bottom of the gauge usually should be 1 to 2 ft above the ground surface, for observer convenience and to raise the gauge and inspection door above puddles or snow accumulation. As described for the standard 8-inch gauge installation, use a spirit level to ensure that the gauge top is perfectly level.

If the weighing gauge will be operated year-round in an area of deep snow accumulation, install it on a platform or tower (fig. 18.2). In such cases, a wind shield should be used, particularly in an open location, as windspeeds can increase steeply with height in the layer of air near the ground. The gauge height will depend on the expected maximum snow depth. Where possible, tower location should take advantage of windbreaks provided by trees (section 18.1). The recommended distance of these trees from the gauge is twice their height above the gauge orifice; the distance should at least equal this height where exceptions are made. A standard 8-inch nonrecording gauge, with its top 3 ft above ground, should also be employed—for comparison during the snow-free months or fire season. Depending on wind effects, it may be advisable to use this lower gauge for the official precipitation readings during the fire season. The weighing-gauge record will still be used to obtain the time and duration of precipitation.

18.3 Wind Shields

The Alter wind shield should be installed level and concentric with the precipitation gauge, with the top of the baffles (leaves) one-half inch above the gauge orifice. Toward leveling the shield, use a spirit level placed on a rigid straight edge spanning the 4-ft-diameter baffle ring. Adjust the position and height of the support pipes as necessary and imbed the ends into the ground or concrete. Where greater height of the shield is required (gauge orifice raised), the support pipes may be attached to wooden posts (Winter and Sturges 1989). On a tower or platform installation, attach the shield supports to the structure or to special horizontal wings. Angled supports are used to attach the wind shield directly onto a standpipe gauge (fig. 9.15).

Figure 18.1—The rain gauge installation should be level and plumb.

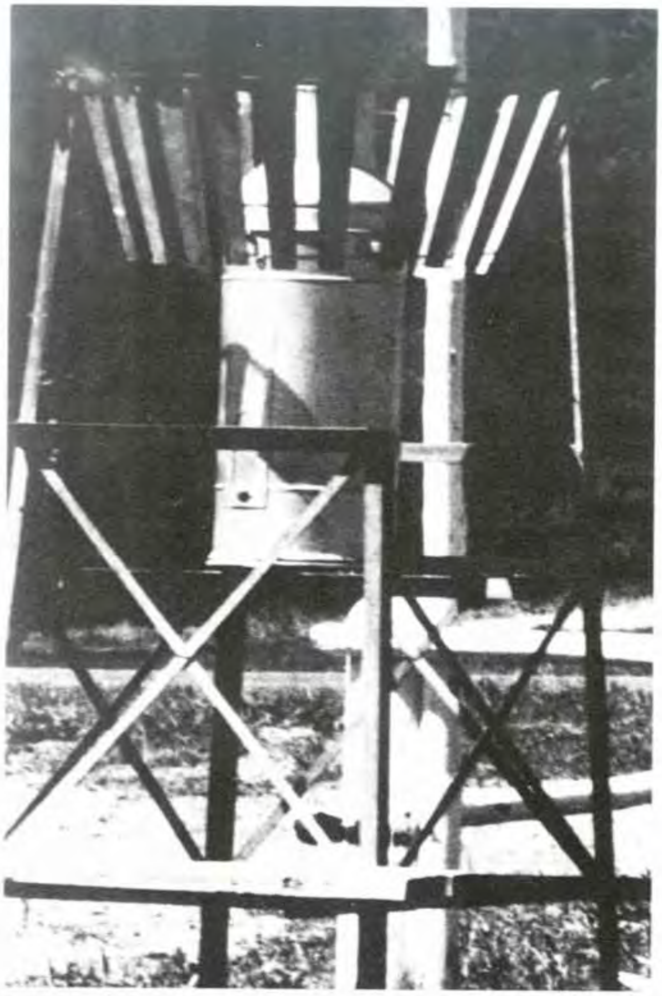


Figure 18.2—Recording precipitation gauge mounted, with wind shield, on tower in area with heavy snowfall.

18.4 Snow Stakes

Install a snow stake vertically with the zero line at the ground surface. Fasten the stake to a galvanized angle iron or wooden post set vertically and securely into the ground. Location should be representative (section 9.5), away from trees, buildings, and other influences affecting wind flow and snowmelt near the stake. The ground at the stake should be free of bushes and tall grass, but low leafless vegetation near the stake may help curtail drifting of snow.

CHAPTER 19. FUEL MOISTURE EQUIPMENT

19.1 Fuel Moisture Sticks

DUFF BED

Prepare a bed of conifer needles or hardwood leaves 2 inches deep over a 3-ft-square area of level ground. The underlying ground surface usually requires some form of treatment to eliminate herbaceous vegetation. Place the needles evenly on the level surface to assure proper runoff of water after rainfall occurs. The purpose of the duff bed is to provide a standard reflective surface and to prevent mud from splashing on the sticks during heavy rain. Burlap-sack material secured to the ground under the sticks provides a satisfactory alternative if litter is not readily available.

STICK EXPOSURE

Weathering (the effect of sun, rain, wind, and repeated wetting and drying) reduces the ovendry weight of fuel moisture sticks over a period of time. Therefore, install a new set of indicator sticks at the beginning of each season and, if necessary, periodically during the season. Install the sticks several days prior to the beginning of measurements to allow the sticks time to attain equilibrium with the surrounding air. Expose the sticks horizontally 10 inches above a fresh duff bed. Place two galvanized wire racks over the duff to support the sticks (fig. 19.1).

Screening—In the past, at many openly exposed fire-weather stations, fuel moisture sticks have been shaded. This was an attempt to simulate a forest canopy's effect on the moisture content of fuels on the forest floor. The shading, a practice now generally discontinued, is accomplished by use of screens.

In the Western United States, a double layer of 14-mesh screen has been used, held taut in a 3-ft-square frame located 13 inches above the ground. This installation produces shading about equal to that existing on an old-growth area from which three-fourths of the canopy has been removed.

Whether or not screening is used depends on the objective of the fuel stick measurements. For example, if the measurements are taken to help decide when to broadcast burn a clearcut area, screening should not be used—because there would be no tree canopy over the clearcut. *Current fire-danger rating procedures do not use screens.*

19.2 Fuel Moisture Scales

FORESTER SCALE

A Forester (or Appalachian) scale, mounted in an Appalachian scale shelter, is recommended for weighing fuel moisture sticks at a standard fire-weather station (figs. 10.2 and 19.2). Construction details of the Appalachian shelter are provided in appendix 5.

The scale shelter should be plumb and firmly secured to the ground. It should be located in a spot where it neither shades the fuel sticks nor interferes with the exposure of the instrument shelter or rain gauge.

Install the Forester scale on the mounting board or backplate of the shelter, and level it as shown in figure 19.2. The scale must be exactly plumb to yield accurate readings. After the scale is properly mounted, zero the scale by manipulating the three wing nuts located about the face of the scale.

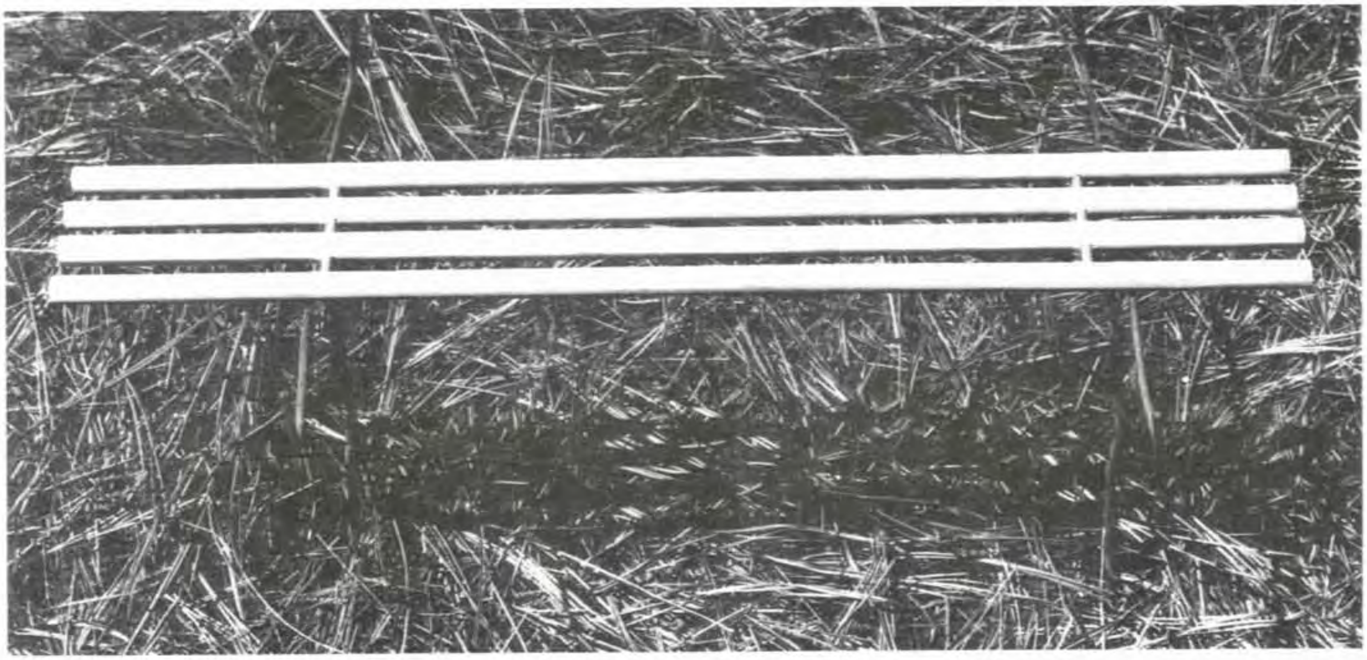


Figure 19.1—Fuel moisture stick installation over a bed of conifer needles.

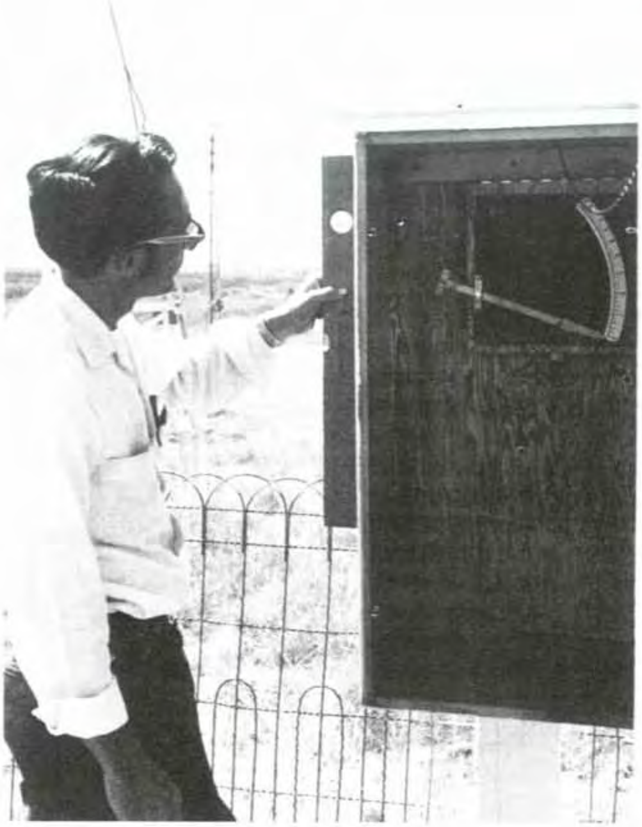


Figure 19.2—Checking the installation of Forester scale in an Appalachian shelter. Both the shelter and the scale should be level and plumb.

CHAPTER 20. PYRANOMETERS AND SUNSHINE RECORDERS

20.1 Exposure

Because a pyranometer measures global solar radiation (both direct beam and diffuse sky radiation), the exposure site ideally should be free from any obstructions above the horizontal plane of the sensing element; the site should also be readily accessible. Otherwise, as much as possible, the site should be free of obstructions (including terrain) extending more than 5 degrees above the horizontal plane—particularly within the azimuth range of sunrise and sunset during the year (World Meteorological Organization 1983). The pyranometer should not be exposed near light-colored walls or other objects that may reflect sunlight onto it. Where available, a flat roof usually provides a good location for mounting the pyranometer on its support. Alternatively, the pyranometer may be installed on a board fastened horizontally atop a post inside the station enclosure or atop the roof of the instrument shelter.

Correct exposure of a sunshine recorder is less stringent, requiring only an uninterrupted view of the sun at all times of the year. This applies to times of day when the sun's altitude is more than 3 degrees above the horizontal plane. The recorder can be installed on the roof of a building or on a board atop a post inside the station enclosure.

20.2 Installation

Detailed installation instructions for specific pyranometers and sunshine recorders can be obtained from manuals furnished by the manufacturers. The World Meteorological Organization (1983) presents some general instructions concerning pyranometers, together with calibration methods. The following paragraphs summarize the basic installation principles.

PYRANOMETERS

A pyranometer should be firmly mounted on its support and correctly leveled so that the receiving surface is truly horizontal. Avoid subjecting the instrument to jolts or vibration during installation. Connecting cables between the pyranometer and its recorder should be waterproof and firmly attached to the pyranometer mount to minimize breakage or disconnection in windy weather; observe the circuit polarity of the cables.

CAMPBELL-STOKES SUNSHINE RECORDER

Again, firm mounting and correct leveling are essential. The spherical segment should be adjusted according to instructions; latitude and meridian adjustments are necessary. When observing the sun's image at local noon, the image should fall on the noon mark of the spherical segment or card. If all adjustments have been carefully made, the burns should be parallel to the center lines of the cards.

CHAPTER 21. EVAPORATION STATION EQUIPMENT

21.1 Class A Evaporation Pan

Before placing the evaporation pan on its wooden support, first level and anchor the support to the ground, using earth fill underneath and around it. The fill should raise the support sufficiently to keep the bottom of the pan above the level of surface water in rainy weather. Tamp the fill firmly between the support boards to within one-half inch of the top, thus leaving an air space between the bottom of the pan and the fill surface. This space will facilitate inspection of the pan for leaks while it is in use.

Center the pan on the support and fill with water to within 2 inches of its rim. This will require about 62 gallons of water. The combined weight of the pan and water (about 550 lb) should hold the pan securely in place.

STILLING WELL

Place the stilling well, for either the hook gauge or fixed-point gauge, in the pan about 1 ft from the pan's north edge. Level the top rim of the well, using the leveling screws in its base and a spirit level. The well, weighing about 10 lb, should rest firmly on the bottom of the pan, which must be free from buckling.

21.2 Supplemental Instruments

PRECIPITATION GAUGE

Install the precipitation gauge or gauges, as described in section 18.2, on the north side of the evaporation pan (fig. 15.2). This will avoid casting of shadows on the pan.

TOTALIZING ANEMOMETER

Install the anemometer, mounted on a display stand, on the northwest corner of the pan support (figs. 12.1 and 15.2). The stand is fastened with wood screws through holes provided in its base. The center of the cups should be 6 to 8 inches above the rim of the pan. In their northwest position, the cups may cast a shadow on the pan only during late afternoon. Some anemometers have a knurled retaining screw for mounting and height adjustment on the stand; tighten the screw only by hand.

WATER TEMPERATURE THERMOMETER

Float-Mounted Six's Thermometer—Position the thermometer by attaching a flexible line from each of the two floats to an anchor. The lines should be at least 10 inches long, but short enough to keep the thermometer 1 ft from the edge of the pan and the stilling well. Thermometer should rest one-fourth inch below the water surface; if necessary, adjust screws holding the bulb end.

Submerged-Mount Six's Thermometer—Fasten handle to the bulb end of the thermometer mount and hook the handle ring over the edge of the pan (fig. 12.1). Locate the mount on the south-side bottom of the pan, to shade thermometer as much as possible from direct sunshine. Submerge the unit gently.

CHAPTER 22. SOIL TEMPERATURE AND MOISTURE INSTRUMENTS

22.1 Soil Thermometers

LOCATION OF SOIL PLOT

The location chosen for exposure of soil thermometers should have natural soil and ground cover conditions that are representative of its general area. Ordinarily, the soil plot should be closely level, well-drained, and open to full sunshine throughout most of the day; it should not be subject to irrigation. Additional criteria are given in section 22.2, for plots where both soil moisture and soil temperature will be measured. When snowfall occurs, the soil plot should have representative snow cover. The plot should be as free as possible from nearby obstructions that affect the wind and lead to either localized drifting or scouring of snow.

Ground cover may be sod, where the climate and soil normally permit this, or other natural cover that is common to the area. Alternatively, the cover may be removed, by use of a hoe or chemical treatment, to create a bare soil plot.

Because the site will usually be within or adjacent to the plot where other weather or climatological measurements are taken, the above considerations should enter into the overall selection of station location. Suitable fencing or other protection should be afforded to prevent trampling of the soil plot.

INSTALLATION OF THERMOMETERS

Soil thermometers or sensing elements should be located centrally in their observation plot, in close contact with undisturbed soil. The soil should be free of insulating air spaces and artificial channels through which water can enter. When temperatures are measured at more than one depth, mercury-in-glass thermometers are installed along a horizontal line. Mercury-in-steel thermometer and electrical thermometer sensing elements are installed in a vertical line.

Mercury-in-Steel Thermometers—The following installation steps are based on U.S. Department of Commerce (1972) instructions:

1. Dig a small trench or pit immediately adjacent to and north of the observation spot. Existing sod cover should be carefully removed and set aside on boards or tarpaulin for later replacement (except where a bare soil plot is desired). The soil should be removed in layers and also set aside, or put in boxes, to be later replaced as nearly as possible in its original condition and order. The pit should be slightly deeper than the lowest sensing depth, to allow sufficient working space and also permit slight looping of the flexible thermometer cables. This will help prevent a moisture channel to the sensing element.

2. Position each sensing element (fig. 13.1), which is 13 inches long and five-sixteenths inch in diameter, with a rod of similar diameter and 18 inches long. The rod is pressed into the soil face on the south end of the pit, at the proper depth, and driven nearly its full length horizontally into the soil. It can be withdrawn by grasping firmly with pliers and turning or twisting slightly while tapping outward on the pliers with a hammer.

3. Carefully press each sensing element, by hand, into the hole formed in step 2. If too much resistance is met, the element should be withdrawn and the hole cleared again with the rod.

4. Replace the soil in the pit, in correct order of layers, to conform as nearly as possible to the original condition. The soil will usually require firm packing as each layer is replaced; this can often be facilitated by soaking the replaced layer. The added moisture will usually not move far enough laterally, before its depletion, to affect the soil in contact with the sensing elements. Finally replace the sod (where a sod cover is desired); the added moisture will help in renewing its growth.

Electrical Thermometers—The same procedure as above is followed for installing sensors such as thermistors or thermocouples (U.S. Department of Commerce 1972). For these smaller sensors (and probes), however, the rod used in step 2 should have a correspondingly smaller diameter—equal to or only slightly larger than that of the probe.

THERMOMETER HEAD SHELTER

The shelter protecting the soil thermometer heads should be located over or alongside the pit, about 1 ft from the south face, when mercury-in-steel thermometers are used (fig. 22.1). If the shelter is located over the pit, its supports can be set in the floor of the pit before replacing the soil. The shelter may be located away from the pit in the case of electrical sensors and their connecting wires to recording dials.

The height of the shelter above ground surface should be sufficient to make reading convenient within the limitations of the cable length. The 5-ft mercury-in-steel thermometer cable will permit a shelter height of about 2 ft, with the lowest sensing element at a 20-inch depth, allowing for a slight loop in the cable at the floor of the soil pit.

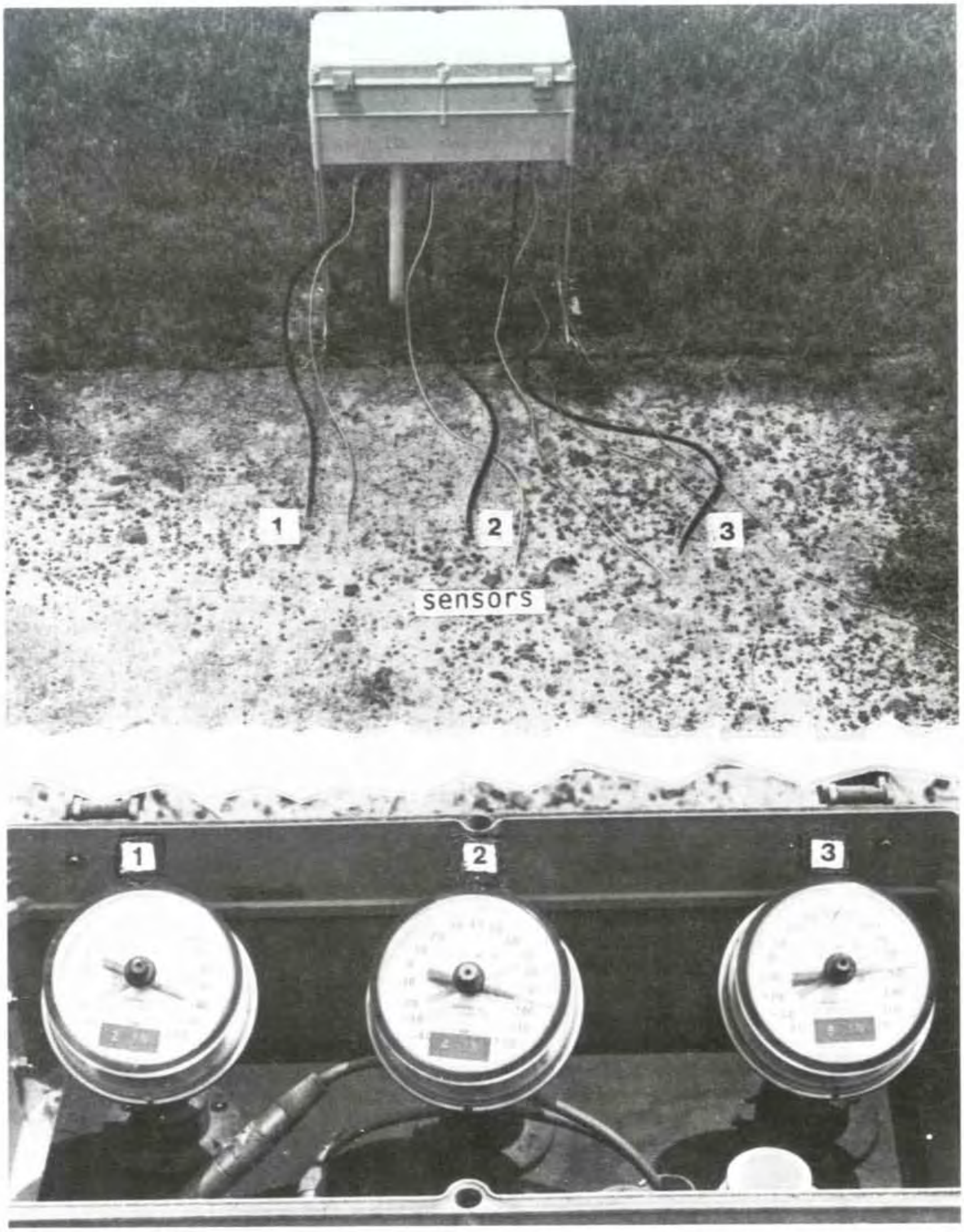


Figure 22.1—Top: a soil-thermometer installation in bare soil plot, with thermometer-head shelter alongside plot. Bottom: thermometer heads inside shelter. (Photo from National Weather Service.)

22.2 Soil Moisture Meters

SITE SELECTION

Because of large, local variations in soil moisture, observation sites must be carefully selected to be typical of their surroundings (World Meteorological Organization 1983). With respect to topography, a site is considered typical of surroundings if it is situated on level ground or on a slope of uniform aspect and inclination. Soil type, depth of water table, obstacles, and land-use practices must also be considered. When observations are for hydrological uses, the site should be typical of the watershed in slope, soil cover, and exposure for the elevation selected (USDA SCS 1972); steep slopes should be avoided. No standard measurement depths are specified, but depths as great as 3 to 6 ft may be required for hydrological and other purposes.

ELECTRICAL RESISTANCE METERS

Installation of electrical resistance blocks (or units) requires excavation of a pit, with soil carefully set aside and later replaced, in a manner largely similar to that described for soil thermometers (section 22.1). The depth will often be greater, however, and a post-hole digger will thus be helpful. After the pit is dug (USDA SCS 1972), the resistance units are placed in holes extending 2 to 6 inches into undisturbed soil in the uphill face, which must be vertical. The bottom unit is installed first, and each successively higher unit is installed after first refilling and packing the pit up to that unit's level.

The wires leading from the resistance units are run though a vertical pipe set in concrete. The pipe, 2 inches in diameter, should be placed about 3 ft from the units and 2 to 3 ft deep into the soil. The pipe should be long enough to protrude above maximum snow cover during the months of soil moisture measurement. One cubic foot of concrete around the pipe should be adequate, and wires must not be imbedded in the concrete. A 6-inch nipple and a cap are used at the top of the pipe to hold a terminal strip for the wires. Further details are given by the USDA Soil Conservation Service (1972).

NEUTRON PROBE

Use of a neutron probe requires installation of an access tube or pipe vertically into the soil. The pipe, usually made of steel or aluminum, has a diameter of about 1½ to 2 inches, depending on the probe's outer diameter. The pipe should be watertight and the bottom sealed. It should fit tightly in the soil, without any cavity between the soil and pipe. The pipe extends a few inches above the ground and is capped.

To obtain a tight fit, the access pipe may be installed in a hole drilled with a soil auger having a slightly smaller diameter (World Meteorological Organization 1983). Where a larger hole is dug, the space around the pipe must be carefully refilled and packed, using soil corresponding to the layers that were removed. A depth of at least 3 ft is used by the USDA Soil Conservation Service (1972).

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:

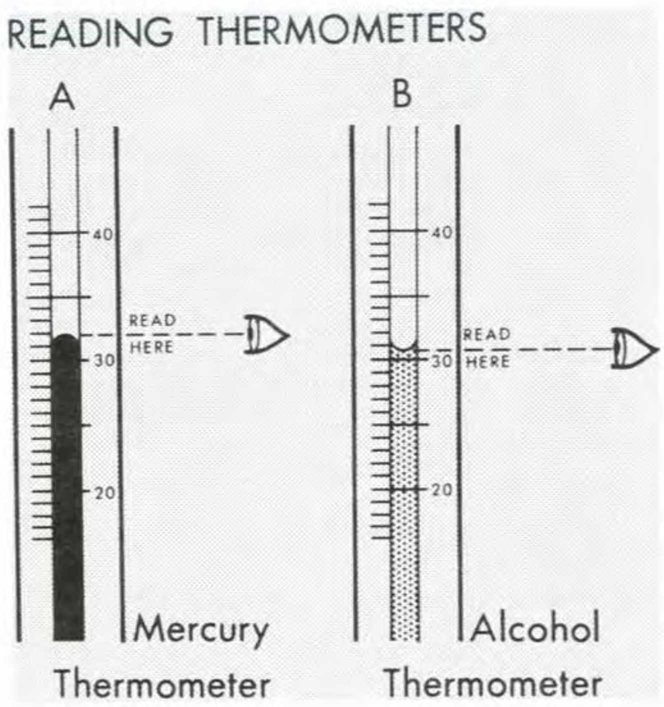


Figure 23.1—Reading thermometers; diagram shows correct eye position for avoiding parallax error.

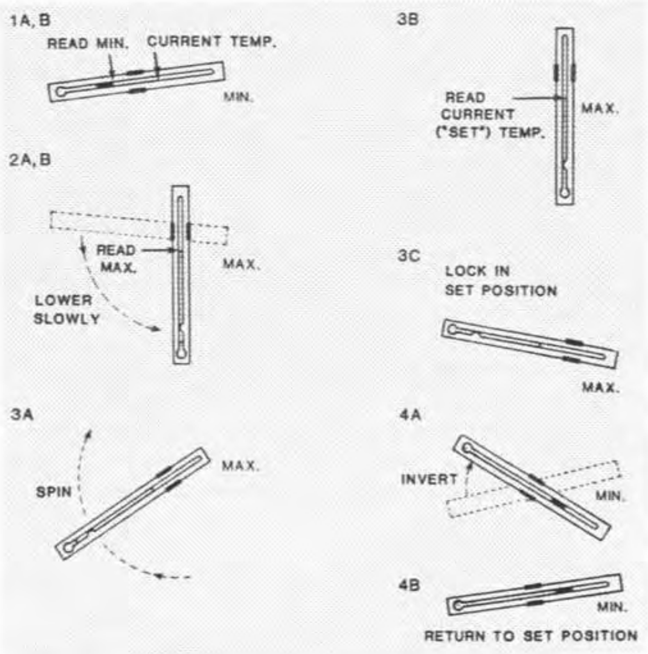


Figure 23.2—Reading and setting standard liquid-in-glass maximum (MAX.) and minimum (MIN.) thermometers. (Adapted from U.S. Department of Commerce 1972.) Panel numbers correspond to instruction numbers in text, section 23.2.

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.

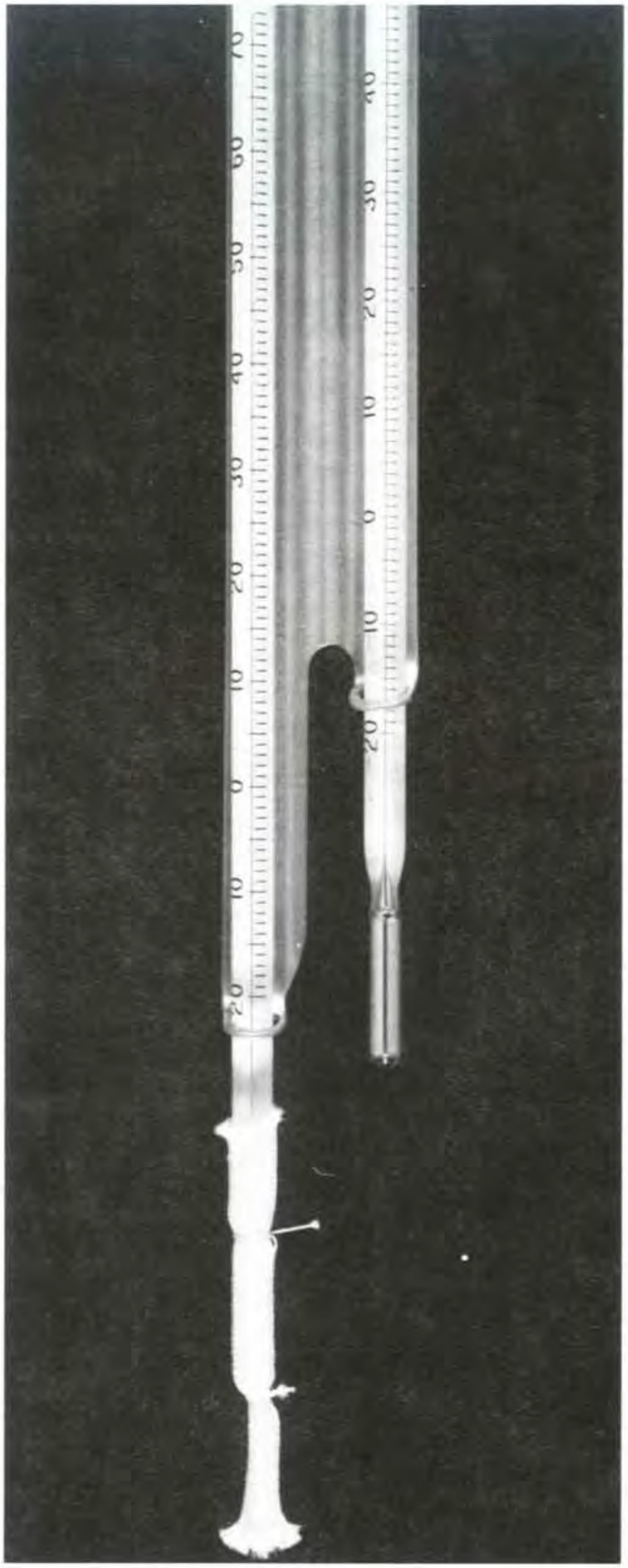


Figure 23.3—A properly installed psychrometer wick.

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.

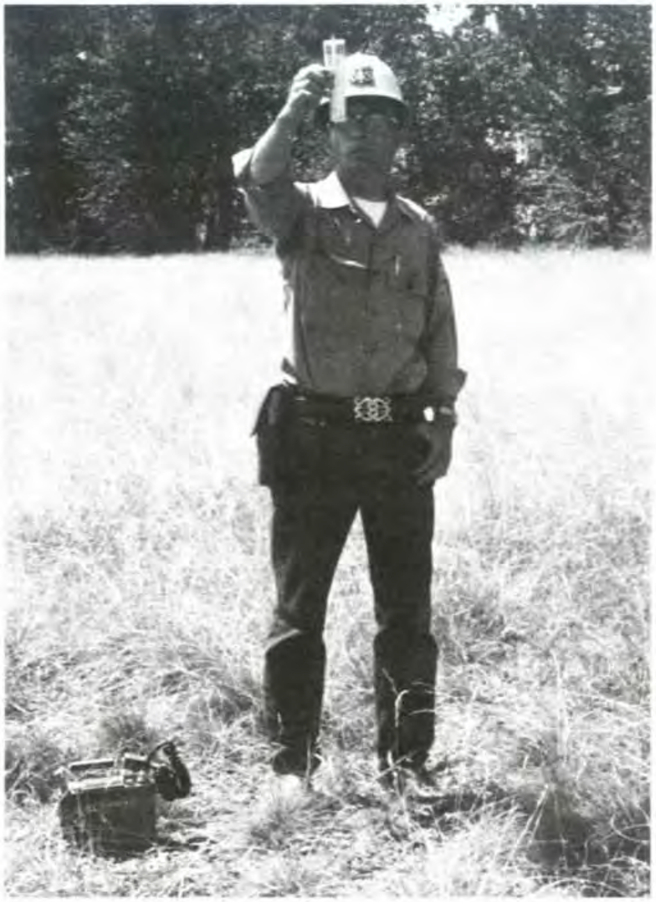


Figure 24.2—Use of Dwyer hand-held wind meter, facing into wind. Keep fingers clear of top stem when measuring winds less than 10 mi/h.

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.

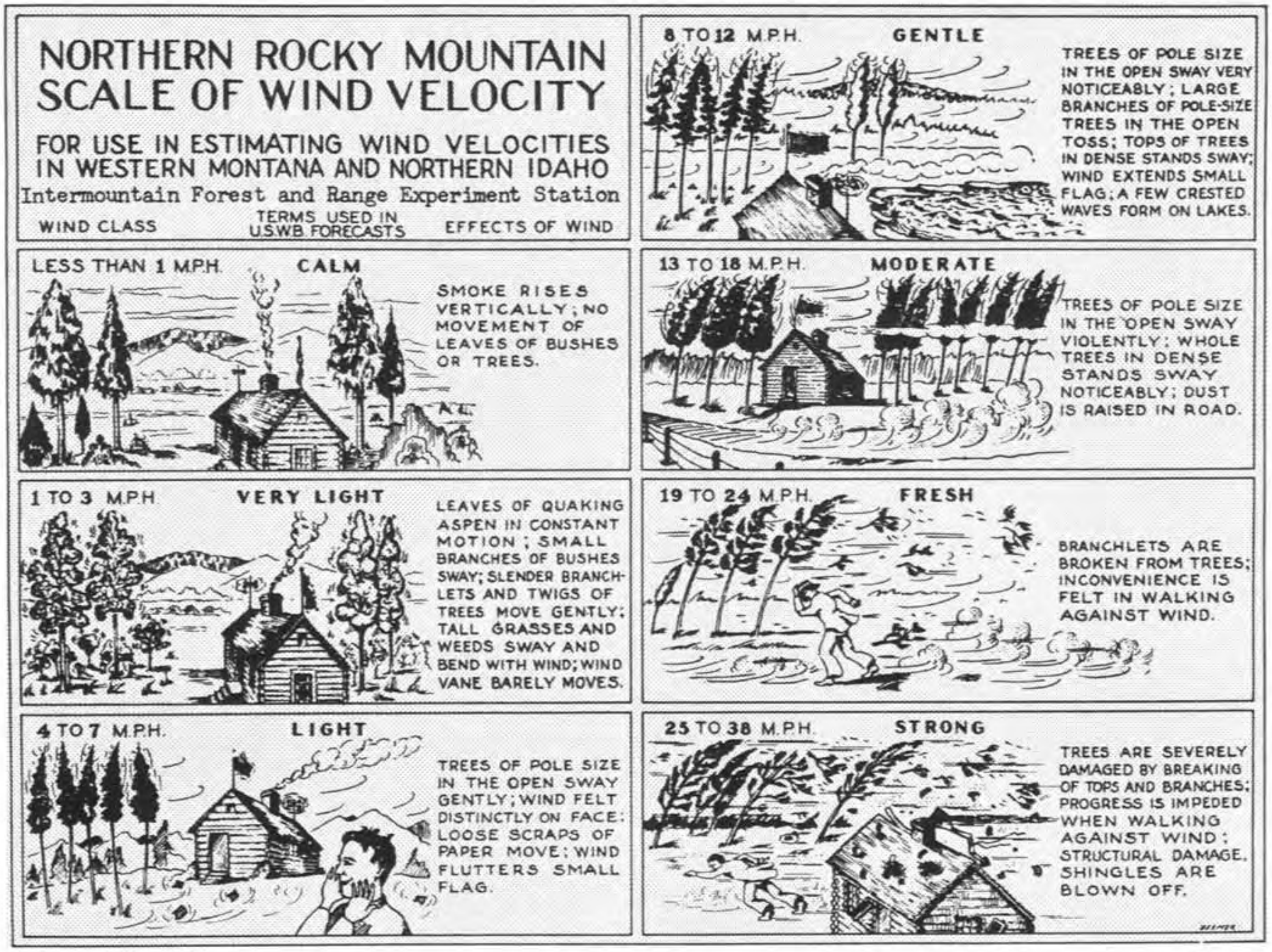


Figure 24.4—Modified Beaufort wind scale, devised for Northern Rocky Mountain area. (From MacCready and others 1955).

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.

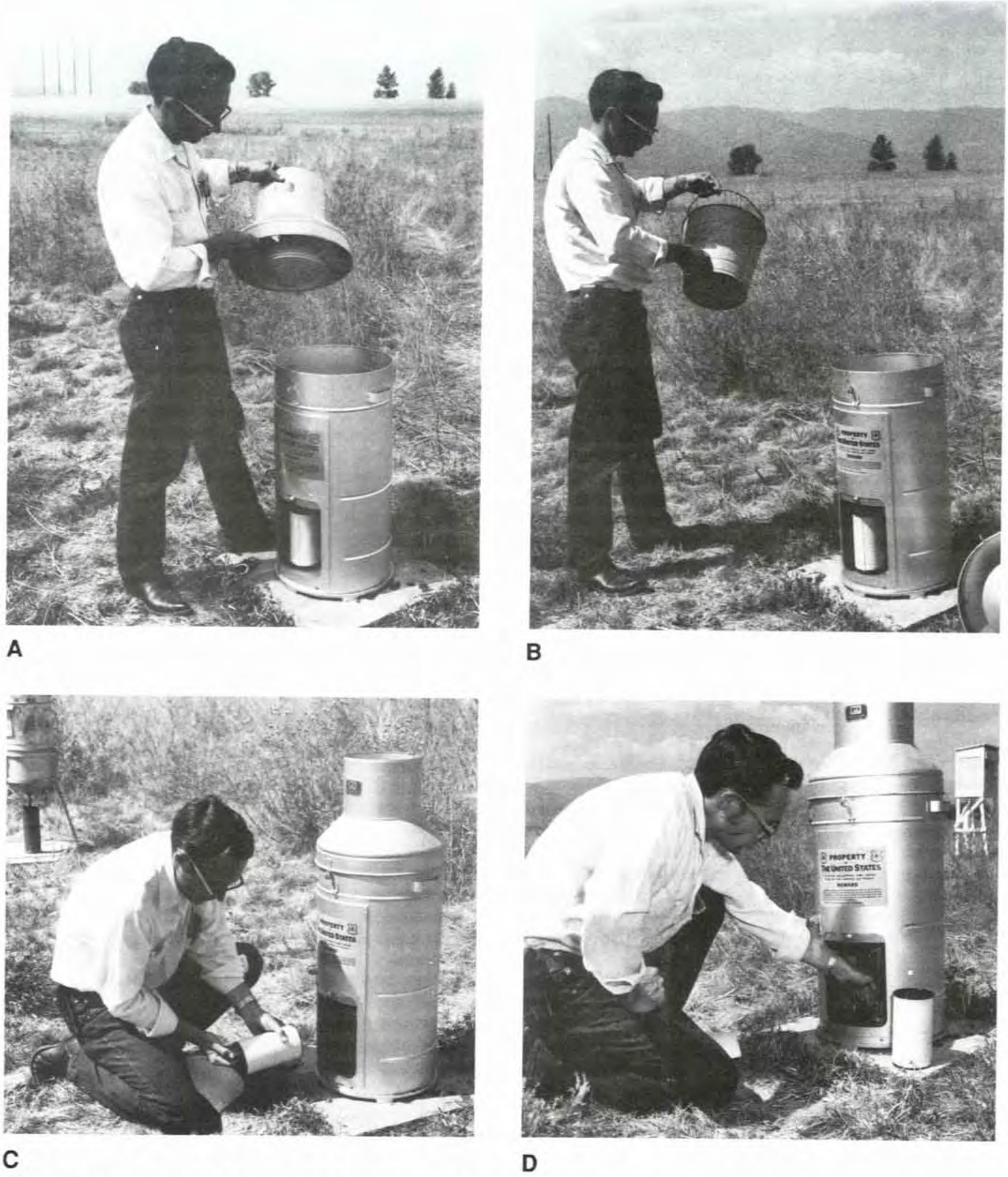


Figure 25.1—Operating procedure for Universal weighing gauge: A, remove the collector, after releasing pen from chart; B, empty bucket; C, remove chart drum and install new chart; D, wind clock; E, replace chart drum and zero the pen.

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).

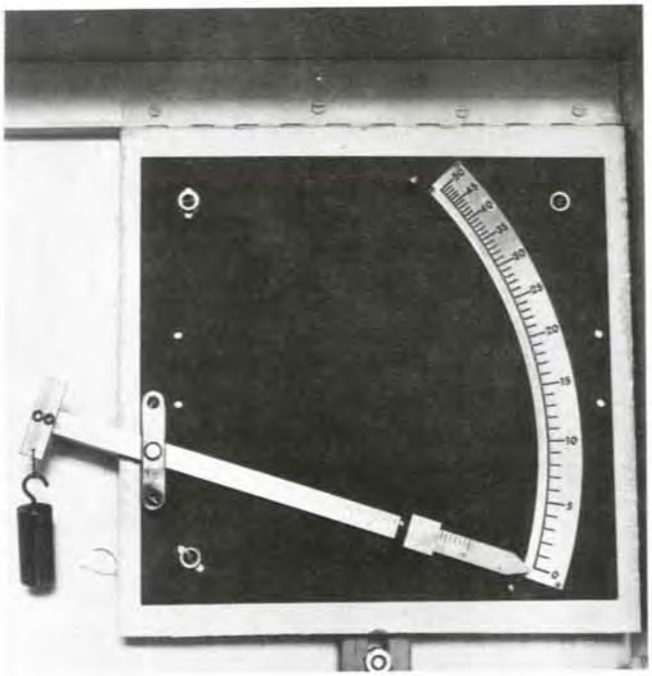


Figure 26.1—Use of a 100-gram test weight to check calibration of the Forester scale.

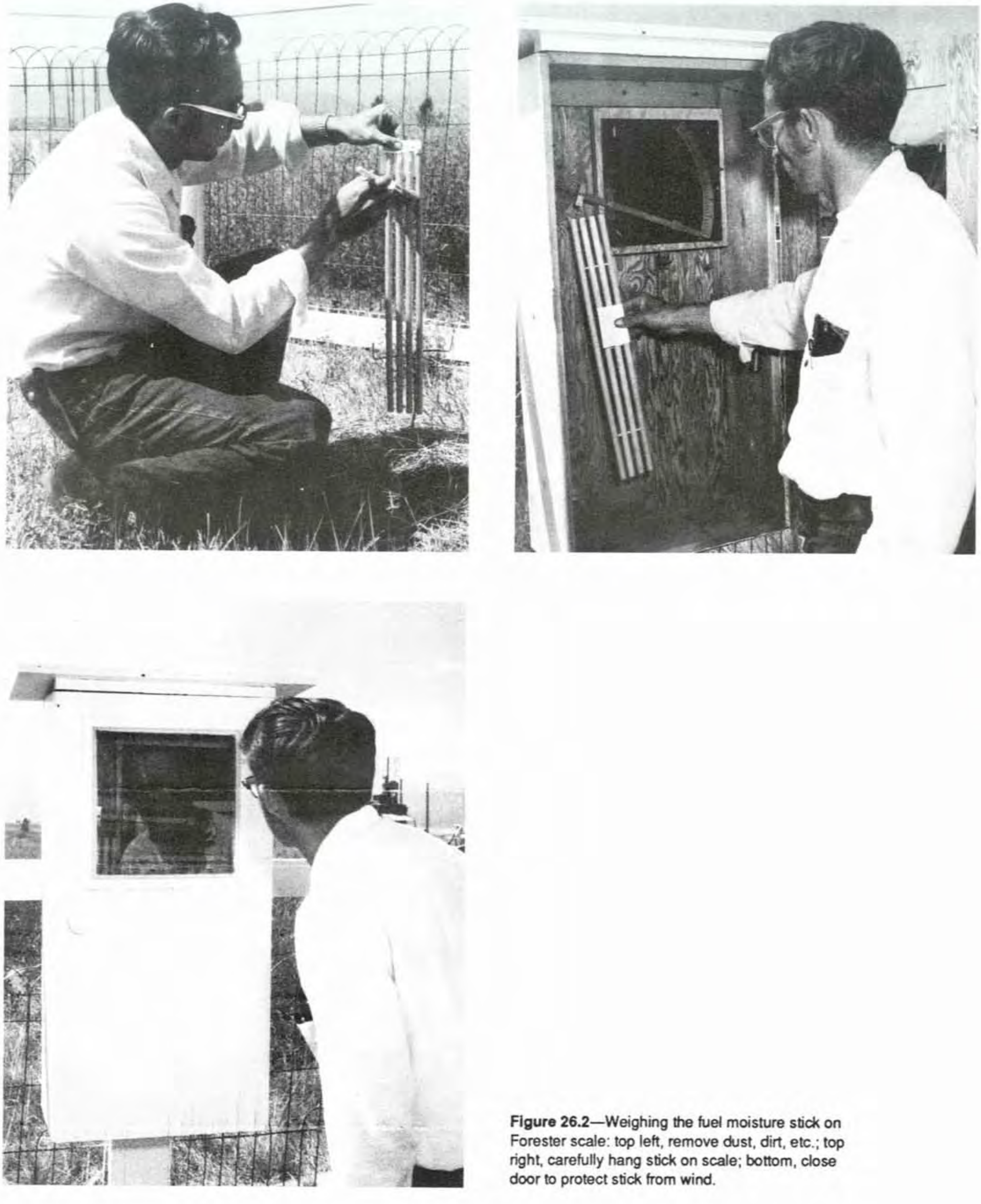


Figure 26.2—Weighing the fuel moisture stick on Forester scale: top left, remove dust, dirt, etc.; top right, carefully hang stick on scale; bottom, close door to protect stick from wind.

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.

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).

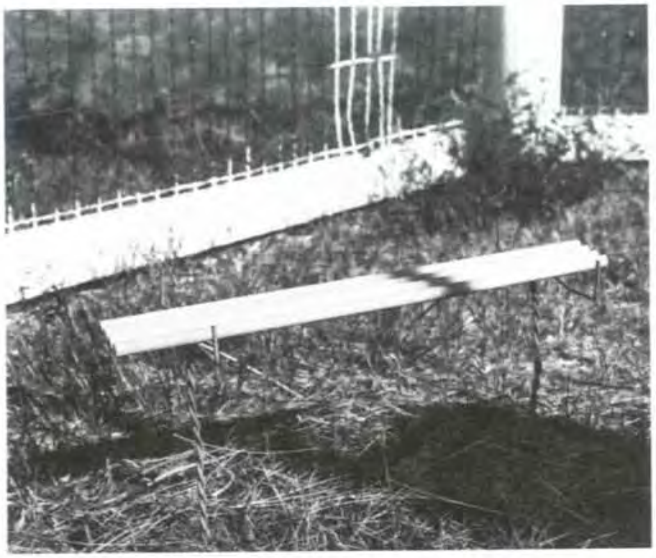


Figure 26.4—After weighing, replace the stick on wire rack, with hook to north and brads facing downward.

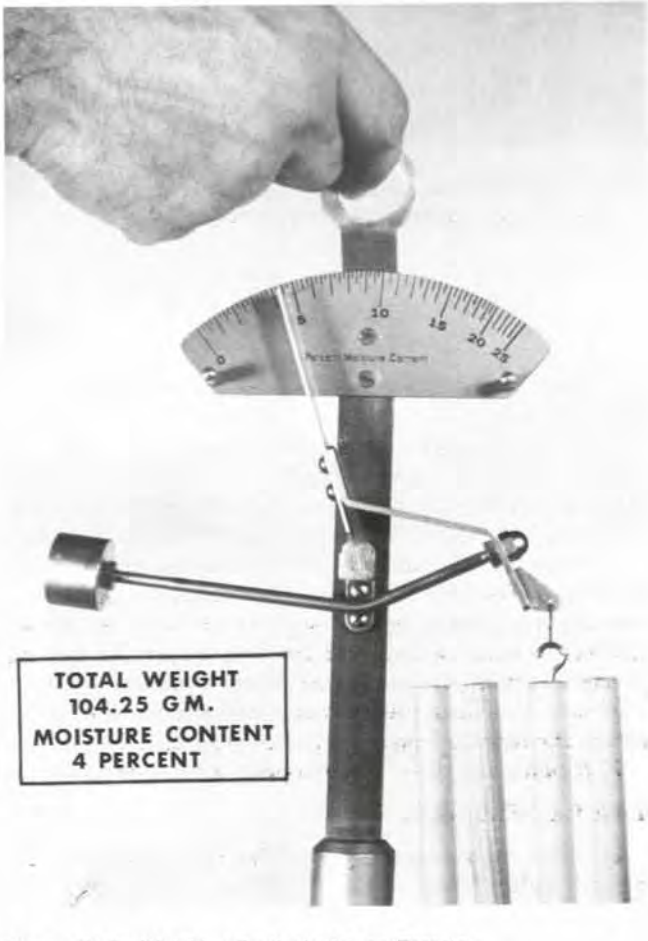


Figure 26.5—Weighing the fuel stick on Forester (Chisholm) portable scale. The stick weighs 104.25 grams, so its moisture content is 4 percent as indicated by the pointer.

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.

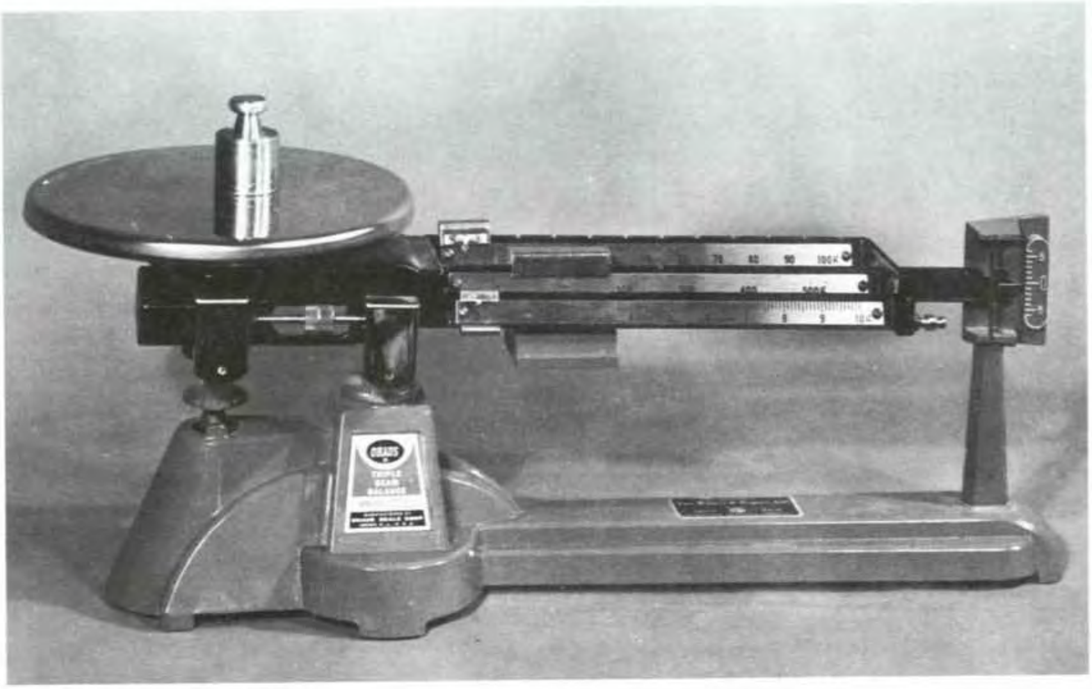


Figure 26.8—Checking the balance of triple beam balance.

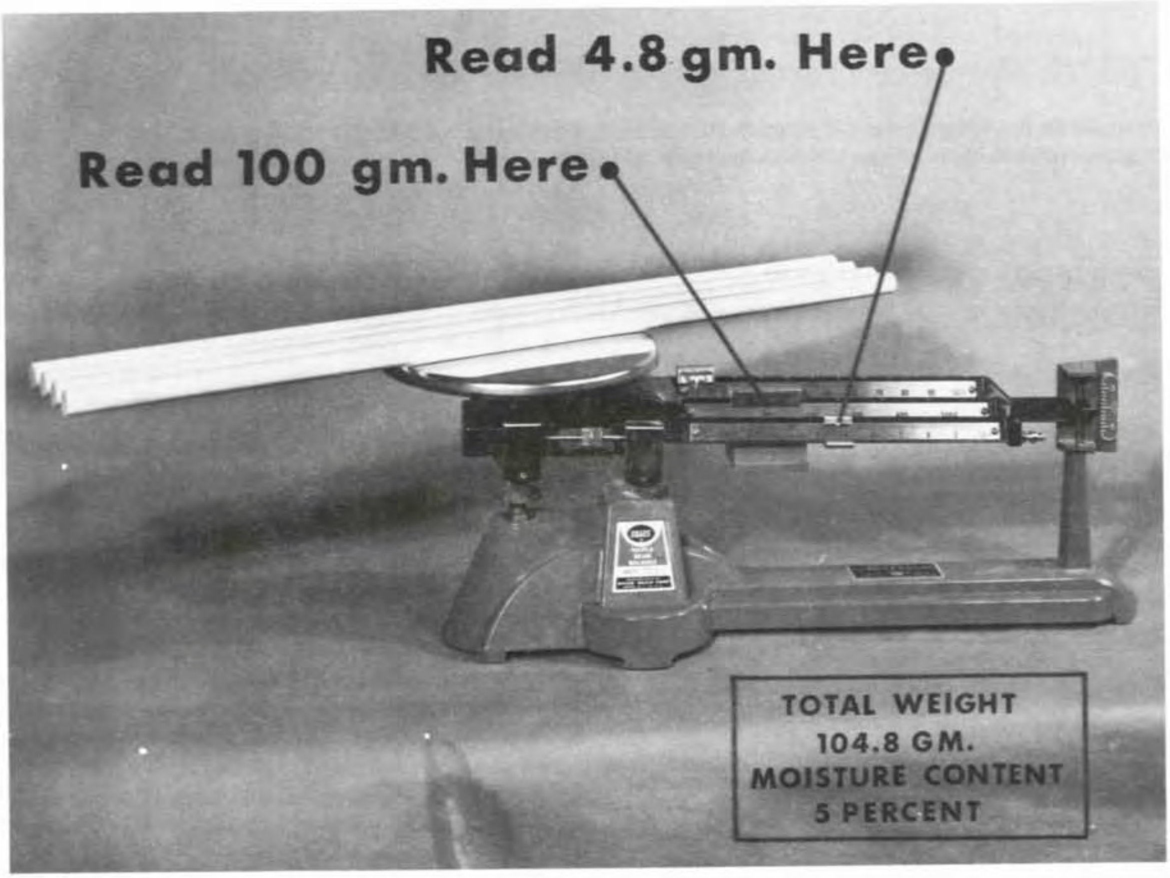


Figure 26.9—Weighing the fuel stick with triple beam balance. The stick weighs 104.8 grams, so its moisture content is 5 percent as indicated on the first scale bar.

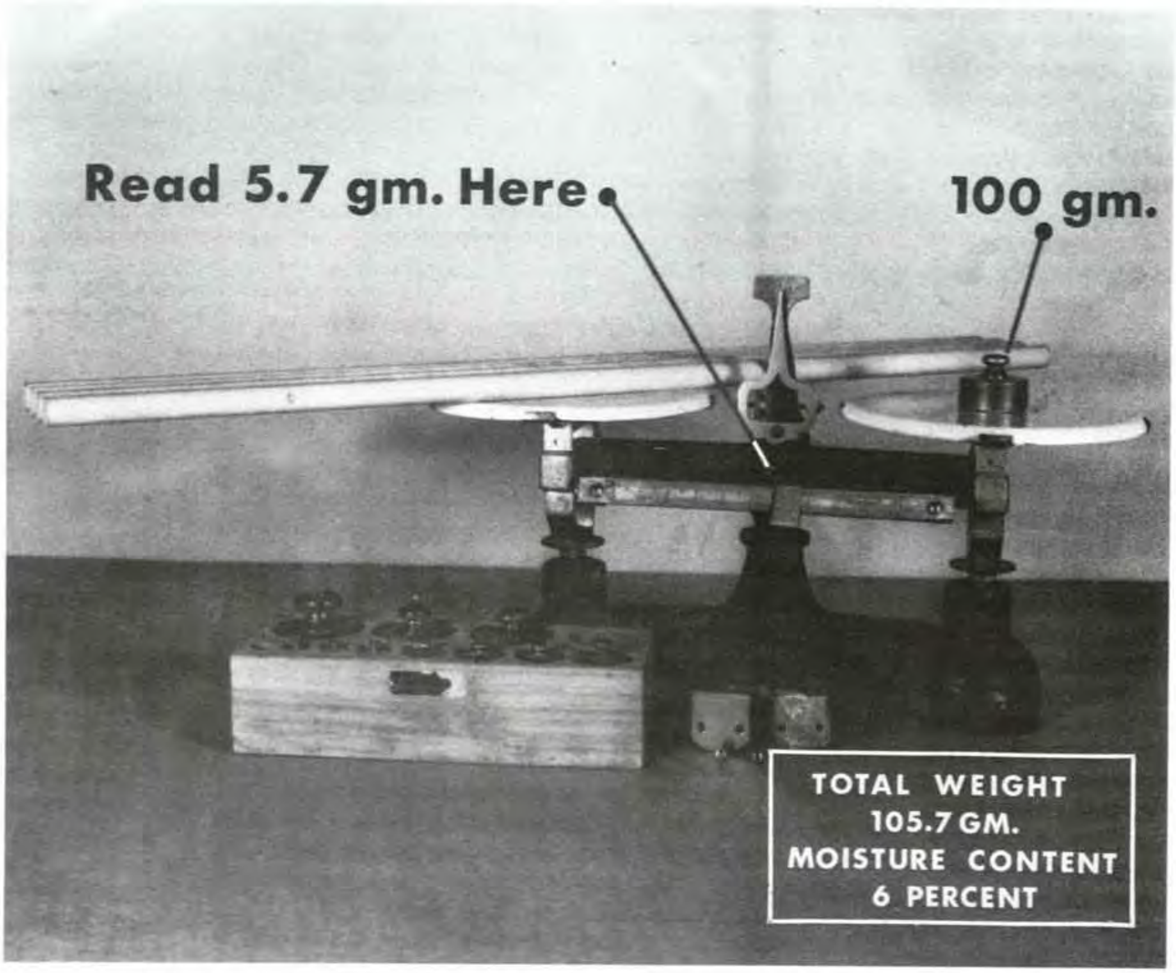


Figure 26.10—Weighing the fuel stick with Harvard balance. The stick weighs 105.7 grams, so its moisture content is 6 percent as indicated on the scale.

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.

PART 2D. MANUAL WEATHER STATIONS: MAINTENANCE

CHAPTER 29. GENERAL MAINTENANCE PRINCIPLES

Proper maintenance of observational equipment is essential toward obtaining reliable, accurate weather data. Equipment must be in good operating condition, and this cannot be assured without a program of regular inspection and maintenance.

Specifically who should perform the maintenance will depend on the job and available facilities. Routine and simple maintenance can be accomplished by the observer, but the more detailed and technically difficult maintenance will generally require the skill of a specialist. Agencies or offices that have electronics technicians on staff often assign the bench maintenance of weather instruments to these persons. Some agencies train a fire control technician specifically for the instrument maintenance and accomplish this work at a central location during the quiet, off-season months.

If trained personnel are not available, the work can be contracted to a local shop or clock repairman. Alternatively, the equipment can be returned to the manufacturer for service.

Checklists to aid and evaluate fire-weather station maintenance are presented in appendix 4. Frost and Haines (1982), using the form in figure A4.2, found that the general maintenance of fuel moisture sticks and fuel moisture scales scored lowest among seven equipment categories. This finding was for stations (in the Northeastern States) not previously inspected. These two categories showed a noticeable improvement, however, at stations having repeated inspection.

29.1 Basic Maintenance Program

A program of regular maintenance of weather instruments should include:

1. Daily and periodic maintenance throughout the service life of an instrument. This maintenance includes (1) routine cleaning, (2) lubrication, (3) calibration checks and necessary adjustments, and (4) prompt repair or replacement of worn or broken parts. The first three measures can often be accomplished by the observer.
2. Annual or semiannual inspection and general service. At this time, an instrument should be brought to the workbench, disassembled, and closely inspected for wear and defects. This job requires a trained technician. If necessary the instrument should be replaced. Some types of equipment, particularly anemometers, do eventually wear out; some models may become obsolete.
3. Following repair or replacement of worn or broken parts, an instrument should be carefully tested to ensure that all components are operating properly and that it is accurately calibrated.
4. If an instrument is not returned to operation following the annual check, it should be properly stored until needed again.

29.2 Maintenance Equipment

Maintenance of weather instruments will be easier and more efficient if the proper tools are readily available. The presence of the correct tool or service item may often determine whether or not it is possible to perform the required maintenance. For this reason, appropriate tool caches should be provided both at the weather station and at a maintenance workbench.

STATION TOOL CACHE

The cache of tools (and other materials) at the station can be housed in a small, moistureproof box attached to a fencepost or the anemometer pole. A shelf in the cabinet recommended for wind readout devices (fig. 17.8) can be used. The cache should include the following items:

1. Clean wiping cloths.
2. Assorted soft brushes for dusting instruments, hygrothermograph hairs, and fuel sticks.
3. Needle-nose pliers.
4. Small- and medium-size screwdrivers.
5. Medium-size carpenter's level.
6. Anemometer oil.
7. Light instrument oil (sewing machine oil, gun oil, etc.).
8. Charts for recording instruments (hygrothermograph, rain gauge).
9. Ink for recording charts.
10. Clean psychrometer wicking; heavy duty white thread for fastening the wick.
11. Small, sharp scissors or single-edge safety razor blade.

WORKBENCH ITEMS

A more complete cache of tools and other equipment is required for annual or bench maintenance of instruments. In addition to the above list, the following items should be available:

1. Supply of fresh batteries.
2. Spare thermometers.
3. Nonflammable cleaning solvent for instruments.
4. Toothbrushes.
5. Battery tester.
6. Continuity tester (volt-ohm meter).
7. Anemometer calibration device.
8. Soldering gun and rosin-core solder.
9. Crocus cloth.
10. Special lubricants.
11. Hygrothermograph hair elements.
12. Hygrothermograph and recording rain gauge pens.
13. Lampblack oil color.
14. Hard-finish paper.
15. Compressed air.

Maintenance instructions for the equipment most widely used at standard fire-weather stations are given in chapters 30 through 33. Much of the content also applies to climatological and evaporation stations; instructions for additional types of equipment are given in chapters 34 through 36. The chapter format includes general instructions that pertain to all instruments of a basic type, in addition to instructions for specific makes or models. For further details, including maintenance of less commonly used and newer or more complex instruments, consult existing instruction manuals provided by the manufacturers. Such manuals should be kept in a designated place for ready reference.

CHAPTER 30. TEMPERATURE AND HUMIDITY EQUIPMENT

30.1 Instrument Shelters

COTTON REGION SHELTER

Maintenance of the standard wooden, cotton region shelter consists of periodic cleaning or dusting, occasional repainting, checking structural condition and rigidity, and necessary repairs. Repairs may include tightening or replacement of loose, broken, rotting, or missing boards.

The frequency of required painting, as evident from signs of weathering, cracking, peeling, etc., of the exterior surfaces, will vary with the location's climate and air quality; also with the quality of the paint job (including surface preparation). The frequency may average once every 3 years, but the time interval can vary from 1 to 5 years. A good white, low-gloss latex paint is recommended for best performance. Repainting may often be unnecessary at these times for the protected interior surfaces, although they should be kept in clean, sound condition.

Traditionally, white paint has been standard for both the inside and outside surfaces of the instrument shelter. The white color is more critical for the outside surfaces, to reflect solar radiation. It may actually be advantageous to have less reflective interior surfaces, to deter reflection of stray radiation onto the temperature sensors. (Thus, some metal or plastic solar radiation shields come with dark-painted interior surfaces.)

30.2 Thermometers and Psychrometers

Great care must be exercised in maintenance of thermometers, particularly the traditional, fragile glass types. Whenever possible, handle a glass thermometer in its mounting frame (metal or plastic backing). Be especially careful not to strike the bulb against any object.

Thermometer maintenance is concerned mainly with cleaning, restoring worn or faded markings, and, most importantly, recognizing and correcting defects.

CLEANING

To help keep thermometers and mounting frames clean, dust regularly with a soft brush. Periodically, the thermometer should be removed from its frame and both the thermometer and frame washed with detergent and water. Use vinegar or a nonflammable cleaning solvent to remove stubborn dust or corrosion. Rinse thoroughly in clean water. When remounting a thermometer in its frame, be careful not to use excessive force in fitting the mounting brackets against the glass tube. A difficult fit may indicate a bent bracket; tightening the screws in such a case may crack the glass.

RESTORING WORN MARKINGS

With time, the scale markings (and numbers) etched on a thermometer stem may become worn and, consequently, difficult to read. These markings can be renewed by spreading a small amount of lampblack oil color on the stem and immediately rubbing off the excess with a piece of hard-finish paper. The lampblack oil color is obtainable at art supply stores and some paint stores. Otherwise, the markings can be restored temporarily by lightly rubbing a pencil against the scale; or, if available, a reliable spare thermometer can be substituted.

THERMOMETER DEFECTS

Liquid-in-glass thermometers should be checked periodically for two types of defects (fig. 30.1):

1. Fractured constrictions in maximum thermometers.
2. Separated alcohol or mercury columns.

Fractured Constrictions—As described in section 7.4, the standard maximum thermometer has a constriction in the capillary, just above the bulb. This constriction allows the mercury to move upward as the temperature rises but does not allow the mercury to retreat into the bulb when the temperature falls. The mercury trapped above the constriction is free to slide in the capillary; this is not a defect.

Because of this sliding tendency, however, the thermometer must be *slowly* lowered to the vertical position before reading. If the thermometer is *abruptly* lowered, particularly with a very high maximum temperature (long column of mercury), the sliding column might hit the constriction with enough force to fracture it. Even if no fracture occurs, mercury may be forced back through the constriction, causing an erroneously low temperature reading. The constriction is more prone to damage during resetting, if the thermometer is spun before the mercury comes to rest in the vertical position.

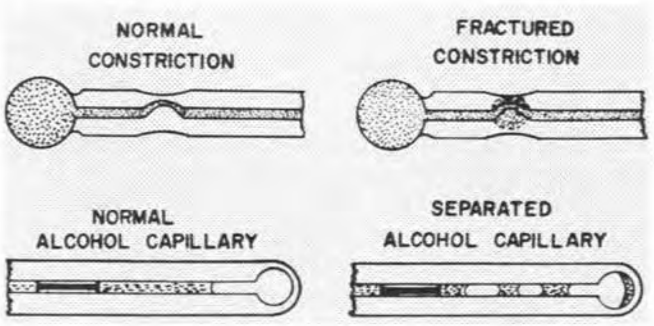


Figure 30.1—Thermometer defects: top, normal and fractured constrictions in maximum thermometers; bottom, normal and separated alcohol columns in minimum themometers.

The result of a fractured constriction is that the mercury can freely retreat into the bulb when the temperature falls. The mercury will not remain at the actual maximum temperature. The defective thermometer, termed a "retreater," must be replaced.

Fractured constrictions may sometimes be difficult to detect, particularly when the maximum thermometer is read near the time of maximum temperature occurrence. These defects should be suspected when the maximum temperature reading is often more than 1.0 °F lower than the "set" reading at the previous observation. Defects can be more easily verified by comparison with a hygrothermograph trace or by supplementary early morning readings of the maximum thermometer.

Separated Columns—A separated column is one in which portions of the mercury or alcohol become separated from the main column. Column separation is common in thermometers, particularly after transit or other situations producing excessive jarring. In alcohol thermometers, column separations may appear as small bubbles. These can be caused by a distillation tendency during warm weather; alcohol vapor condenses in the upper portion of the bore. Column separation may entrap the minimum thermometer index rod.

REJOINING SEPARATED COLUMNS

Separated columns can usually be reunited by one of the following methods: tapping, applying centrifugal force, and heating. The procedures follow:

Tapping—Grasp the thermometer securely in one hand, slightly below the middle with bulb end down, by curling the fingers and thumb around the edges of the mounting frame. Do not touch or press on the glass tube itself, or this may crack during tapping. Be sure that the thermometer is fastened securely to its frame. Strike the edge of the frame against the palm of the other hand. Repeat several times as necessary, or until success is doubtful.

In cases where a short segment of mercury is lodged in the upper end of the bore, hold the thermometer inverted (bulb end up) during the tapping. This procedure is particularly suited for a maximum thermometer; the heavier, main column of mercury above the constriction will easily slide to unite with the short segment.

Use of Centrifugal Force—Grasp the thermometer securely as in the tapping method, except grasp the thermometer slightly above the middle and hold it with the bulb end pointed outward. With the arm extended in a near-horizontal position, swing the thermometer rapidly downward; stop abruptly when the thermometer has reached a vertical position. Repeat several times as necessary. Be sure that the thermometer is securely mounted and has sufficient clearance from obstructions.

With a minimum thermometer, the downward swings can be started with the arm extended upward, giving an arc of 3 or 4 ft. Swings with a maximum thermometer must always be started with the arm at or slightly below the horizontal, with the mercury column resting against the constriction; otherwise, the constriction may be fractured.

Alternatively, a minimum thermometer can be whirled rapidly on a strong cord, wire, or chain that is fastened through the hole near the top of its mounting frame. The cord or chain can be grasped directly or attached to a sling psychrometer handle; the cord length should be about 8 inches.

Heating—Heating the thermometer bulb is often the quickest and most successful method of repairing column separations. The heat can be applied by holding the bulb under a faucet of hot running water or by immersion in a pan of slowly heating water. Take care to remove the bulb from the water before the mercury or alcohol column rises too far into the expansion chamber at the top of the thermometer bore. The procedures for reuniting the columns are:

1. *For a minimum (alcohol) thermometer,* heat the bulb in the above manner until the main column enters but does not completely fill the expansion chamber. This heating should force all air bubbles up the bore and into the expansion chamber, where they should rise above the alcohol. *Do not let the alcohol completely fill the expansion chamber*—continued heating and resulting internal pressure will rupture the thermometer tube (at either the bulb or top).
2. *For a maximum (or mercury) thermometer,* if there is only one separated column segment, first try method 1 (tapping) with the thermometer bulb inverted. If, however, there are several small, separated column segments, apply heat until a small amount of mercury enters the expansion chamber. Holding the thermometer securely, as in method 1, quickly tap the edge of the mounting frame a few times. Allow the thermometer to cool and then see if the column is reunited; if not, repeat the entire procedure. Repeat for each column segment. *Do not let the mercury completely fill the expansion chamber.*

Whatever method has been used, after separations in an alcohol thermometer have been reunited, hang the thermometer in a vertical position (bulb down) for several hours. This will permit any alcohol that is clinging to the sides of the bore to drain down into the column.

Additional maintenance instructions for thermometers follow.

30.3 Maximum and Minimum Thermometers

STANDARD THERMOMETERS WITH TOWNSEND SUPPORT

Annual Maintenance, Thermometers—(Refer to figure 30.2.)

1. Remove the upper and lower retaining strips (as shown at E) and lift the thermometers from their mounting frames (metal backing) (D). Carefully set aside the tiny retaining screws.
2. Use a detergent and water to clean the thermometers and metal backing. Remove stubborn dirt or corrosion with nonflammable instrument-cleaning solvent or vinegar.

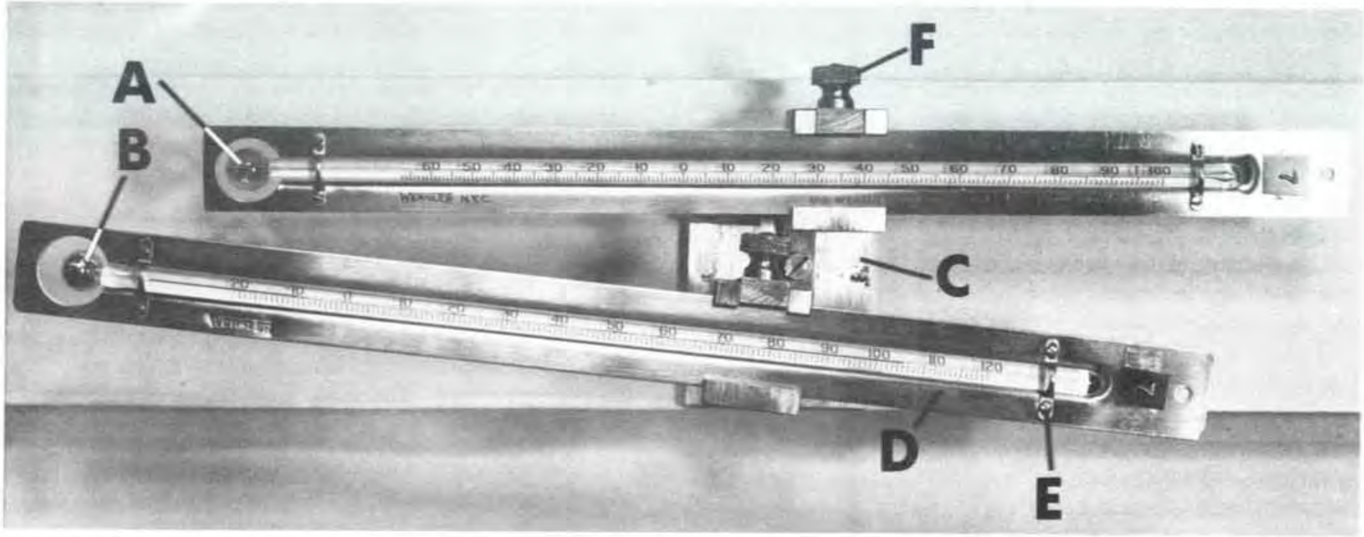


Figure 30.2—Standard liquid-in-glass maximum and minimum thermometers mounted in Townsend support: A, minimum thermometer; B, maximum thermometer; C, Townsend support; D, thermometer mounting plate; E, thermometer retaining strip and screws; F, Townsend support thumbscrew.

3. Carefully check the thermometers for defects (section 30.2). Repair or replace as necessary.
4. If the scale markings are worn, renew according to instructions in section 30.2.
5. Reassemble the thermometers securely in their metal backing.

Annual Maintenance, Townsend Support—(Refer to figure 30.3.)

1. Remove the screw (A) that holds the spinning clamp (B) to its shaft (D), and slide the clamp off shaft.
2. Wash all parts thoroughly with instrument-cleaning solvent.
3. Clean the oil hole (C) on spinning clamp.
4. Apply a drop of light instrument oil on spinning shaft (D) and replace clamp (B).

Periodic Maintenance—

1. Add one drop of oil through the oil hole (C) (fig. 30.3) on the spinning clamp as needed.
2. Check both thermometers for defects (section 30.2).
3. Check the thumbscrews (F) on clamps for tightness.
4. Dust the thermometers with a soft brush to remove any accumulated dirt. If necessary, use facial tissue moistened with water; dry with tissue.
5. Remove any accumulated dirt from Townsend support.

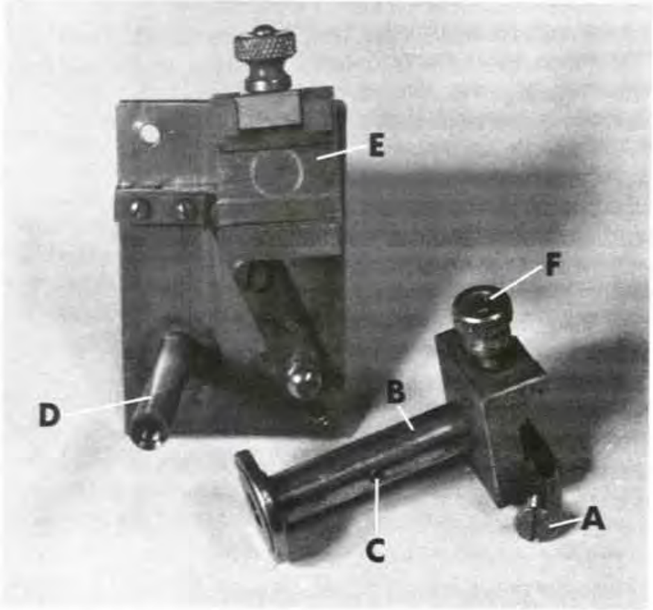


Figure 30.3—Disassembled Townsend support: A, spinning (maximum-thermometer) clamp; B, spinning-clamp retaining screw; C, oil hole; D, spinning-clamp shaft; E, minimum-thermometer clamp; F, thumbscrew.

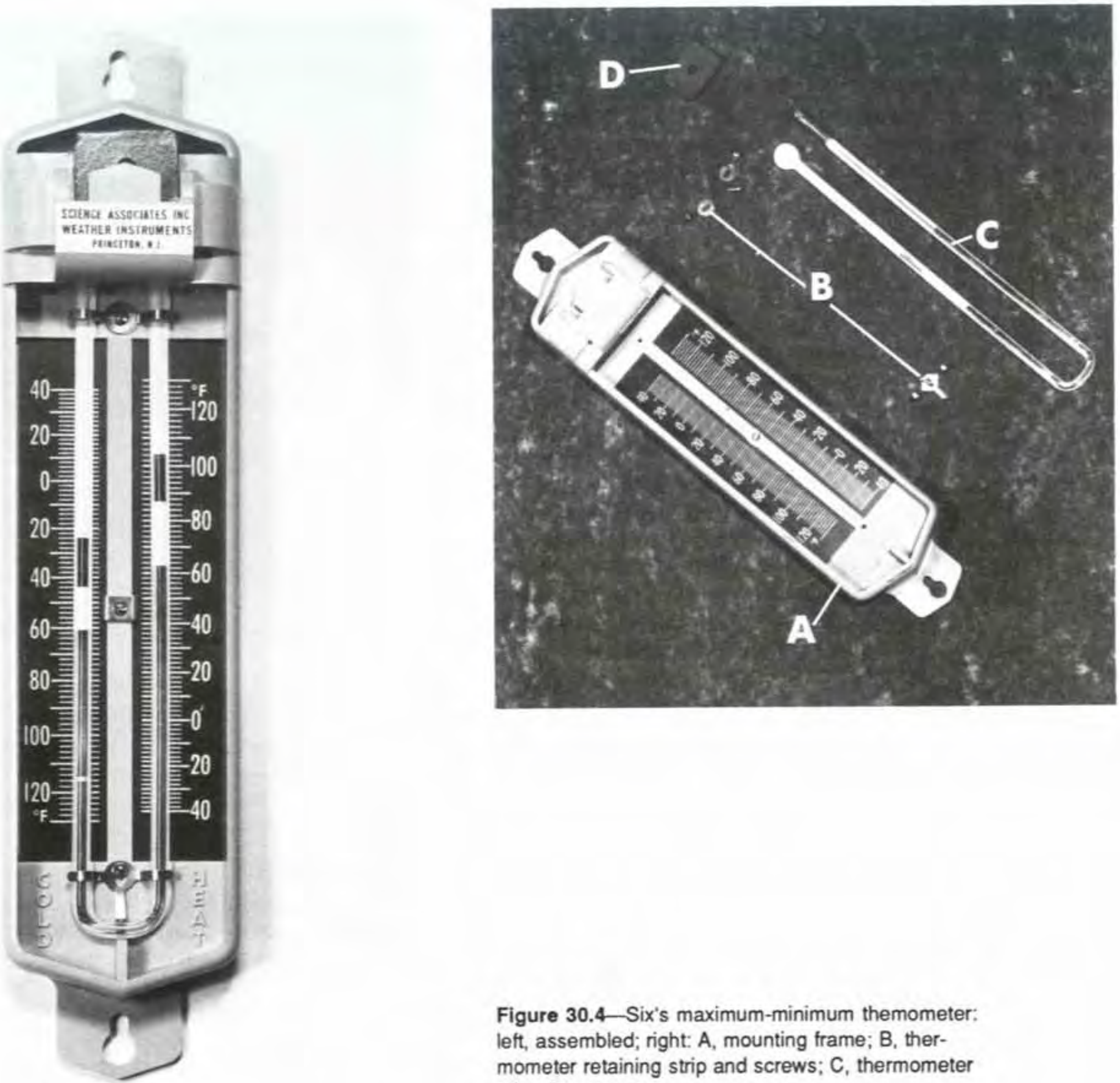


Figure 30.4—Six's maximum-minimum themometer: left, assembled; right: A, mounting frame; B, thermometer retaining strip and screws; C, thermometer tube; D, magnet.

SIX'S THERMOMETER

Annual Maintenance—(Refer to figure 30.4.)

1. Remove the upper and lower retaining strips (B) and very carefully lift the thermometer tube from its mounting frame (A).

2. Clean the thermometer and frame with detergent and water. Use instrument-cleaning solvent or vinegar to remove stubborn dirt or corrosion; do not use the solvent on plastic surfaces.

3. Reassemble the thermometer securely in its frame.

4. Inspect the thermometer for defects.

a. If column is separated, grasp the instrument's mounting frame securely with curled fingers and thumb; *do not* touch or press on the glass tube itself. Hold horizontally with the bottom of "U" tube pointed outward. Swing the hand forcefully downward in an arc, as described in section 30.2.

b. If either of the index rods is caught in the mercury column, attempt to correct this also by the procedure just described.

c. If an index has entered into a bulb at the top of the thermometer tube, first attempt to free the index by using the magnet (D). If this does not succeed, gently tap the bulb to manipulate the index at least partially into the bore; then draw it completely into the bore with the magnet.

Periodic Maintenance—

1. Dust thermometer tube with a soft brush to remove accumulated dirt. If necessary, use facial tissue and water.

2. Dust or clean the mounting frame as necessary to keep the scale easily readable.

3. Check for defects whenever the instrument is reset. Compare the current temperature readings on both arms of thermometer—with each other and with readings from

a more precise thermometer (such as a standard dry bulb).

4. If the readings in step 3 differ consistently by more than 1.0 °F, and the difference is not due to a column separation, use the dry bulb thermometer as a basis for corrections. Where the Six's thermometer scale plates are movable (as in the Taylor model), slide them into correct or optimum position (accuracy may well vary with the temperature). Otherwise, determine corrections to apply to the Six's thermometer readings.

30.4 Psychrometers

Psychrometer maintenance attends to the thermometers (as in section 30.2) and additional components. It consists primarily of regular cleaning, wick replacement, battery replacement, periodic lubrication where required, and repair or replacement of worn parts as necessary. In addition to these ongoing measures, general servicing and a more thorough cleaning and lubrication are performed during scheduled annual maintenance.

Specific maintenance instructions for standard and other psychrometers used for fire-weather observations are given later in this section.

DRY- AND WET-BULB THERMOMETERS

Maintain the dry- and wet-bulb thermometers as described in section 30.2. It is also important to check that the two thermometers agree within one-half of a scale division when both are read as dry bulbs. Thus, for thermometers having 1-°F graduations, as in most psychrometers, agreement should be within 0.5 °F. Closer agreement is recommended at temperatures below 32 °F. Comparisons should be made before the wet-bulb wick is wetted and also with the wick removed, prior to wick replacement.

When replacing a broken thermometer on a psychrometer, be sure that the replacement is in good agreement with the other, unbroken thermometer. To ensure the required accuracy, both the broken and unbroken thermometers are often replaced with a new, factory-matched pair. When replacing thermometers and wicks, remember that (with frames providing a vertical offset), the wet bulb thermometer should always be the lower-positioned thermometer (fig. 30.5). This minimizes the chance of blowing moistened air from the wet bulb across the dry bulb during ventilation.

THE WET-BULB WICK

A clean and absorbant wick is essential for accurate wet-bulb readings. It should be replaced at the first sign of dirt, crust, discoloration, or difficulty in wetting. When in daily use, the wick should be replaced at least once every 4 weeks regardless of appearance. Only clean, distilled or other mineral-free water should be used to wet the wick; otherwise, it is advisable to replace the wick at least every 2 weeks.

The recommended procedure for replacing a wick (fig. 30.5) is given in the following steps. Hands should first be washed with soap and water, then rinsed thoroughly in clean water.

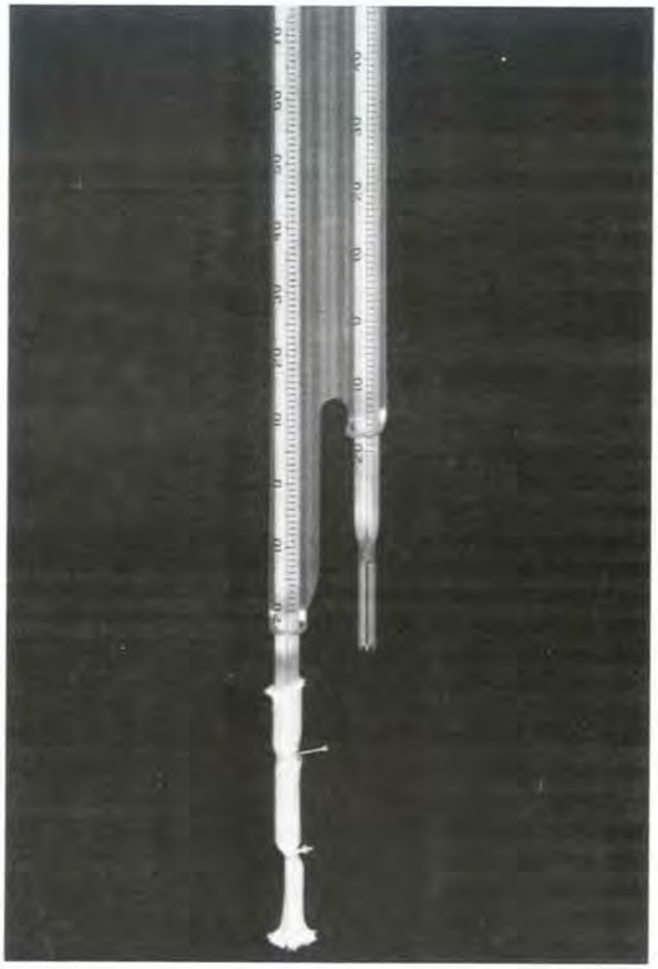


Figure 30.5—Installed psychrometer wick, tied at upper and lower ends of bulb on wet bulb thermometer.

1. Remove the old wick, using a razor blade or fine-point knife or scissors to cut ties.
2. Cut a 3-inch length of clean wicking. Remove any sizing by washing the new wick in distilled or other mineral-free water; rinse thoroughly.
3. Clean the bulb and adjacent stem of the wet-bulb thermometer. Use vinegar to remove any stubborn mineral deposit. Rinse with clean water.
4. Slide the new wick over the wet bulb until it extends about one-half inch above the upper end of the bulb.
5. If the wicking is tight-fitting, sliding with effort, it may be unnecessary to tie it to the bulb. If, however, the wick slides easily, it should be tied in two places—as follows:

    a. Using an extra-strength white sewing thread, tie the wick near its upper end, against the narrow portion of the stem above the bulb.

    b. Tie the wick near its lower end. To obtain a snug fit on the bulb, make a loop of thread to form a knot and position it slightly above the tip of the bulb where it begins to round off. Carefully draw the knot tight, causing the loop to slip off the tip of the bulb, thereby stretching the wick snugly against the bulb and securing it firmly.

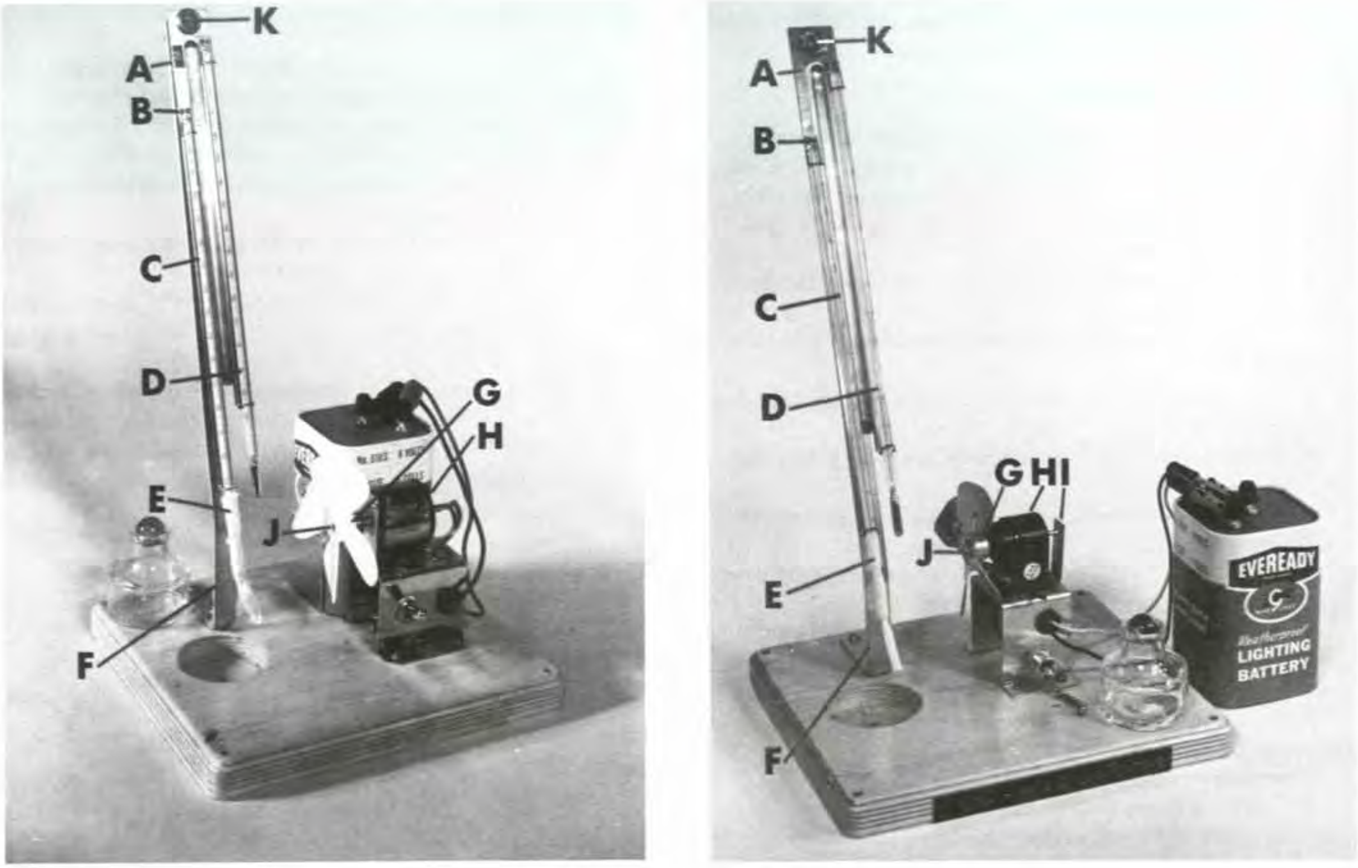


Figure 30.6—Standard electric fan psychrometer, Forester Model 9X060 (left) and Forest Service model (right): A, thermometer mounting frame; B, thermometer retaining clip and screws; C, wet-bulb thermometer; D, dry-bulb thermometer; E, wet-bulb wick; F, support bracket; G, fan and shaft; H, motor; I, thrust plate; J, fan bushing; K, spacer screw.

c. Trim the excess thread and wicking. The wick should extend about three-fourths inch below the tip of the wet bulb.

If the wick is fairly snug before tying, it will be sufficient to tie only the upper end. The reduced task should help encourage regular replacement. During observations, however, be sure that the wick is drawn tightly over the wet bulb; replace if fraying has occurred and affected bulb coverage.

If new wicking is temporarily unavailable, tubular white cotton shoelaces, rinsed in clean mineral-free water and cut to proper length, can provide a satisfactory substitute. Alternatively, the dirty wick can be removed, washed in soap and water, rinsed thoroughly, and replaced on the bulb.

STANDARD ELECTRIC FAN PSYCHROMETER

The maintenance instructions for this psychrometer apply to models including Forester Model 9X060 (Western Fire Equipment catalog No. 92060), Sierra/Misco Model 2030 (WeatherWise Model 2030), and former Weather-Measure Model HM20. Refer to figure 30.6.

Daily Maintenance—Before each use:

1. Using a soft brush, remove any dust or dirt that may have accumulated since previous use.
2. Before wetting the wick, check to see that the two thermometers agree within 0.5 °F.
3. Inspect the wick and replace if there is any dirt or discoloration, or fraying that affects bulb coverage.
4. Check the water container. Clean and refill if the water is dirty or if scum is forming on the side of container.

Periodic Maintenance While in Use—At least once every 2 weeks:

1. Replace the wet-bulb wick. This may be done every 4 weeks if the wick appears clean, wets easily, and has been wetted only with distilled or other mineral-free water.
2. Remove any dust or dirt from the instrument surfaces with a soft brush.
3. Oil the fan shaft bearings (G) if necessary.
4. Check all screws and tighten if loose.
5. Check the battery and replace at first sign of weakness. (A 6-volt battery may last up to 6 months with once-daily use.)

6. Check the water container. Clean and refill if water is dirty or if scum is forming on the side.

Annual Maintenance—

1. Remove spacer screw (K) and lift thermometer mounting frame (A) from the support bracket (F). Carefully remove the dry- and wet-bulb thermometers from frame and set aside the tiny retaining screws (B). Remove and discard the wet-bulb wick.

2. Inspect the thermometers for defects (section 30.2) and repair as necessary.

3. Clean the thermometers and mounting frame (section 30.2).

4. If necessary, renew the thermometer scale markings (section 30.2).

5. Refasten the thermometers securely on mounting frame.

6. Install a clean wick on the wet bulb thermometer (C), as described earlier in this section.

7. Clean the fan (G) and exterior of motor (H), but do not attempt to disassemble the motor.

8. Apply one drop of oil to the fan shaft bearings (G) and wipe off excess. Use a light, nongumming instrument oil.

9. Check and tighten, as necessary, all mounting screws, the fan hub setscrew, and all electrical connections.

10. Install a fresh 6-volt lantern battery. Follow the correct polarity in connecting wire leads; check by turning the fan motor on. Fan should blow air across the thermometer bulbs. Reverse the connecting leads if air is drawn toward the fan.

11. On motor units with a thrust plate, check for proper adjustment of plate (I). Turn the motor on and carefully bend the thrust plate to the point where the number of revolution per minute is greatest.

12. If the instrument will not be put into immediate service, disconnect the battery from the motor.

HAND FAN PSYCHROMETER

The maintenance instructions for this psychrometer (Forester Model 9X050) refer to figure 30.7.

Daily Maintenance—Before each use: follow the daily maintenance instructions (1 through 4) given for the standard electric fan psychrometer.

Periodic Maintenance—At least once every 2 weeks:

1. Replace the wet-bulb wick (as described previously, this may be done every 4 weeks).

2. Remove any dust with a soft brush.

3. Apply one drop of oil both on the crankshaft (M) and the fan shaft (G).

4. Tighten all screws. Be sure that the unit is firmly mounted to the floor of the instrument shelter.

5. Check the water container for dirt and scum. Clean and refill if necessary.

Annual Maintenance—

1 through 6. (See annual maintenance instructions 1 through 6 for the standard electric fan psychrometer.) Remove the spacer screw (L) and remove the thermometers; clean the thermometers and mounting frame, check the thermometers, reassemble, and install a new wick.

7. Clean the fan unit.

8. Lubricate the crankshaft (M) with one drop of oil in the hole (N) on top of the bearing.

9. Apply one drop of oil on the fan shaft. To gain access to this shaft, spring its supporting steel strap away from the drive wheel (I) and slip the fan (G) off.

10. Inspect for slippage between the drive wheel and the hub of the fan shaft. If there is too much slippage, increase tension by tightening the tension screw or bending the fan support.

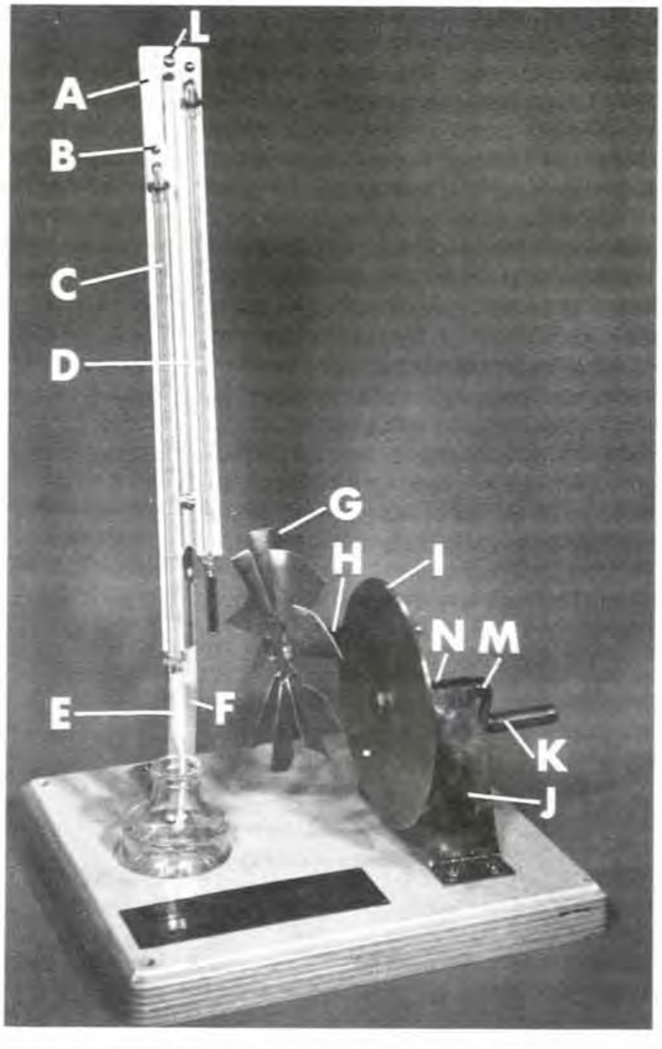
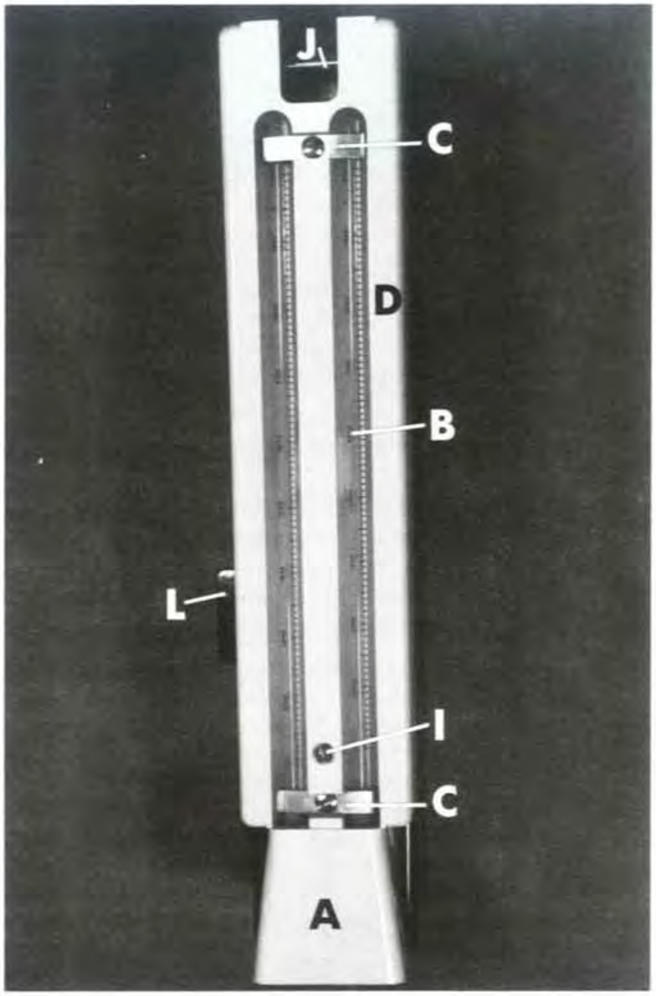


Figure 30.7—Hand fan psychrometer: A, thermometer mounting frame; B, thermometer retaining clip and screws; C, wet-bulb thermometer; D, dry-bulb thermometer; E, wet-bulb wick; F, support bracket; G, fan and shaft; H, fan pulley; I, drive wheel, J, fan pedestal; K, crank; L, spacer screw; M, crankshaft; N, oil hole.



11. Inspect the hub of the fan shaft. If the hub is badly worn, disassemble the fan blade and hub, turn the hub over, and reassemble. This will allow the drive wheel to engage the unworn groove in the fan shaft hub.

PORTABLE ELECTRIC FAN PSYCHROMETER

The maintenance instructions for this psychrometer apply to models including Belfort (formerly Bendix) Psychron Model 566, Gemware Model Electro V, and WeatherMeasure Model 5227; refer to figure 30.8.

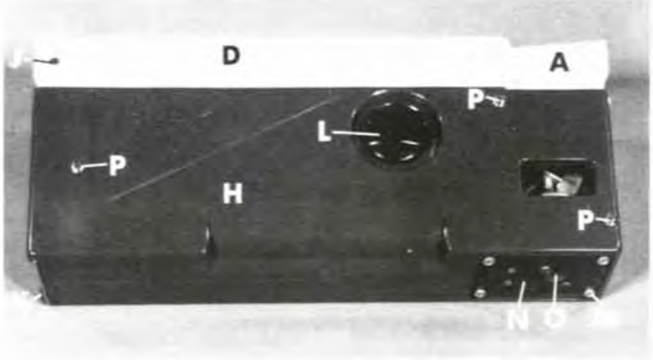
Periodic Maintenance—The timing and extent of maintenance on portable electric psychrometers depends on the model and amount of use.

If the instrument receives daily use, cleaning is a constant maintenance item; lubrication should be done at least monthly. The wick should be changed at the first sign of dirt or discoloration, difficulty in wetting, or fraying that affects bulb coverage. When in daily use, the wick should be changed at least once every 4 weeks (as previously described).

When not in use, store the instrument in its protective case in a safe place away from sunshine.

Annual Maintenance—The following maintenance should be performed as needed, but at least once a year if the instrument receives regular use:

1. Remove the sliding air intake (A) and, while holding the thermometers in place, remove the two thermometer-retaining strips (C).
2. Lift the thermometers from their holder (D) and inspect them for defects (section 30.2). Check for agreement within 0.5 °F when both are read as dry bulbs. Repair or replace as necessary.



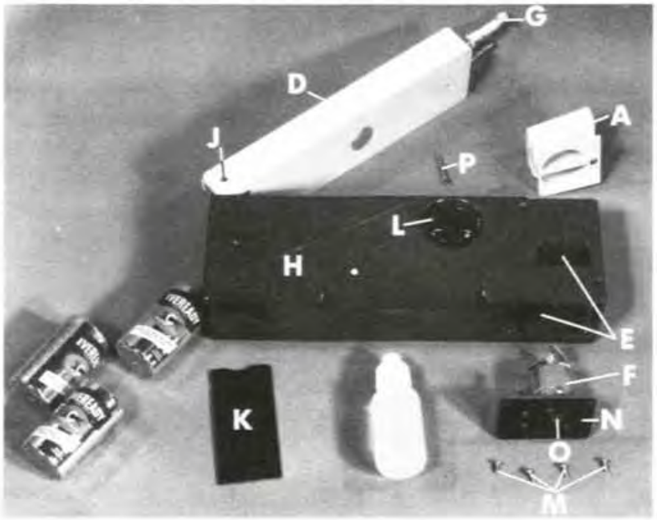


Figure 30.8—Portable electric fan psychrometer, assembled and disassembled: A, air intake; B, dry-bulb thermometer; C, retaining strip; D, thermometer holder; E, air-intake cylinder; F, fan and motor; G, wet-bulb thermometer and wick; H, psychrometer housing; I, retaining screw; J, thermometer holder shaft; K, sliding door; L, switch; M, motor-mounting screws; N, motor-mounting plate; O, fan shaft; P, housing screws.

3. Clean the air intake, the air intake cylinder (E), the thermometer holder, the fan (F), and the fan motor. Use a small brush and nonflammable cleaning solvent to remove stubborn dirt.

4. Remove and discard the wet-bulb wick. Carefully clean both thermometers (section 30.2).

5. If necessary, renew the thermometer scale markings (section 30.2).

6. Remove the thermometer holder from the psychrometer housing (H). To do this, remove the screws (I) on top of the holder and also (for the Bendix model) the shaft (J) at the rear of the holder. Clean the bottom of the holder and top of the housing (see instruction 3).

7. Remove the sliding door (K) at rear of the housing. Remove the water bottle from the upper compartment and the batteries from the lower compartment. Remove the hard paper liner from the battery compartment; if dirty, clean or replace it.

8. Reinstall the battery compartment liner and carefully insert three fresh, heavy duty or alkaline, C-size flashlight batteries. Hold the housing at a slight angle so that the batteries do not slam against the forward contact. Be sure that the batteries are inserted with their center tips (positive terminals) forward.

9. Apply one drop of oil on the bottom end of the fan shaft (O). Also apply one drop on the fan shaft between the motor and the fan blade.

10. Turn on switch (L) and check the lamp on top of the housing. Replace the lamp bulb if necessary.

11. Turn on the switch and check fan operation. If fan blades rub against the cylinder wall, turn off the switch and loosen the screws (M) on the motor mounting plate (N) at bottom of the housing. Insert fingers into the fan cylinder and reposition the motor so that the fan blades clear the cylinder wall.

12. Refasten the thermometer holder on top of the housing.

13. Reinstall thermometers in the holder. Be sure that the retaining strips are tightly secured.

14. Install a new wick on the wet bulb, as described earlier in this section.

15. Clean the water bottle and fill with clean, distilled or other mineral-free water.

Troubleshooting—

1. If the switch is on but the lamp does not operate, replace the lamp bulb on top of housing.

2. If switch is on and the lamp is very dim, replace the batteries (see annual maintenance item 8).

3. If switch is on and the lamp operates but the fan does not operate, check to see if fan blade is caught on cylinder wall (annual maintenance item 11).

4. Further troubleshooting requires complete disassembly of the instrument as follows:

a. Remove sliding air intake (A).

b. Remove thermometer holder (D) from housing (H).

c. Remove sliding door (K) from rear of housing.

d. Remove screws (M) from motor mounting plate (N) at bottom of housing.

e. Remove screws (P) from side of housing and carefully pull apart the two halves of the housing.

5. Check all contacts and electrical connections. Use crocus cloth to remove any corrosion. Bend distorted contacts back into place. Resolder any loose connections.

6. If neither the lamp nor the motor operate after following the previous instructions, replace the switch.

7. If, after checking and repairing contacts and connections, the lamp operates but the fan does not, replace the motor.

SLING PSYCHROMETERS

The following instructions apply to standard and pocket models; refer to figure 30.9:

Periodic maintenance—

1. Change the wick at least once every 4 weeks if the instrument is used daily (see instructions for standard electric fan psychrometer). If instrument is used irregularly, change the wick at first sign of dirt, discoloration, or difficulty in wetting.

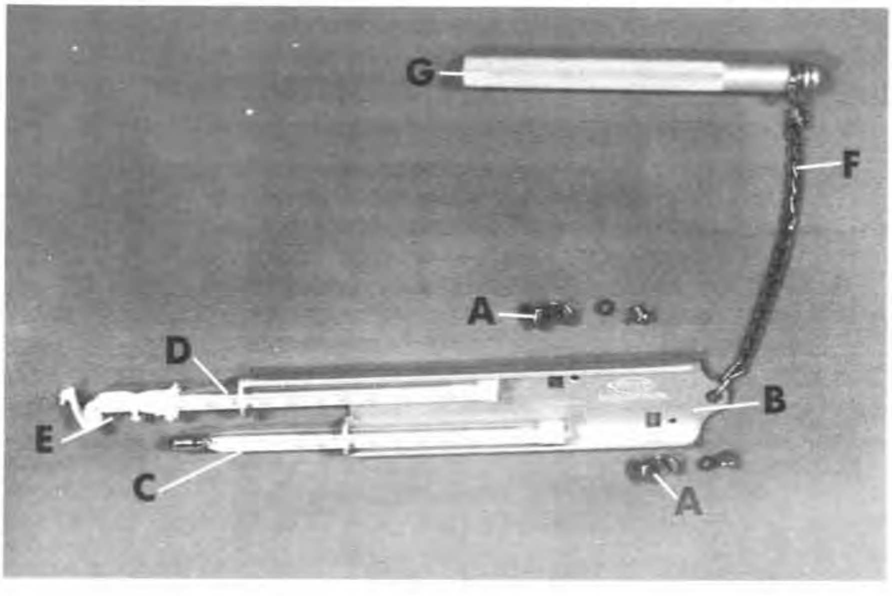


Figure 30.9—Sling psychrometer (pocket model): A, thermometer retaining clip and screws; B, mounting frame; C, dry-bulb thermometer, D, wet-bulb thermometer; E, wet-bulb wick; F, sling chain; G, sling handle.

2. Before each use, always inspect whirling parts and connections for signs of wear or slippage. Also be sure that all parts are aligned to whirl freely.

3. When not in use, store the instrument in its protective case whenever possible. If stored uncased, damage is less likely if the instrument is hung rather than laid down. Store in a safe, clean location away from sunshine.

Annual Maintenance—

1. Remove retaining clips (A) and lift the thermometers from mounting frame (B). Remove and discard the wet-bulb wick.

2 through 6. (See annual maintenance instructions 2 through 6 for the standard electric fan psychrometer.) Clean the thermometers and mounting frame, check the thermometers, reassemble, and install a new wick.

7. Inspect the whirling parts and connections for wear. These include chain links and hooks (F), swivel on handle (G), and eye near the upper end of the thermometer mounting frame (B). Repair or replace worn parts.

8. Tighten all screws.

9. Lubricate swivel shaft on the handle and points of friction along the sling chain assembly.

MORTARBOARD PSYCHROMETER

The instructions for this psychrometer (Southern Forest Fire Laboratory model) refer to figure 30.10. They describe the regular, periodic maintenance for the various components.

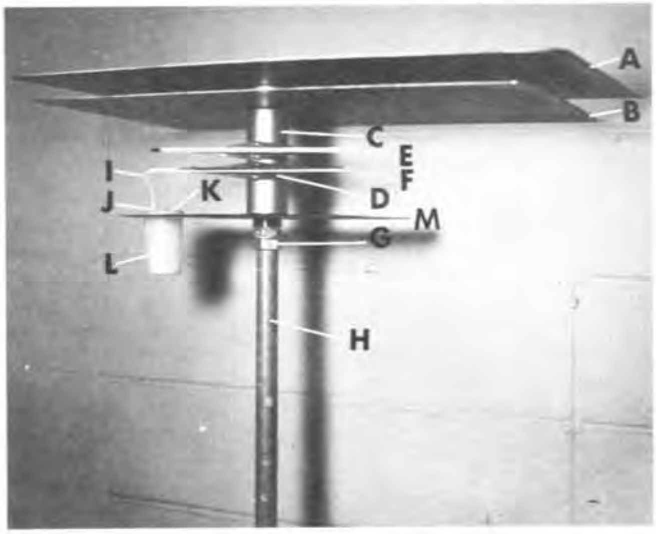


Figure 30.10—Mortarboard psychrometer: A and B, upper radiation shield plates; C, spacer; D, thermometer clip; E, dry-bulb thermometer; F, wet-bulb thermometer; G, connectors and couplings; H, support; I, wet-bulb wick, J, plastic tubing; K, water-cup cap; L, water cup; M, lower radiation shield.

Dry-Bulb and Wet-Bulb Thermometers—Follow the maintenance instructions in section 30.2, with respect to cleaning, renewal of worn markings, and repair of separated mercury columns. At least once every 2 to 4 weeks (or when the wet-bulb wick is changed), inspect the two thermometers for agreement when both are read as dry-bulb thermometers. If the readings consistently differ by more than 0.5 °F, even after possible column separations have been repaired, replace the thermometers with a new matched set.

Water Cup—

1. Inspect the cap (K) and tubing (J). The cap should fit tightly on cup (L) and the tubing should extend from just above the bottom of cup to 1 inch below the tip of wet bulb (F).

2. Wash the cup and tube in clean water each time a fresh supply of wicking (I) is installed.

3. Maintain the water level in cup; keep at least half full.

Wet Bulb Wick—Wicking is installed in 28-inch lengths, with the excess coiled in the bottom of the water cup. Wick changes on the wet bulb thermometer are made from this supply.

1. Before installing a fresh length of wicking (I):

    a. Remove old wicking.
    b. Clean the water cup (L) and tubing (J).
    c. Clean the thermometers.
    d. Wash hands and rinse thoroughly.

2. Coil a 28-inch length of fresh wicking and place it in the bottom of the water cup.

3. Pull end of fresh wicking through the cap (K) and tubing.

4. Slip end of fresh wicking over the wet bulb (F) to a point 1 inch up the stem. Be sure there are no snags in the wick between the cup and wet bulb.

5. The wick (portion of wicking covering the wet bulb) should be changed whenever it becomes dirty or discolored but at least once every 2 to 4 weeks.

6. To change the wick, cut off the exposed portion of wicking halfway between the tube and wet bulb. Remove the old wick from wet bulb and discard.

7. Pull up a length of fresh wicking out of the water cup and slip it over the wet bulb, as in step 4.

8. When the supply of wicking in the water cup no longer reaches the bottom of the cup, install a new 28-inch length of wicking.

Radiation Shield—Keep the top, reflective surface of the upper radiation shield (A) clean at all times. Polish this surface periodically (about every 3 or 4 months).

30.5 Hygrothermographs

The reliability of hygrothermograph data depends to a large extent upon proper maintenance of the instrument. Despite best efforts, however, large humidity errors can occasionally occur, due to inherent characteristics of the hair-element (section 7.7). These errors can be minimized through ongoing general maintenance and calibration checks.

A hygrothermograph should be serviced and recalibrated as necessary in any of the following situations: (1) prior to each period of use, (2) after the hair element has been replaced, and (3) whenever changes or losses in calibration occur during use.

The following tools and materials are required for efficient hygrothermograph maintenance: needle-nose pliers, small screwdriver, small adjustable wrench, camel's hair brush, crocus cloth, and clean wiping cloth.

Do not attempt temperature and relative humidity calibration unless the hygrothermograph is in good mechanical condition. General maintenance items that apply to most hygrothermographs are discussed in the following paragraphs. Refer to manufacturers' instrument manuals for further details. Components of three commonly used hygrothermograph models are shown in figures 30.11, 30.12, and 30.13. Reference letters used in the following instructions refer to these figures.

Always avoid rough handling, as hygrothermograph parts are easily damaged.

CLEANING

Cleaning the instrument is essential, because dirt and dust can cause binding of the pen arm linkages. Remove loose dust from metal surfaces and parts with a small camel's hair brush. Use instrument-cleaning solvent, brushed lightly, to remove hardened dirt. Do not oil except as directed. Usually only the clock needs to be oiled, and this is best done by a clock repairman. Avoid getting oil or solvent on the hair element.

Remove dust from the hair element with a soft, dry, clean camel's hair brush applied gently; do not touch hairs with fingers. If extremely dusty, wash the element with clean, mineral-free water, again using a camel's hair brush. Never use cleaning solvent for this purpose. Be careful not to put tension on the hairs. Replace the hair element about every 5 years, but sooner if damage has occurred (hairs loose or pulled).

PEN ARM ASSEMBLIES

Allow only enough pen pressure on the recording chart to produce a sharp, continuous trace. Pen pressure can be adjusted by rotating the pen arm on its pivot or by carefully bending the pen arm. To produce a satisfactory trace, the pens must be clean and the nibs properly spaced; the nibs should not be worn or damaged. A trace that is too broad may indicate residue in the nibs or excessive spread between the nibs. Excessive spread may also result in an inking failure. In such a case, evident by inspection, it is best to replace the pen with a new one. To remove dirt or congested ink from the pen, draw a piece of chart paper or similar lint-free, hard-finish paper through the nibs. Do not use the edge of a razor blade or screwdriver for this purpose, as this will permanently spread the nibs; it is very difficult to properly rejoin them.

If the pen is clogged with dry ink, remove the pen and wash it in warm, soapy water. To remove the pen, gently pull it straight off the pen arm while holding the arm firmly near the pen. Reseat the pen by sliding it back on the arm through the two pairs of clamps on the pen's stem. If necessary, gently press these clamps with pliers to hold the pen securely.

If, after cleaning, the pen trace is still too broad, the pen may be sharpened as a possible remedy. To sharpen, carefully file the edges of the nibs until the point will not reflect light; use a point file or a fine mill file. Do not oversharpen; the pen could scratch the chart paper and catch fibers. If the pen fails to ink properly after cleaning, sharpening, and any further rotation of the pen arm, install a new pen.

Once proper inking is obtained, check whether the temperature and humidity pens indicate the same time on the chart. If the times differ, adjust one of the pens by sliding it slightly on its pen arm. As mentioned in section 7.7, however, do not expect the two pens to agree exactly at all times. Be sure that the pens are fastened firmly enough so that they do not slide out of position while in use.

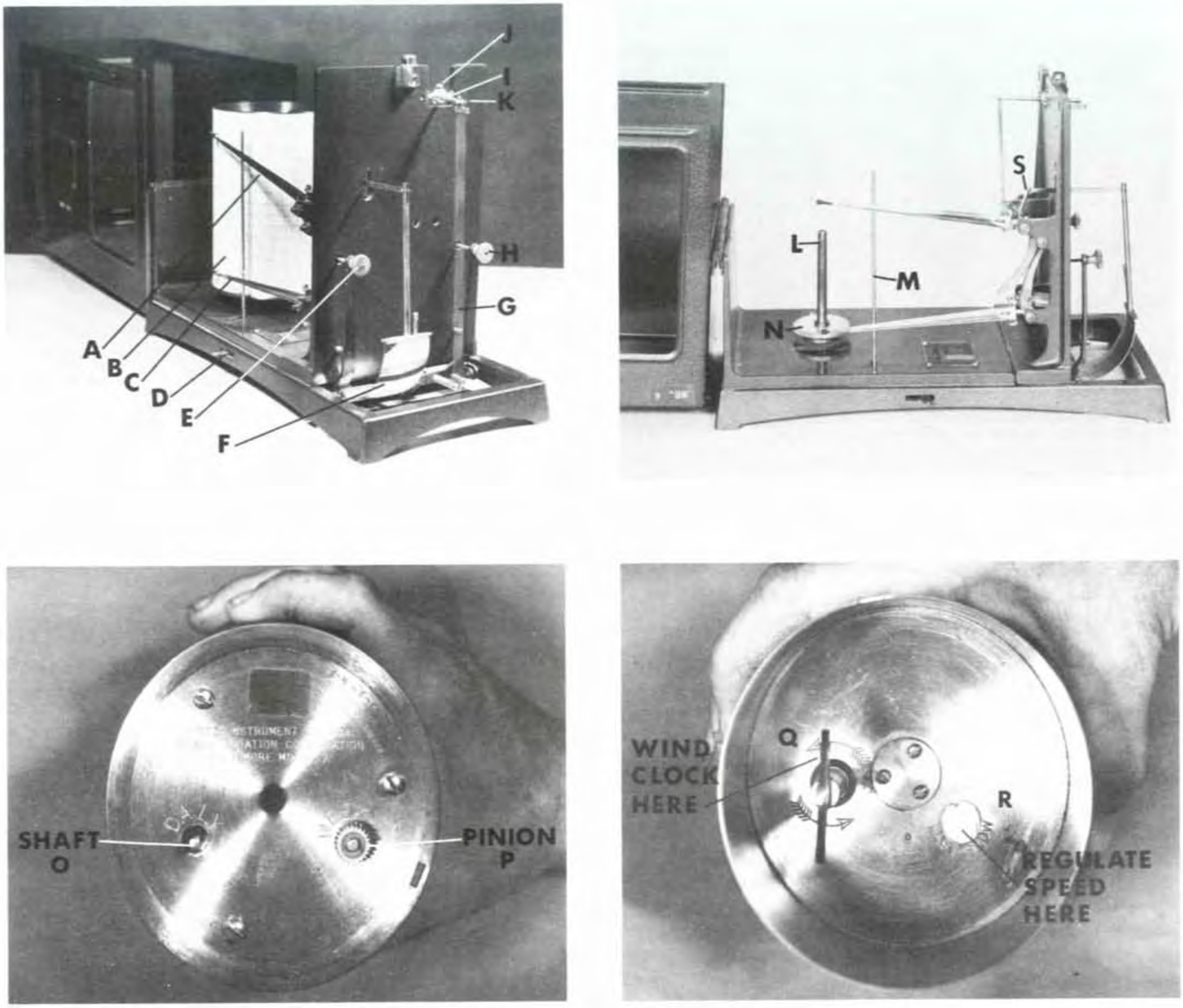


Figure 30.11—Bendix-Friez hygrothermograph (clock-within-drum type): A, temperature pen arm; B, chart and drum; C, relative humidity pen arm; D, pen-arm shifting rod lever; E, temperature zero-adjustment knob; F, Bourdon tube (temperature sensor); G, banjo-spread hair element (humidity sensor); H, humidity zero-adjustment knob; I, humidity magnification bar; J, swivel hub and swivel hub setscrew; K, pivot pin; L, spindle; M, pen-arm shifting rod; N, spindle (drive) gear; O, pinion shaft; P, pinion gear; Q, clock winding key; R, clock speed regulator; S, temperature range adjustment rod.

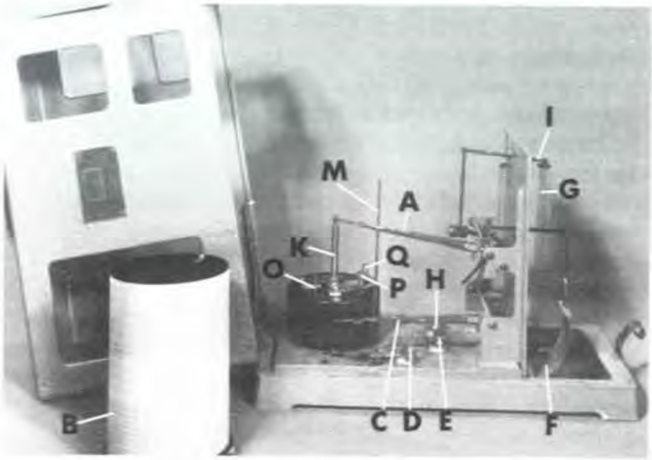


Figure 30.12—Belfort hygrothermograph (clock affixed to base, separate from drum): A, temperature pen arm; B, chart and drum; C, relative humidity pen arm; D, pen-arm shifting rod lever; E, temperature zero-adjustment knob; F, Bourdon tube; G, banjo-spread hair element; H, humidity zero-adjustment knob; I, humidity magnification bar; K, spindle; M, pen-arm shifting rod; O, pinion shaft; P, pinion gear; Q, clock winding lever.

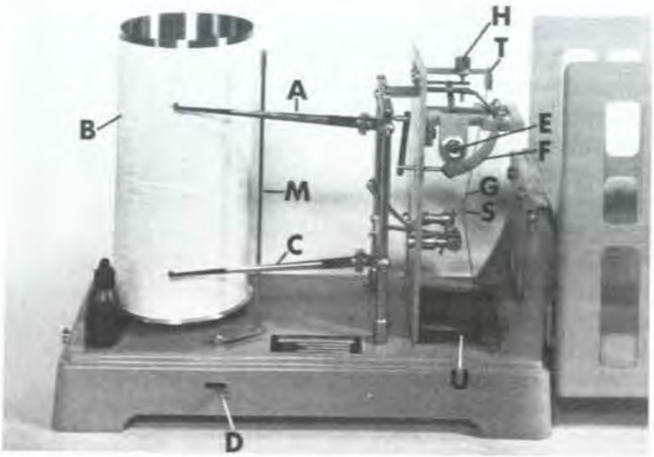


Figure 30.13—WeatherMeasure (Weathertronics) hygrothermograph; instrument shown has a battery-operated clock in the chart drum. A, temperature pen arm; B, chart and drum; C, relative humidity pen arm; D, pen-arm shifting rod lever; E, temperature zero-adjustment knob; F, bimetal strip (temperature sensor); G, hair bundle (humidity sensor); H, humidity zero-adjustment knob; M, pen-arm shifting rod; S, hooked humidity magnification lever; T, upper hair jaw; U, lower hair jaw.

CHART DRIVE ASSEMBLY

Remove all dirt and corrosion from the spindle (L) and gears. Lubrication of the spindle is often recommended to prevent corrosion; however, too much lubrication encourages the accumulation of dirt. It is often better, instead, to polish the spindle with crocus cloth and minimize the chance of dirt accumulation. Be sure that the spindle is exactly vertical and that the spindle and gears are securely fastened.

Backlash—Backlash can be a problem with hygrothermographs of the clock-within-drum type (fig. 30.11). To test for backlash, lift pens from the chart and rotate the drum lightly back and forth. The amount of play should cause an audible click between the gears, but not enough to cause more than one-half hour's movement on a weekly chart. Test at several rotational positions of the drum. If there is either no backlash or too much, adjustment is needed.

To adjust the backlash, remove the drum from its spindle and loosen the three screws spaced equally on the bottom of the drum (fig. 30.14). Shift the pinion gear (P) (fig. 30.11) away from the center of the drum, reassemble, and test again for backlash. Continue this procedure until, through trial and error, an acceptable amount of backlash is obtained.

The chart drive gear may mesh too tightly with the large stationary gear (N) at the bottom of the spindle (L) or inside the chart drum (B), causing the clock to either stop or lose time. To test for this condition, remove the drum from spindle; if the clock then operates normally, the gears are meshing too tightly. A bent spindle can cause a backlash on one side of the drum and a drag on the other side. Replace a bent spindle if it cannot be completely straightened to a vertical position.

If there is a drag between gears on clock-within-drum chart drives, remove the drum from spindle and loosen very slightly the three screws on the bottom of the drum (fig. 30.14). Then move the pinion gear (P) away from the center of the drum. A very slight movement will usually be sufficient. Tighten the screws, reinstall the drum, and test for amount of backlash.

CLOCK

Through daily time-check marks on the rotating chart, observe whether the chart drive is keeping accurate time. Necessary adjustments of clock speed can be made, where a traditional clock is employed, using the regulator (such as that in fig. 30.11). Move the regulator's pointer toward "S" if the clock is running fast, or toward "F" if it is running slow. The clock should be overhauled by a competent clock or watch repairman if it does not respond to the above adjustment. It is good practice to have the clock cleaned and adjusted professionally every 2 or 3 years; annually, if the chart drive is subjected to extreme environmental conditions. Provide the repairman with the instrument manual, if available, as it contains needed specifications on lubrication and timing. This information follows for two commonly used hygrothermograph models.

Bendix-Friez, Model 594 Series—

Timing of the escapement: 18,045 beats per hour.

Mainspring lubrication: Use a mixture (by volume) of one part oil, Elgin M-56A or Bendix-Friez oil Part No. 502763, to three parts flake or powdered graphite.

Drive mechanism pivots: These may be lubricated with the oils mentioned above, used alone without the graphite.

Belfort, Catalog No. 5-594—

Timing of the escapement: The timing should be 9 seconds per hour (45 beats per hour) fast.

Mainspring lubrication: Use Belfort Instrument Oil No. 5660 for warm-season operation. For operation in cold weather (at 0 °F and below), drain oil from the mainspring barrel and relubricate with fine powdered graphite or molybdenum disulfide (Molykote).

Mechanism gear train lubrication: Use Belfort Instrument oil No. 5586. This oil will not congeal at low temperatures but must be used sparingly and never allowed to come in contact with paint or lacquered surfaces.

BATTERY-POWERED CHART DRIVE

Battery-operated chart drives, like spring-wound clocks, require periodic cleaning, lubrication, and possible adjustment; also, periodic replacement of their two $1^1/_2$-volt C-size batteries. Only alkaline-manganese dioxide batteries should be used in temperatures below freezing. At temperatures of 40 to 100 °F, in use with the quartz-crystal (Belfort stepper-motor) chart drive, these batteries have a rated service life of 6 months; zinc-carbon batteries, 4 months. The alkaline batteries have, however, performed for at least 2 full years in continuous, year-round service in western Montana. Battery life is shorter in chart drives (from WeatherMeasure) employing a more traditional clock movement. Timing adjustment, if required, is difficult for the stepper-motor chart drive, which does not have a conventional regulator.

CALIBRATION

Hygrothermograph calibration should be checked against daily psychrometer and maximum and minimum thermometer observations, as described below. Where large or persistent discrepancies are noted, the hygrothermograph should be adjusted. This adjustment, or recalibration, primarily involves the "zero" setting and the range. Manufacturers' instrument manuals, while containing much information on hygrothermograph maintenance, may give insufficient coverage to the adjustment procedures.

The zero adjustment is a simple linear adjustment, whereby the pens are shifted upward or downward on the recording chart. The need for this adjustment is indicated when the temperature or relative humidity trace reads consistently higher or lower than the correct values determined by "control" instruments—usually standard maximum and minimum thermometers and dry- and wet-bulb thermometers.

Figure 30.14—To correct for backlash and drag between gears, loosen three screws on bottom of drum and shift gear away from center of drum.

The range, or spread, adjustment changes the distance that the pen arms travel upward and downward between maximum and minimum values. The need for this adjustment is indicated when the chart recording reads consistently too high at the maximum and too low at the minimum, or the converse—too low at the maximum and too high at the minimum; allowance is made for instrument lag.

ZERO ADJUSTMENT

Temperature Pen—Check the calibration by comparing current temperature readings, ideally at a time when the temperature is steady, and also the maximum and minimum temperatures. Compare the chart temperatures with those indicated by a dry bulb thermometer (inside the instrument shelter) and by maximum and minimum thermometers that have been checked for possible defects (section 30.2).

Due to the characteristic instrument lag of hygrothermographs, the chart maximum temperature may in comparisons often read 1 °F too low and the minimum 1 °F too high. This condition would not indicate a need for zero adjustment. But if, during steady conditions, the current chart temperature differs from the dry bulb or "set" maximum temperature by 1.0 °F or more, an adjustment may be needed. Before taking action, it may be best to check further on succeeding days to see if the discrepancy persists. However, an immediate adjustment is advised if the discrepancy is 2.0 °F or greater. After an adjustment has been made, perform followup comparisons and possible fine tuning of the adjustment on succeeding days.

To make a zero adjustment, move the pen upward or downward on the chart by turning the knurled thumbscrew (E) connected to the temperature element (F). On Belfort instruments with the thumbscrews located at the base, turn the temperature screw clockwise to raise the pen; counterclockwise to lower it. Briefly lift the pen off the chart during adjustment and lightly tap the instrument base. This will eliminate possible effects of friction between the pen and chart or within the pen arm linkage.

Relative Humidity Pen—Shift of the zero setting is a major source of error in relative humidity data obtained from hygrothermographs. Depending on its direction, zero shift will result in recorded humidities that are either higher or lower than the actual values (see section 7.7). This shift tends to be reversible with weather regimes. It may be minimized by periodic, forced saturation of the hair sensing element during extended regimes of low relative humidity. The saturation is accomplished by thoroughly wetting the element with distilled water applied with a camel's hair brush.

Check the relative humidity adjustment by means of carefully taken psychrometer observations (section 23.3); be sure that the dry bulb and wet bulb agree closely when both are read as dry bulbs. As with temperature, to minimize effects of hygrothermograph lag, check the humidity at times when the values are steady. This will be generally near dawn for maximum relative humidity and near midafternoon for minimum relative humidity. Avoid calibration checks and adjustments at low temperatures if possible, because lag of the hair element increases greatly at temperatures below +20 °F. (Also, at lower temperatures, small errors in dry- and wet-bulb thermometer readings lead to larger errors in calculated relative humidity used for the calibration check.)

Adjust the pen if the chart relative humidity, over a 1-week period, is consistently more than 3 percent higher or lower than values from daily afternoon psychrometer measurements. Adjust the pen upward or downward by turning the knurled thumbscrew (H) connected to the hair element (G). On Belfort instruments, turn the base-mounted humidity screw clockwise to lower the pen; counterclockwise to raise the pen. Briefly lift the pen off the chart and tap the instrument base to eliminate frictional drag.

RANGE ADJUSTMENT

Check periodically to make sure that all screws used in range adjustments are tight. This may prevent accidental slippage of adjustments.

Temperature Pen—Check the accuracy of the recorded temperature trace over a 1-week period by comparing the maximum and minimum values with those obtained from standard maximum and minimum thermometers (checked for possible defects). A need for recalibration is indicated if (1) the range between daily maximum and minimum temperatures on the chart averages more than 3 °F too small or more than 1 °F too large and (2) the accuracy is found to vary with temperature. The greater tolerance for a small range allows for the hygrothermograph lag.

Adjustment of temperature range is not often required. If required, this can be performed on the Bendix-type instrument by loosening a screw and sliding a vertical rod (S) in the temperature pen arm linkage (fig. 30.11). Slide the rod upward to decrease the range or downward to increase the range; retighten the screw. Adjustment is more difficult with other hygrothermographs that do not have this sliding rod. It may be best to return such instruments to the factory for adjustment.

A range adjustment will usually alter the zero setting. This setting should be checked afterward with the dry bulb or set maximum thermometer reading, and adjusted if necessary, as previously described.

Relative Humidity Pen—Check the afternoon minimum relative humidity recorded on the hygrothermograph trace over a 1-week period. With a properly adjusted humidity pen, these values should be as low as the afternoon humidity observed with a psychrometer. They should be somewhat lower if the trace at observation time shows a higher relative humidity value than the minimum. The humidity pen should also show a rise to about 95 to 100 percent at night if fog or heavy dew has occurred.

It is quite common for hygrothermograph traces to show a humidity range that is either too large or too small. Like zero shift, this range shortening or elongation is a major source of error in humidity data obtained from hygrothermographs. Again, such error may vary with the weather regime. Compensating instrumental adjustments can be made, as described in the following methods.

For illustration purposes, assume that the instrument is in good adjustment at low humidities and that saturated air is present at night. If the nighttime humidity shown on the chart exceeds 100 percent, the range should be decreased. If, however, the maximum recorded humidity is below 95 percent, the range most likely should be increased.

Adjust the humidity range only at a time of day when the humidity pen has leveled off at its lowest value for an hour or more, preferably on a day when the humidity is below 30 percent.

Trial-and-error method—(Refer to figures 30.11, 30.12, and 30.13.) This adjustment method is best suited for field correction of minor range errors. It can be performed without interrupting the instrument record.

1. In the afternoon, after relative humidity has reached a steady value, carefully take a psychrometer observation (section 23.3).
2. Observe the difference between the psychrometer humidity value and that indicated by the pen (C) on the hygrothermograph chart.
3. Draw a pencil line on the magnification bar (I), at the edge of the swivel hub (J). This will serve as a reference or starting point for the ensuing trials.
4. Loosen the swivel hub setscrew that holds the magnification bar in place (fig. 30.15).
5. Move the magnification bar far enough to change the humidity pen indication about one-half the difference observed in step 2. Move the bar to right, away from chart drum to decrease the humidity range. Move the bar to left, toward the chart drum, to increase the range. A movement of one-sixteenth inch will alter the range by several percent relative humidity.
6. Tighten the swivel hub setscrew firmly.
7. Check the zero setting, which has probably been altered by the range adjustment. Adjust the pen with thumbscrew (H) to agree with the psychrometer humidity value (step 1).

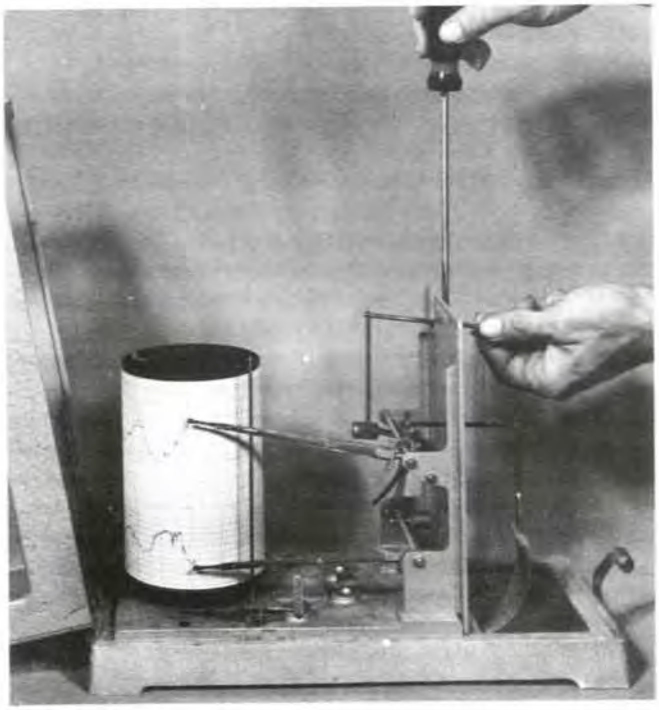


Figure 30.15—Adjusting the magnification bar on a Belfort hygrothermograph.

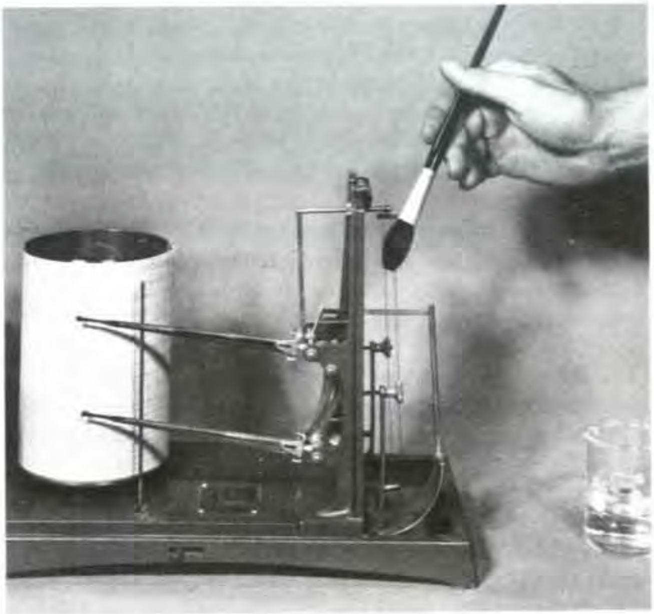


Figure 30.16—After saturating hair element with a soft camel's hair brush, the humidity pen should indicate between 91 and 95 percent relative humidity.

On hygrothermographs such as the WeatherMeasure (fig. 30.13), the function of the magnification bar is performed by a hooked lever (S) through which the hair bundle passes. Loosening its small fixing screw, slide this lever downward to increase the humidity range, or upward to decrease the range; retighten the screw. The range can also be changed by rotating the pen arm relative to the pen arm quadrant (after loosening a fixing screw); details are given in the manufacturer's instrument manual.

Often, several adjustments over a period of 1 or 2 weeks are required before the optimum calibration is obtained with the trial-and-error method.

Hair-wetting method—This is a more precise, time-consuming adjustment method. Good results can be obtained in about 2 hours; however, followup with the trial-and-error method is recommended. The wetting method is especially helpful after installing a new hair element.

1. Perform this method either in the instrument shelter on a warm, dry afternoon or inside a warm, dry room.
2. Carefully take a psychrometer observation to determine the correct relative humidity; set the humidity pen accordingly.
3. Dip a soft camel's hair brush in clean, distilled water. Gently stroke the humidity hairs upward on both sides until they are immersed in a continuous stream of water (fig. 30.16). Keep the water container close to the hairs. Continue this procedure until the humidity pen has reached its highest position on the recording chart.

4. If the humidity pen now indicates about 93 percent, leave the humidity range adjustment as it is. If the the pen indicates over 95 percent, the range is probably too great; if under 91 percent, too small. (The pen will normally indicate about 93 percent when the hairs are saturated with water and 100 percent when saturated with moist air or fog.)

5. If range adjustment is necessary, follow the instructions for moving the magnification bar or lever as outlined in the trial-and-error method.

6. After the range has been adjusted, wet the hairs again (step 3).

7. Set the humidity pen at 93 percent, using the thumbscrew (H) adjustment.

8. Let the instrument sit for at least 30 minutes to allow the hairs to dry and the pen to return to a stable low humidity value. A small, AC-powered electric fan can be used to speed the drying (if the range adjustment is done indoors), but keep the fan about 3 ft from the instrument.

9. Take another psychrometer observation—as a precaution against a possible humidity change since the original observation. Then reset the pen if necessary.

10. Repeat steps 5 through 9, as necessary, until the humidity pen will indicate 93 percent when the hairs are wet and will agree with the psychrometer value when the hairs are dry.

Occasionally, a hair element will indicate only about 80 percent relative humidity when wetted with water but 100 percent when saturated in fog. In such a case, install a new hair element. After 3 or 4 days of outdoors exposure, proceed with the adjustment process.

Wet-towel method—This adjustment method is similar to the hair-wetting method, just described, except the instrument is surrounded by wet towels or placed in a box lined with wet towels. The towels should be left in place (approximately 10 minutes) until the humidity pen reaches its highest point. If correctly adjusted, the pen should then read 100 percent.

CHAPTER 31. WIND EQUIPMENT

31.1 General Maintenance of Contacting Anemometers

Contacting anemometers are relatively sturdy instruments and can provide many years of trouble-free operation if given careful handling and regular maintenance. For most of these anemometers, maintenance consists of an annual check and monthly or periodic lubrication while in use. During the annual check, the instrument should be disassembled, cleaned, lubricated, and inspected for proper calibration and mechanical soundness.

CLEANING

All anemometer parts, except the electrical contact unit, may be cleaned with a nonflammable instrument-cleaning solvent such as methyl ethyl ketone. Several commercial preparations of this and other acceptable solvents are available under various brand names (MEK, VARSAL, etc.). Do not use preparations containing carbon tetrachloride—it can cause rust, but more importantly, its fumes are highly toxic. Likewise, do not use gasoline or other highly flammable liquids. Pipe cleaners and toothbrushes are handy for applying solvent and removing gummed oil or stubborn dirt from anemometer parts.

Electrical contacts should be cleaned, first with crocus cloth and then by drawing a clean piece of hard-finish paper between them. Replace the contacts if they are badly pitted or so dirty that a file or emery cloth is needed to clean them. Badly burned or pitted contact points are often the result of excessive electrical current.

When available, compressed air may be used in cleaning the anemometer housing and removing dirt from the gears and other hard-to-reach places.

LUBRICATION

Depending on the anemometer model, either anemometer oil or special silicone type fluids are specified for lubrication. These lubricants are usually available from the anemometer manufacturer. Anemometer oil is simply a light, nongumming instrument oil; thus, any similar oil, such as sewing machine oil, can be substituted if necessary. Use only substitutes that will not impair anemometer operation at low temperatures.

Anemometers should be lubricated carefully and sparingly. Wipe off excess oil immediately. Most anemometers require only one or two drops of oil at any lubrication point. One drop can be defined as the amount of oil that will collect at the end of a piece of fine wire (about the size used for paper clips). Such a wire can serve as a convenient applicator. Merely dip the end of the wire into the oil, let the excess run off, and then apply the remaining amount where required.

MECHANICAL INSPECTION AND RECALIBRATION

Many mechanical deficiences can be identified by merely spinning the anemometer cups by hand and observing their motion. The cups should be capable of starting when you blow into them. Also, the cups should never come to an abrupt stop, even at very low speeds. Sluggish starting and abrupt stopping may indicate a need for lubrication or cleaning, bent or worn parts (worn gears), or improper assembly. In normal operation, cups should not wobble while spinning. Wobble often indicates a bent shaft.

Although periodic calibration checks, and recalibrations when necessary, are essential for proper anemometer performance, these are often not performed. This neglect is commonly due to the lack of appropriate test equipment and the expense of having the work done by the manufacturer. Even at optimum calibration, anemometers have characteristic reponse errors, particularly at lower windspeeds, differing among models (Haines and Frost 1984); provided corrections should be applied to observed speeds.

Portable tester-calibrator devices have been developed by Ryan (1970) and Haines and others (1980). These allow accurate recalibration of anemometers at fairly low cost. A single unit can service many weather stations. The time required per anemometer is less than 1 hour. The Haines unit (fig. 31.1) is more compact than the Ryan

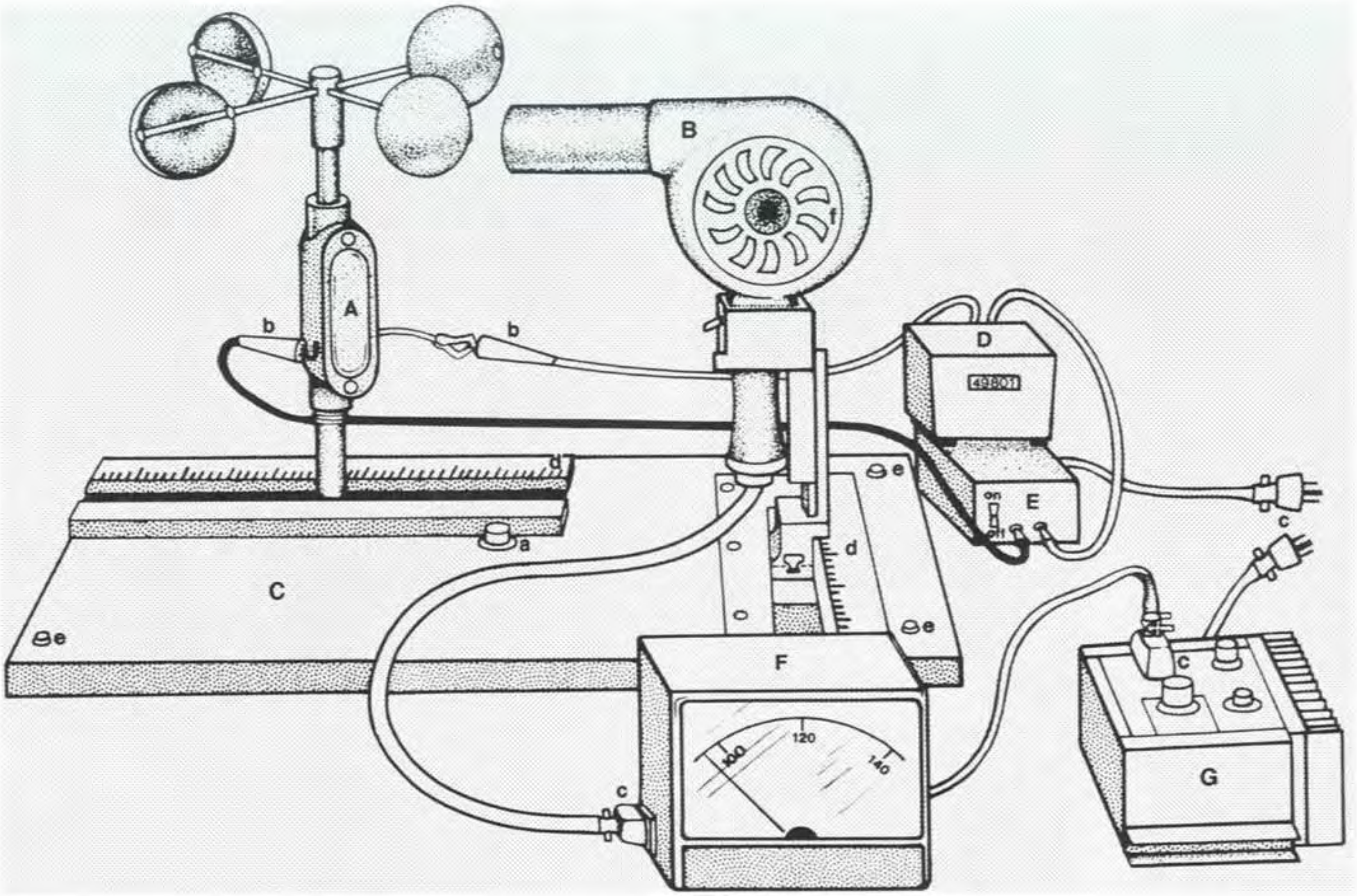


Figure 31.1—Diagram of portable anemometer tester (Haines and others 1980). Assembled components are: A, anemometer to be tested; B, industrial blower; C, 12- by 21-inch solid testing board; D, 12-volt DC counter; E, 12-volt regulated DC power supply; F, line voltage monitor; G, variable voltage controller. Additional parts are: a, bubble level; b, connections to counter; c, electrical plugs; d, tracks with metal measures; e, level-adjustment screws; f, blower manifold.

unit (Fischer and Hardy 1976), weighing less than 30 pounds with its case. In 1980, it could be built at a cost of about $200.

CIRCUIT CHECK

When inspecting an anemometer, it is highly important to check for a flow of electrical current from the anemometer to its readout device. Perform this check by testing the switch contacts wich a continuity tester. As an alternative, attach a wind counter, turn the cups by hand, and record the number of cup rotations required to advance the counter reading by one count. Then check to see if this number of rotations consistently advances the counter.

If the counter or other readout device fails to respond properly, the wires or connecting cable may be at fault. Before checking the wiring, however, first inspect the contact mechanism. If the anemometer has multiple contacts, the fault may lie with one or more of the pins on the contact wheel. If worn too short, the pins will not close the contact as they travel past it.

To check for a broken wire in either the anemometer or the readout device, first disconnect the suspected wire. Attach a lead from the continuity tester to one end of the wire and the second lead to the other end (fig. 31.2). A break in the wire is indicated if the pointer on the continuity tester dial does not move from the zero position.

To check for a short in a multiple conductor cable, disconnect the cable and attach one lead from the continuity tester to the end of one of the wires in the cable. Then touch the other lead to each of the other wire ends, one at a time. A short is indicated if the pointer on the tester dial moves from the zero position. Repeat the procedure, checking each wire in the cable against all other wires.

Figure 31.2—Using a continuity tester to check an anemometer circuit.

31.2 Details for Specific Anemometers

This section gives detailed maintenance instructions for specific models of anemometers in present or possible future use at fire-weather and other manually operated stations. Most of the instruments discussed by Fischer and Hardy (1976), mostly contacting types, are included, although some of these have now been discontinued in their manufacture (section 6.1). Also included are recent generator-type alternatives (section 8.3), which require very little maintenance.

While the instructions can be followed step by step, a complete reading is recommended before an anemometer is disassembled.

FORESTER NO. 9X140 ANEMOMETER

The maintenance instructions refer to figure 31.3. This anemometer has been replaced by a similar model, the Forester No. 9X145 Anemometer (Western Fire Equipment Catalog No. 92145). The Forester No. 9X140 was described in a catalog as a greatly improved version of the Chisholm Model 2B3C anemometer (whose maintenance instructions can be found in Fischer and Hardy 1976).

Monthly Maintenance—This instrument requires complete lubrication at least once for every 3 months of continuous use. To accomplish this, the instrument must be taken from the anemometer mast, disassembled (steps 1 through 4, below), lubricated (steps 8 through 11), and reassembled (steps 14 through 18).

Annual Maintenance—

Disassembly

1. Unscrew cap nut (A) and remove the cups (B).
2. Remove the cylinder-shell screw (D) on side of the cylinder head (C). Use a twisting motion to remove the cylinder head and stud (C).
3. Unfasten the slotted screw (H), located at top of the main shaft (F), that seals the oil channel to the lower bearing. (Some early units employ a lockring here instead of a screw.)
4. Remove the main shaft through the bottom of the cylinder shell (E). If the shaft sticks, tap lightly on its top.

Cleaning and lubrication

5. Do not attempt to wash the shielded bearings (E). These operate at 0.0001-inch clearance, and cleaning solvents may do more harm than good.
6. Clean all other parts as needed, using an instrument-cleaning solvent (section 31.1).

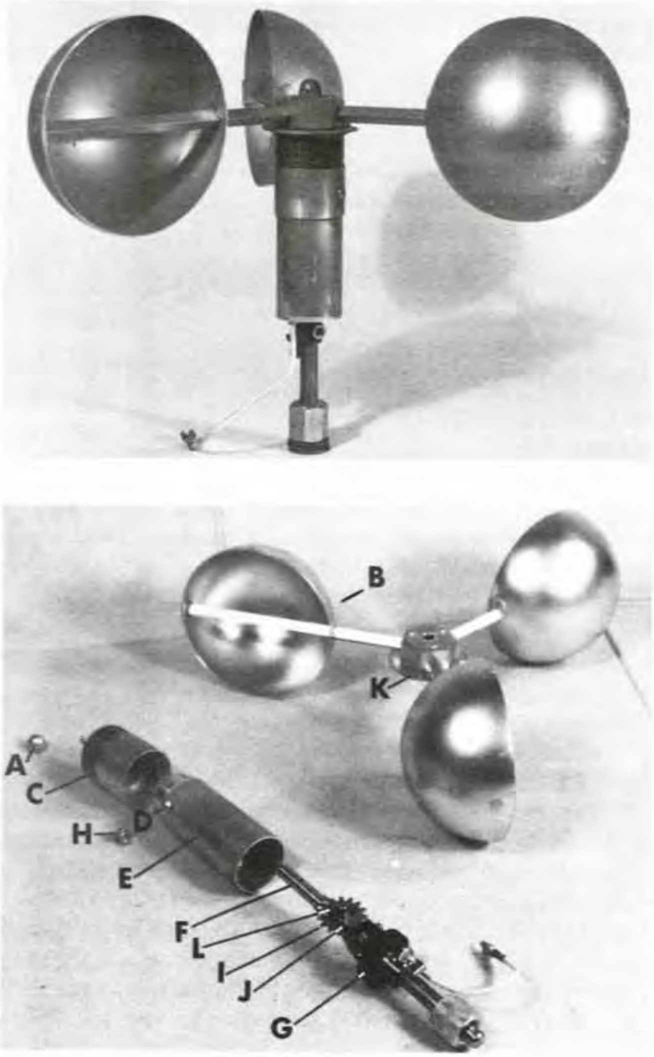


Figure 31.3—Forester Model 9X140 anemometer, assembled (upper view) and disassembled (lower view): A, cap nut; B, cups; C, cylinder head and stud assembly; D, cylinder-shell screw; E, cylinder shell with internal gear; F, main shaft; G, sprocket gear assembly; H, main shaft oil channel screw; I, sprocket gear; J, contacts; K, balance disc; L, sprocket gear striking pin.

7. Inspect the silver contact points (J) and replace with new points if they are badly burned or pitted. If they are only dirty, clean with crocus cloth and then pull a piece of hard-finish paper between them.

8. Apply two drops of anemometer oil on the shield of each bearing (section 31.1).

9. Apply one drop of anemometer oil on the sprocket gear shaft (I).

10. Apply two drops of oil at top of the internal gear located inside the cylinder shell (E).

11. Immediately wipe off any excess oil that may have run onto parts not requiring lubrication.

Mechanical inspection

12. Check the contact mechanism (J) by rotating the sprocket gear (I) and seeing if the striking pin (L) causes the bronze fingers (J) to make and break contact. The movement of the inside contact point should be between one-thirty-second and one-sixteenth inch. The outer contact point should deflect about one-sixty-fourth inch.

13. Check to make certain that the screws holding the contact arms are tight and secure.

Reassembly

14. Insert the main shaft (F) into bottom of the cylinder shell (E) and up through the two bearings.

15. Install the oil channel screw (H) (or lockring) at top of the shaft.

16. Using a twisting motion, push on the cylinder head (C), line up the hole in the side, and tighten the screw (D).

17. Install the balance disc (K), being careful to keep the side marked "top" in correct position.

18. Install the cups and tighten the cap nut.

19. Spin the cups and check the instrument for proper operation (section 31.1).

FORESTER MODEL 9X150

Instructions for this anemometer refer to figure 31.4.

Monthly Maintenance—This instrument does not require monthly maintenance if proper annual maintenance is provided.

Annual Maintenance—

Disassembly

1. Remove the 1/8-inch pipe plug from side of the body and drain the Versilube fluid from the instrument. NOTE: Versilube is a special synthetic lubricant that will neither congeal nor impair operation at temperatures below 0 °F. A bottle of this fluid is supplied with each instrument and additional quantities can be ordered from the manufacturer. **DO NOT USE ANY OTHER LUBRICANT.**

2. Unscrew the 1/4-inch stainless steel cap nut (A) and washer (B) on top of the cups. Remove cups (C), balance disc (H), and rain shield (rotor cap) (G). Do not disturb the small weight (I) on the balance disc.

Cleaning and lubrication

3. Clean dust and oil residue from the cups, interior of the rain shield, exterior of the housing (D), and the brass surfaces of the terminal posts (F).

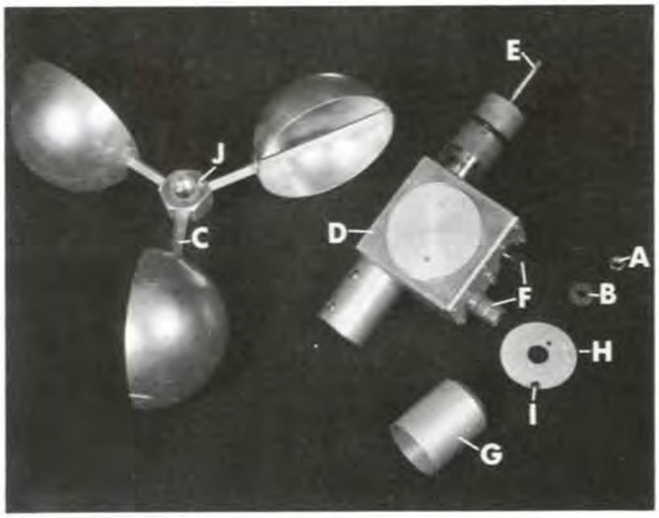


Figure 31.4—Forester Model 9X150 anemometer: A, cap nut; B, washer; C, cups; D, housing; E, upper main shaft; F, exterior terminal posts; G, rotor cap; H, balance disc; I, balance weight; J, rotor hub pin.

4. Briefly turn the anemometer upside down. The Versilube remaining in the body will lightly lubricate the lower main shaft bearing.

5. Return the anemometer upright and add three drops of Versilube on the upper main shaft bearing.

6. With the anemometer upright, refill the body with fresh Versilube fluid. Fill to lower edge of the fill hole.

Reassembly

7. Replace the pipe plug, using Teflon pipe-thread tape.

8. Install the rain shield and the balance disc; then the cups, making certain that the pin (J) on the hub is seated in the holes on the balance disc and rain shield. Install the washer and cap nut.

Mechanical inspection

9. Spin the shaft and check for any binding action. If binding occurs, check for improper assembly, bent or worn parts, dirt, and need for lubrication.

10. Check the switch contacts with a continuity tester (section 31.1). Every 15 rotations of the cups should produce one contact.

11. If the anemometer does not appear to operate properly, return it to the manufacturer. Do not disassemble any further than is indicated above, as the mercury switch inside the housing is easily broken.

SMALL AIRWAYS-TYPE ANEMOMETER

Maintenance instructions for this anemometer (Bendix-Friez and Instruments Corporation models) refer to figure 31.5.

Monthly Maintenance—Remove front cover plate (D) and inspect the spindle (F), upper ball bearing (J), and the worm gear (H). If oil is needed, carefully apply one or two drops each to the upper bearing, the worm gear, and the bottom of the spindle. Wipe off any excess oil before refastening the cover plate.

Annual Maintenance—

Disassembly

1. Unscrew cap nut (A) and lift off the cups (B) and rain shield (C).

2. Remove front cover plate (D).

3. Loosen set screw (O) above cover plate and lift out the spindle (F).

4. Remove back cover plate (Q) and disconnect wire from contact unit (G) by loosening screw (R) at the binding post (N).

Cleaning and lubrication

5. Wash the spindle, gears, and other parts—but not the contact unit (G)—with instrument-cleaning solvent (section 31.1).

6. Drain the solvent and allow the parts to dry.

7. Inspect the contact points (S) and replace if they are badly pitted; if only dirty, clean the points with crocus cloth and then pull a piece of hard-finish paper between them.

8. Check to make certain that positive, but not hard, contact is made when the worm wheel pin (I) closes the contact points. Bent contact fingers (T) can cause hard contact. If the contact fingers are bent, carefully straighten them with needle-nose pliers.

9. Reinstall the spindle and tighten setscrew.

10. Apply one drop of anemometer oil (section 31.1) to each of the following parts and places:

  a. Each end of the worm wheel shaft (I).
  b. Top of gear on the spindle (F).
  c. Lower end of the spindle.
  d. Lower bearing (K).
  e. Upper bearing (J).

11. Immediately wipe off any excess oil that may have run onto parts not requiring lubrication.

Mechanical inspection

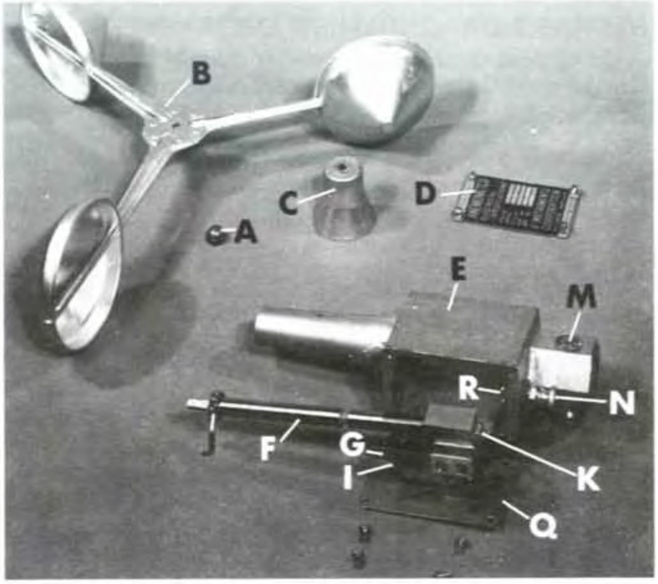
12. Whirl the spindle and see if it coasts freely. If it does not, turn the lower bearing adjustment screw (K). This screw can be reached by inserting a screwdriver through the bottom of the instrument. Turning the adjustment screw, raise or lower the spindle just enough to obtain the longest spinning duration.

13. Reconnect the wire from contact unit to the screw (R) at the binding post (N).

14. Reinstall the rain shield, cups, and cap nut. Spin the cups and check the instrument for proper operation (section 31.1).

Reassembly

15. Fasten the front and back covers. Tighten screws firmly, being careful not to strip threads.



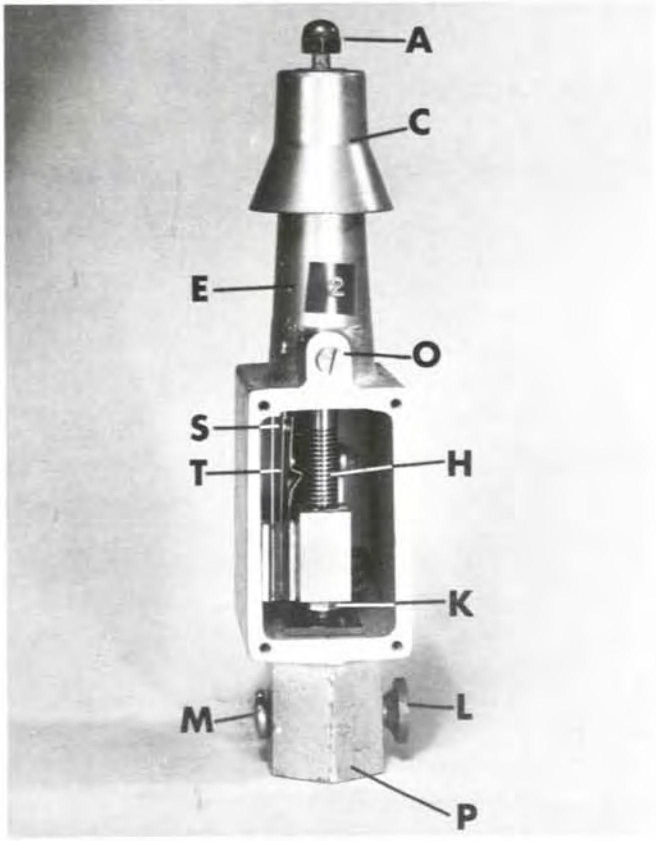


Figure 31.5—Small Airways type anemometer: A, cap nut; B, cups; C, rain shield; D, front cover plate; E, housing; F, spindle with worm gear; G, contact assembly; H, worm gear; I, worm wheel; J, upper ball bearing; K, lower bearing adjustment screw; L, thumb clamp screw; M, grounded terminal; N, insulated terminal; O, spindle retaining screw; P, mounting sleeve; Q, back cover plate; R, binding post screw; S, contact points; T, contact fingers.

STEWART ALUMINUM CUP ANEMOMETER

Instructions for this anemometer refer to figure 31.6. (Instructions for an earlier Stewart model, manufactured prior to 1959, can be found in Fischer and Hardy 1976.)

Monthly Maintenance—According the the manufacturer's instructions, this instrument does not require monthly service unless the electrical contact points need adjustment (step 8, below).

Annual Maintenance—

Disassembly

1. Loosen the setscrew on side of the hub and lift off the cups.
2. Loosen screws and remove cover plate from the housing (A).
3. *Do not* remove the nylon pinion gear (F) or loosen the brass bearing blocks (C) at the ends of the instrument shaft. This would cause spillage of tiny ball bearings—which are extremely difficult to reassemble.

Cleaning and lubrication

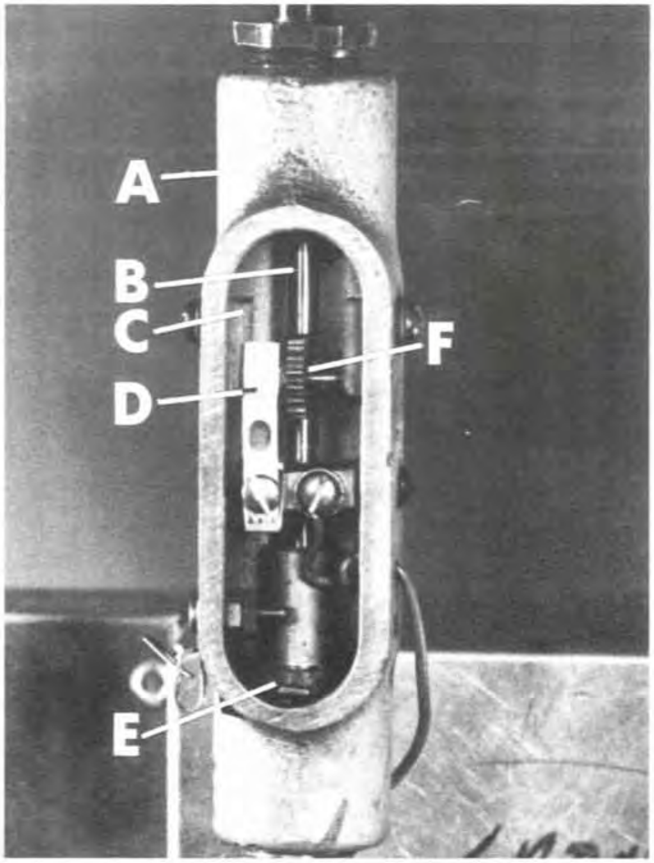
4. Using a clean, soft cloth, wipe off the top of the spindle (B), the spindle sleeve, and the inside of the hub. Lightly oil each of these areas with silicone fluid lubricant.
5. Apply several drops of silicone fluid on the spindle just above the top bearing and just above the lower bearing. Then whirl the spindle clockwise to work the lubricant into the bearings.
6. Apply a small amount of silicone grease (or vaseline) on the gear pinion (F) where the ground strap is attached.

Mechanical inspection

7. Spin the shaft and check for friction or binding. If the shaft binds, check for improper assembly, bent or worn parts, dirt, and need for lubrication.
8. Check the action of the contact leaf spring (D). If necessary, adjust the spring contact so that it is just barely moved by the pin on the ring gear. If the contact is too tight, excessive wear will result and the anemometer will stick at low windspeeds; if too loose, the attached readout device may not indicate properly.

Reassembly

9. Install the cups and tighten setscrew.
10. Fasten the cover plate.
11. Spin the cups and check for proper operation (section 31.1).



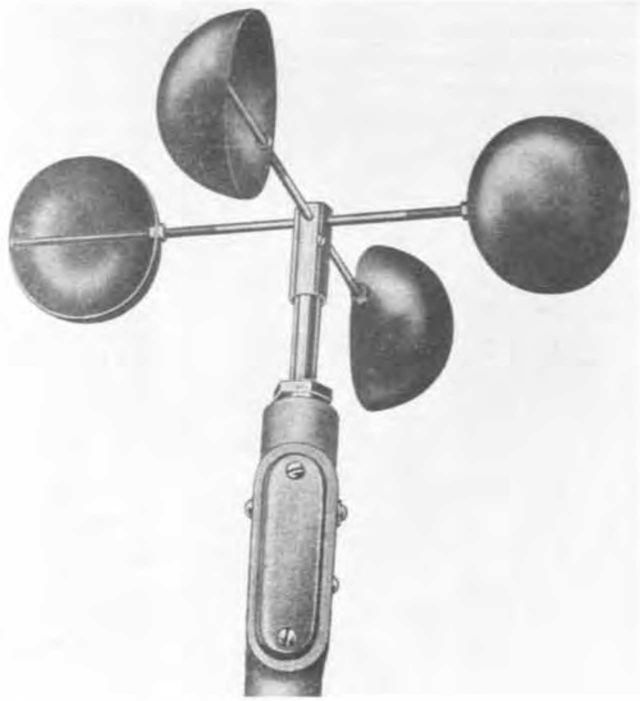


Figure 31.6—Stewart aluminum cup anemometer: A, housing; B, spindle; C, bearing block; D, contact leaf spring; E, lower thrust bearing; F, pinion gear.

BELFORT TOTALIZING ANEMOMETER

Instructions for this anemometer refer to figure 31.7.

Monthly Maintenance—Maintenance should be performed at least every 3 months; more often if the anemometer is exposed to excessive dust, frequent rains, or continuous strong windspeeds. This periodic maintenance should be the same as that outlined below for annual maintenance.

Annual Maintenance—

Disassembly

1. Remove the cap nut (A), loosen setscrew (B) in hub of the cup assembly, and remove the cups (C).
2. Release the spindle retainer screw (F) located in the housing (D), and lift spindle (G) upward out of the housing.
3. Remove the front and rear (E) cover plates.

Cleaning and lubrication

4. Wash the spindle and upper ball bearing (H) in an instrument-cleaning solvent (section 31.1).
5. Inspect the counter mechanism. If mechanism is dirty, wash and oil the lower ball bearing; then wipe off all dirt and oil from the mechanism and from the interior of the housing.
6. Apply one drop of light, nongumming instrument oil, such as Belfort instrument oil No. 5600, to each of the following parts or places:
   a. Upper bearing (H).
   b. Spindle (G).
   c. Worm, lower spindle bearing assembly (I).
   d. Worm assembly (J).
   e. The contact operating pins—*but not the contacts themselves.*

Mechanical inspection

7. Inspect the contacts and replace if they are burned or pitted; if only dirty, clean the contacts with crocus cloth and pull a piece of hard-finish paper between them. Check for overloading.
8. Reinstall the spindle and tighten the spindle retainer screw. Check to verify that the contacts and worm wheel are operating properly.

Reassembly

9. Install the cups on spindle. Tighten the setscrew in the rotor assembly hub just enough to prevent spindle from turning; then fasten the cap nut snugly and finish tightening the setscrew.
10. Spin the cups to see if they turn freely. If they do not, check for improper assembly, bent or worn parts, dirt, and need for lubrication (section 31.1).
11. Fasten the cover plates.

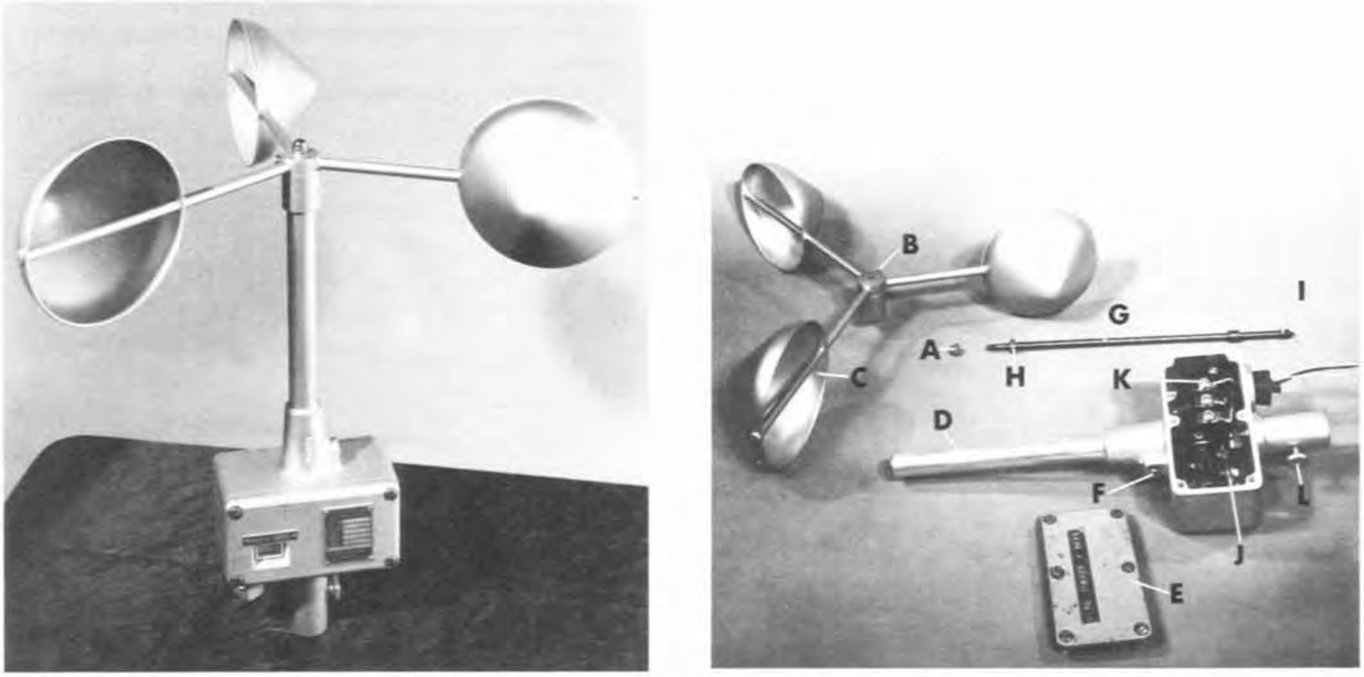


Figure 31.7—Belfort totalizing anemometer: A, cap nut; B, hub screw; C, cups; D, housing; E, back cover plate; F, spindle retaining screw; G, spindle; H, upper ball bearing; I, worm gear; J, worm wheel with pins; K, terminal block assembly; L, thumbscrew.

FRIEZ DIAL-TYPE ANEMOMETER

The instructions for this anemometer refer to figure 31.8.

Monthly Maintenance—Remove plug (P) from the back side of housing (G) (the side opposite the dial). Apply one drop of oil at the top of the worm gear (V) on the spindle (E). Apply one drop of oil at the lower end of the spindle where it enters the lower bearing.

Unscrew the top from oil cup (A) at top of the anemometer. Check to make certain that wicking extends down the center pipe. Fill cup about half full of oil.

Annual Maintenance—

Disassembly

1. Unscrew brass oil cup and the cap nut (A).
2. Loosen setscrew (B) and remove the anemometer cups (C).
3. Unscrew top bushing (D) and lift the spindle (E) from housing (G).
4. Remove the cover plate (F) from dials by removing the two holding screws. Leave the dials in place.

Cleaning

5. Clean the spindle (E) and top bushing (D) with instrument-cleaning solvent (section 31.1).
6. Blow air through the oil duct in top of spindle to clear it of any obstructions—from the top to the small hole in the side of spindle at the level of top bushing.
7. Inspect the contact points. If either the 1/60-mile contact (I) or the 1-mile contact (K) are dirty, clean with crocus cloth and then pull a piece of hard-finish paper between them.

Mechanical inspection

8. If the 1/60-mile contacts do not open sufficiently, increase the clearance by turning the contact adjustment screw (J) to the left. If the contacts do not close sufficiently, turn the contact adjustment screw to the right.
9. If the 1-mile contacts do not open sufficiently, loosen the screw that holds the lower portion of the contact and lower the contact position slightly. If they do not close sufficiently, raise the contact position slightly.
10. It may be necessary to bend the spring section of each of the contacts to obtain proper operation, but this should be a last resort.

Reassembly

11. Install the spindle, making certain that it is seated in the bottom bearing. Replace the top bushing.
12. Install the cups and tighten the setscrew.

Lubrication

13. Apply one drop of anemometer oil on each gear wheel on front of the dial (section 31.1). Replace the glass dial cover, tightening the holding screws.
14. Remove plug (P) from housing on back of the dial. Apply one drop of anemometer oil at top of the worm gear on the spindle. Apply one drop of oil at lower end of the spindle, where it enters the lower bearing. Replace plug.
15. Unscrew cover from the brass oil cup. If wick is missing, one can be made from heavy cotton sewing thread. It should lead from the oil cup down to the oil duct. Fill oil cup with anemometer oil to the level of the spindle.
16. Replace the oil cup on top of the spindle, and check hole in the spindle to be sure that oil is flowing onto the bushing.
17. Spin the anemometer cups and check for proper operation (section 31.1).

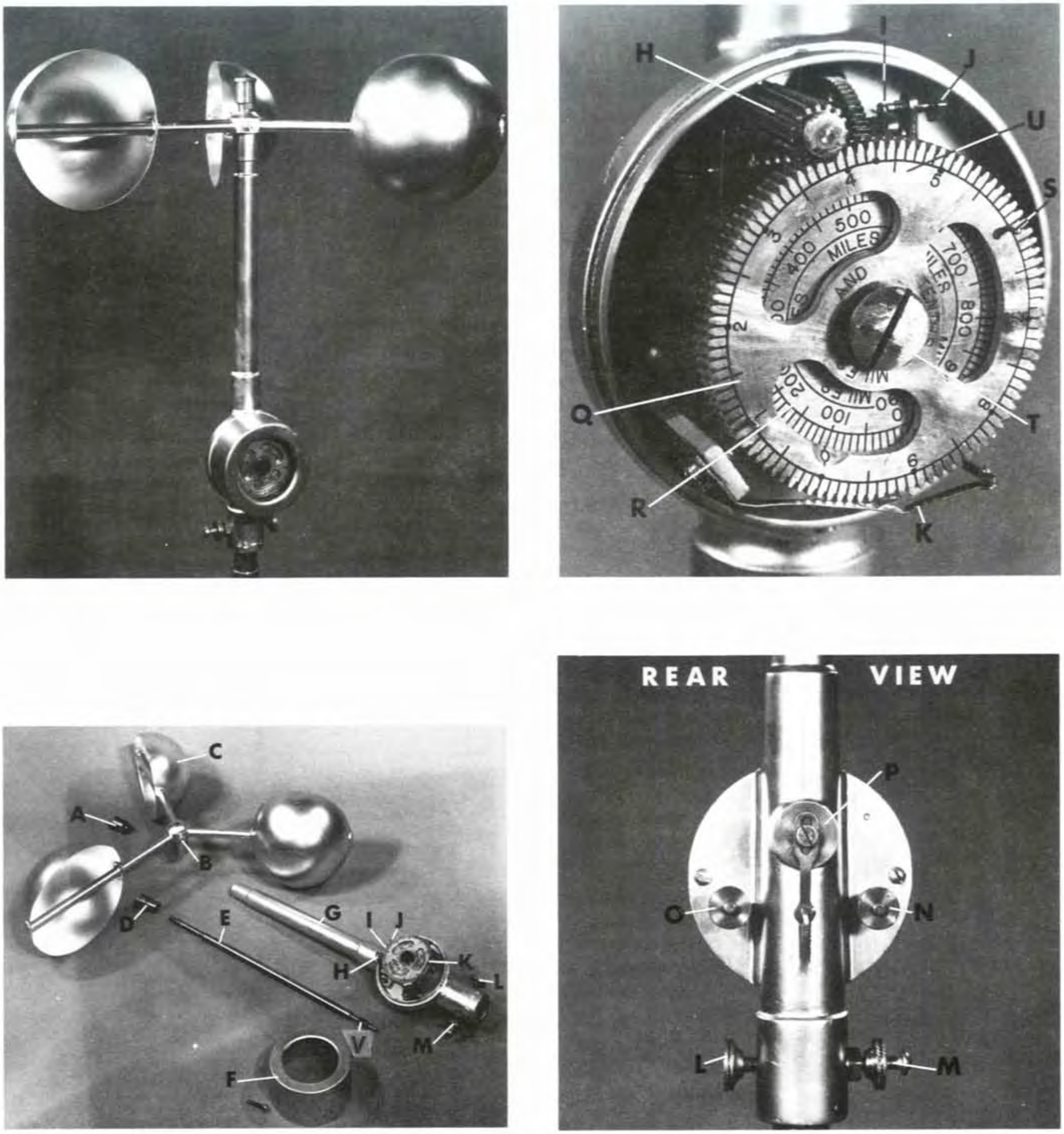


Figure 31.8—Friez dial-type anemometer: A, oil cup and cap nut; B, rotor hub setscrew; C, cups; D, top bushing; E, spindle with worm; F, dial cover plate; G, housing; H, gears; I, $^{1}/_{60}$-mile contact; J, contact adjustment screw; K, 1-mile contact; L, thumbscrew clamp; M, grounded terminal; N, $^{1}/_{60}$-mile terminal; O, 1-mile terminal; P, oil point plug; Q, outer dial wheel; R, inner dial wheel; S, 1-mile contact pin; T, dial screw; U, location of 10-mile bar; V, worm gear.

WEATHERMEASURE W164 AND W164B CONTACTING ANEMOMETERS

Instructions for these two models refer to figure 31.9.

Monthly Maintenance—Routine monthly service is not required if the annual maintenance is performed as specified below.

Annual Maintenance—

Disassembly

1. On instrument model W164B, remove the mechanical counter by removing the counter face plate and the fastener in the back of the counter. To free the counter from the housing, simply press the entire assembly forward. Model W164 does not have a mechanical counter.
2. Remove the cups (A) by unscrewing the lock nut (B) and cap nut (C) at top of the shaft (H) and pushing gently upward at the base of the shaft.
3. Remove the bearing setscrew (D) on the side of housing (I). Then remove the bearing oil seal (E) at top of the shaft (H) by turning it upward off the base assembly. Remove the top bearing (F).
4. Loosen the top housing lock pin (K) and turn the top assembly upward off the bottom housing (L).
5. To disassemble further, remove the bottom gear plate from the bottom support assembly by lifting it upward off the guide pin.
6. Care must be taken to maintain the proper shaft bearing clearance during reassembly. To assure the correct clearance, scribe indicating marks on the bottom bearing support and base-plate assembly prior to the disassembly.
7. To remove the shaft (H), loosen the bottom bearing by screwing it downward until sufficient clearance is obtained to slip the shaft off the worm and out of the bottom assembly.

Cleaning and lubrication

8. Lubricate the bottom and top bearing with anemometer oil that preferably has a silicone base. (See section 31.1.) Use a dry film lubricant on the gears.

Mechanical inspection

9. Inspect the contacts and replace if they are pitted or burned. Check for overload or inadequate spark suppression.

Reassembly

10. Install the shaft, being careful to maintain the proper shaft bearing clearance.
11. Return the bottom gear plate to the bottom support assembly.
12. Screw the top assembly onto the bottom housing. Tighten the top housing setscrew.
13. Replace the top bearing and the bearing oil seal. Tighten the bearing setscrew.
14. Install the cups, fastening the cap nut and then the cap lock nut.
15. Spin the cups and check for proper operation (section 31.1).

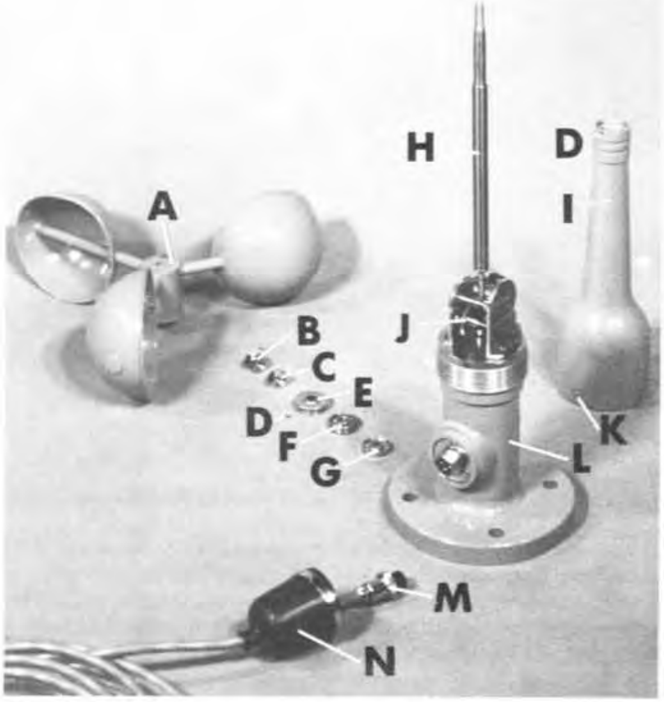


Figure 31.9—WeatherMeasure W164 contacting anemometer: A, cups; B, cap lock nut; C, cap nut; D, top lock screw; E, bearing oil seal; F, top bearing; G, bearing oil seal; H, drive shaft with worms; I, top housing; J, drive gear; K, top housing lock pin; L, bottom housing; M, cannon plug; N, weather boot.

NATURAL POWER ANEMOMETER, MODELS A19, A21, AND A22

According to the manufacturer, these generator-type anemometers require no maintenance except for suggested annual recalibration and replacement of cups every 5 years. Batteries in the accumulator unit should be replaced monthly if these are used as the power source; if the unit is connected to AC power, the batteries should be replaced once every year.

DWYER WIND METER

Maintenance requirements for this instrument (fig. 31.10) are relatively simple. The unit must be kept clean, dry, and static free.

Cleaning—

1. Clean the outer shell (A) with a damp cloth. Do not use cleaning agents that attack plastic.
2. Clean the inner tube (B) by using either the treated pipe cleaners provided with the instrument or regular pipe cleaners (fig. 31.11). Before cleaning the inner tube, unscrew the metal plug (D) at the bottom and carefully remove the white ball (C). After cleaning reinsert the ball and fasten plug.

Do not press on the white ball with fingers or other objects as it is easily deformed and damaged, making it unusable or unreliable; avoid touching it with fingers. If the ball has been damaged, replacement balls are available from the manufacturer.

Drying—If moisture enters the inner tube, unscrew the metal plug and remove the white ball. Clean the tube with a pipe cleaner (fig. 31.11). After all moisture has been removed, reinsert the ball and fasten plug.

Removing Static—A static electricity charge may cause the ball to stick in the tube. This can be corrected by moving a pipe cleaner up and down in the tube. Follow the procedure given for cleaning or drying the tube.

Calibration—Proper calibration depends on instrument maintenance in a clean, dry, and static-free condition. Be sure that the pinhole in the top stem (E) is kept clean and open. For cleaning, use nylon bristles provided with the meter (fig. 31.11). Do not use wire, pins, or other objects that might accidentally enlarge the opening.

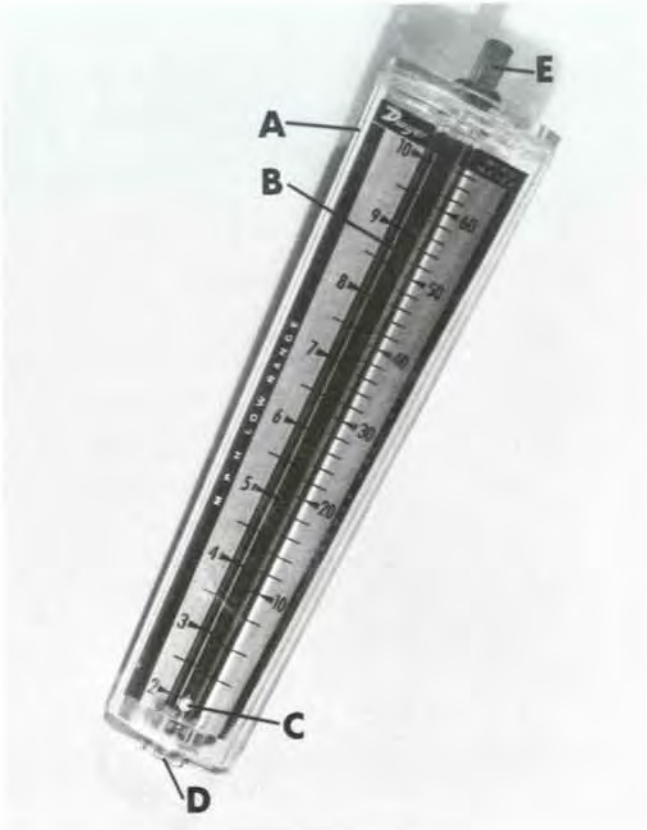


Figure 31.10—Dwyer hand-held wind meter: A, outer shell; B, inner tube; C, indicator ball; D, bottom plug; E, top stem.

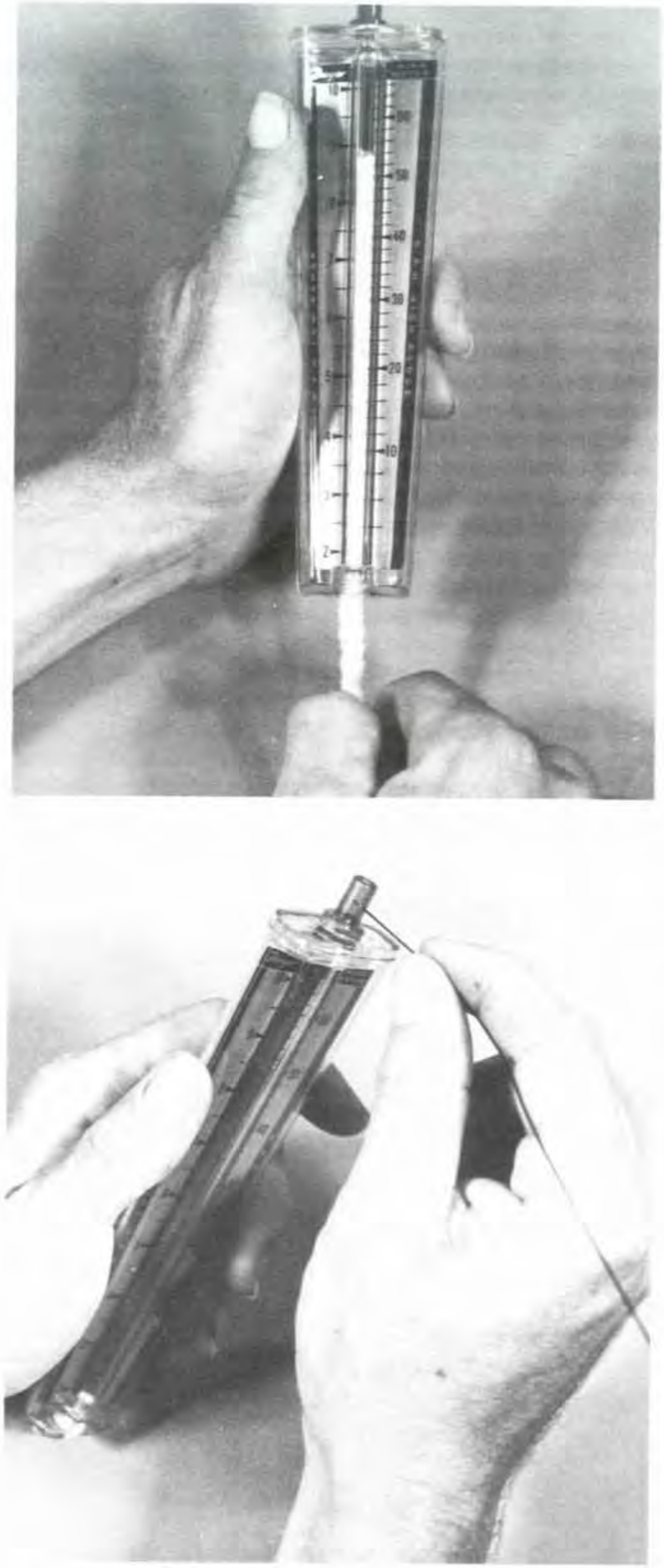


Figure 31.11—Top: cleaning, drying, and removing static from inner tube of Dwyer meter. Bottom: cleaning top stem pinhole.

31.3 Wind Counters

Maintenance requirements for wind counters are concerned mainly with the electrical circuit. Obtaining continuous, trouble-free operation depends on maintaining sufficient battery strength, sound wiring, and clean, tight electrical connections. Specific instructions follow.

BUZZERS AND FLASHERS

1. Install fresh batteries whenever the buzz or flash becomes weak.
2. At least once every year, clean the buzzer contacts with crocus cloth and hard-finish paper.
3. Periodically check electrical connections for tightness. Remove corrosion whenever it appears.
4. If the buzzer or flasher fails to operate, or operates weakly or intermittently, perform the following steps in succession until the trouble is corrected:

    a. Replace the batteries. Make certain that they are connected in series rather than parallel (fig. 31.12).

    b. Replace lamp or flasher bulb.

    c. Check the buzzer contacts. Burned contacts indicate excessive electrical current. Usually two to four 1½-volt batteries are sufficient; the number depends on the line length, buzzer voltage, and battery strength.

    d. Check all electrical connections on buzzer. Snap off the cover and check the inside connections.

    e. Using a rubber-handle screwdriver, create a short circuit between the switch and the buzzer. If there is no response, clean the buzzer contacts. If the contacts are clean and trouble persists, bend the vibrator closer to the magnet. If this does not help, replace the buzzer.

    f. Short-circuit across the terminals at the lightning arrester on the buzzer or flasher side, then on the anemometer side; finally, create a short at the anemometer itself by touching the lead wires together.

    g. If the buzzer sounds or the lamp lights each time these shorts are made, the trouble source is either in the anemometer lead wires or in the anemometer itself.

5. If the buzzer or flasher operates continuously when the switch is closed, check all circuits for shorts or bare wires.

Maintenance instructions for several widely used mechanical windspeed counters follow.

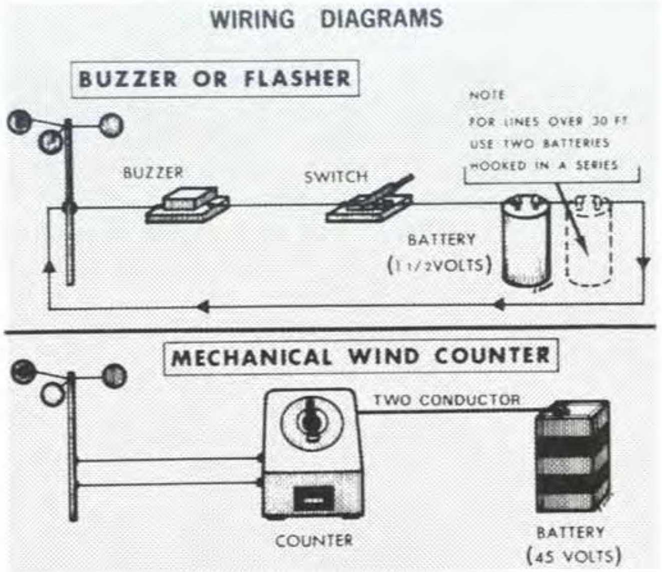


Figure 31.12—Wiring diagrams: upper, for buzzer or flasher; lower, for mechanical wind counter.

FORESTER 9X156 WIND COUNTER

The instructions for this counter (Western Fire Equipment Catalog No. 92156) refer to figure 31.13.

Annual Maintenance—

1. Clean the exterior of the counter. Use nonflammable instrument-cleaning solvent to remove stubborn dirt.
2. Carefully open the counter and clean the inside, using a soft brush. Use the above cleaning solvent for stubborn dirt.
3. Check all electrical connections inside the counter. Tighten loose connections and resolder broken connections, using rosin-core solder.
4. Reassemble the counter and check the timer for accuracy. If necessary, adjust timer setting as follows:
    a. Loosen locking lug.
    b. Rotate time stop to the correct position.
    c. Tighten locking lug.
5. Inspect battery leads and install a fresh battery. Remove any dirt or corrosion from the battery leads and replace any worn or broken lead wires.
6. Inspect anemometer leads and clean or replace as necessary.
7. Test the wind counter by attaching a contacting anemometer (fig. 31.12, lower diagram). Spin the cups by hand and observe if the counter advances each time the anemometer closes a contact. The counter can also be tested by touching the counter leads together at 1- to 1½ second intervals.

Periodic Maintenance and Troubleshooting—

1. Occasionally check the timer against a stopwatch. Reset if necessary.
2. In the event of counter failure, proceed as follows:
    a. Install a fresh battery and check battery lead wires for visible signs of wear or breaks.
    b. Remove one anemometer lead wire from the counter.
    c. Set the timer and while it is running, alternately make and break a short circuit across the binding posts, using a piece of wire.
    d. If the counter advances each time the circuit is closed (step c), the source of trouble is in the anemometer or the anemometer lead wires. Check the lead wires with a continuity tester (section 31.1). If the lead wires are sound, refer to the anemometer maintenance instructions and check contacts and electrical connections accordingly.
    e. If the counter fails to advance when the circuit is closed, and all the previous steps have been followed, test the battery lead wires for continuity (section 31.1). If the trouble source is not here, the counter should be checked by an electronics technician.

Figure 31.13—Forester 9X156 wind counter.

Figure 31.14—Forester (Haytronics) totalizing wind counter.

FORESTER (HAYTRONICS) TOTALIZING WIND COUNTER

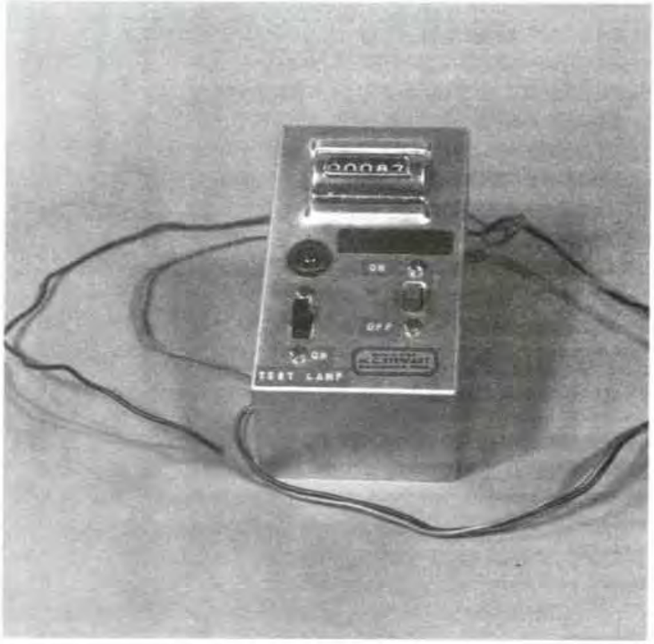
This instrument (Western Fire Equipment Catalog No. 92155) (fig. 31.14) has the same maintenance requirements as the Forester 9X156 counter (above). But it has an "on-off" switch rather than a timer dial, and the above instructions should be modified accordingly.

STEWART ELECTRONIC ODOMETER

The following instructions refer to figure 31.15.

Annual Maintenance—

1. Clean the exterior of counter, using instrument-cleaning solvent to remove stubborn dirt.
2. Open the counter by lightly squeezing on the sides and slowly pulling the two sections straight apart. The wires on the two switches are flexible, allowing the sections to be separated sufficiently to reach the interior.
3. Clean the interior of counter with instrument-cleaning solvent and a soft brush.
4. Check all connections inside the counter. Tighten loose connections and resolder broken connections, using rosin-core solder.
5. Carefully close the counter box, being sure not to pinch any of the interior wiring between the two sections or to disturb the transistors in their sockets. Loop the switch wires into accordion folds; then squeeze the sides of the box and slide the front cover (A) slowly and squarely onto the back section.
6. Inspect the battery lead wires (F and G) for wear, breaks, or corrosion. Clean, repair, or replace as necessary. Install a fresh, heavy-duty, 6-volt lantern battery that has screw posts.
7. Inspect the anemometer lead wires for wear, breaks, or corrosion. Clean, repair, or replace as necessary.
8. Push the counter switch (J) into the "on" position. This is a built-in test of the instrument and should cause the right-hand counter wheel to advance one count. If the counter does not advance one count, do the following until the trouble is corrected:



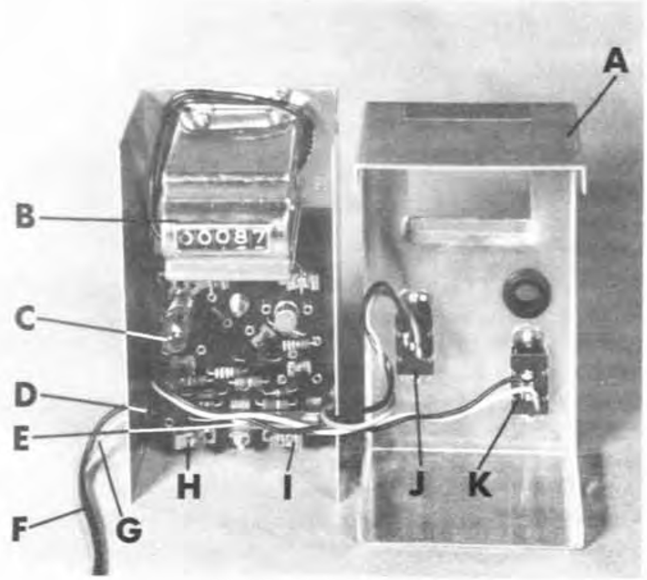


Figure 31.15—Stewart electronic odometer: A, front cover (underside); B, mechanical counter; C, test lamp; D, rubber grommet; E, fuse; F, negative battery wire; G, positive battery wire; H, anemometer ground wire (positive) spring clip; I, anemometer wire negative spring clip; J, counter "on-off" switch; K, test lamp "on" switch.

a. Check battery polarity.

b. Test the battery or install a fresh one.

c. Check all lead wires with a continuity tester (section 31.1).

d. Open the counter and replace fuse (E) on the circuit board. Use 3AG, 1½-amp Littlefuse #31201.5, or its equivalent.

9. Attach the anemometer, spin the cups, and hold the left-hand switch (K) down. This is a test of the anemometer circuit and should cause the test lamp to light each time the anemometer contacts close. If the lamp does not light, do the following until the trouble is corrected:

a. Check battery polarity.

b. Test the battery or install a fresh one.

c. Open the counter and replace the lamp bulb (C). Use a GS48 bulb, or its equivalent.

d. Check the anemometer leads with a continuity tester.

e. Check the anemometer contacts and electrical circuit.

Periodic Maintenance and Troubleshooting—

1. Replace the battery as required. The decline in test lamp brilliance can be used as a guide for replacement time.
2. Before each observation, test the instrument by turning the power switch on and seeing if the counter advances one count. If the counter does not advance, refer to annual maintenance step 8.
3. Before each observation, depress the switch under test lamp to see if the lamp lights when the anemometer contacts close. If the lamp does not light, refer to annual maintenance step 9.

31.4 Wind Vanes

Wind vanes are designed for trouble-free operation over long periods of time. Annual maintenance consisting of cleaning, lubrication, and general refurbishing is usually sufficient to keep an instrument in good operating condition.

Simple, nontransmitting wind vanes require only maintenance that will ensure free turning in light winds. Inspect for binding and excessively worn parts.

At least once every year, the arrow should be removed from the spindle and cleaned with instrument-cleaning solvent. The spindle should also be cleaned and then lubricated with two or three drops of anemometer oil. Inspect all parts for excessive wear and damage, such as a bent spindle or arrow, which could cause binding or irregular turning. If appropriate, repaint worn surfaces—but not the spindle—to guard against corrosion and to enhance general appearance.

STEWART WIND DIRECTION SYSTEM

Annual Maintenance, Wind Vane—(Refer to figure 31.16.)

1. Loosen the setscrew on the hub of the arrow (where the shaft and tail meet) and remove the arrow (A) from the spindle (D).
2. Clean the arrow and spindle with instrument-cleaning solvent.
3. Loosen the four corner screws and remove front housing cover (B).
4. Clean the commutator ring with instrument-cleaning solvent, using a small, soft brush or cotton swab.
5. Note color of wire that is attached to each binding post (F).
6. Remove the wires, one at a time, and clean all dirt and corrosion from the ends of the wires and from the binding posts.
7. Reinstall the wires, tightening all connections.
8. Inspect the front housing cover gasket. If it is worn, torn, or otherwise damaged and unable to provide a moistureproof seal, install a new one cut from similar material.
9. Refasten the front housing cover.
10. Place three drops of anemometer oil on the spindle (D), just above the top bearing.
11. Reinstall the arrow, tightening the setscrew.

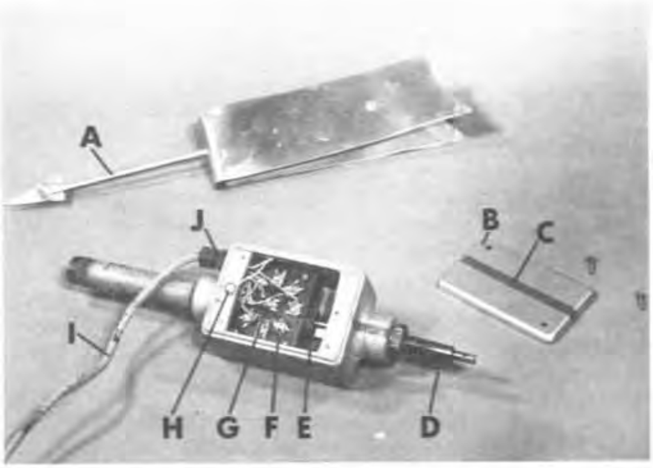


Figure 31.16—Stewart wind direction system—wind vane component: A, arrow; B, front cover; C, orientation mark; D, spindle; E, contact roller; F, terminal block binding post; G, anemometer wire binding post; H, ground connection screw; I, multiple conductor cable; J, nut and compression sleeve.

Annual Maintenance, Wind Direction Indicator— (Refer to figure 31.17.)

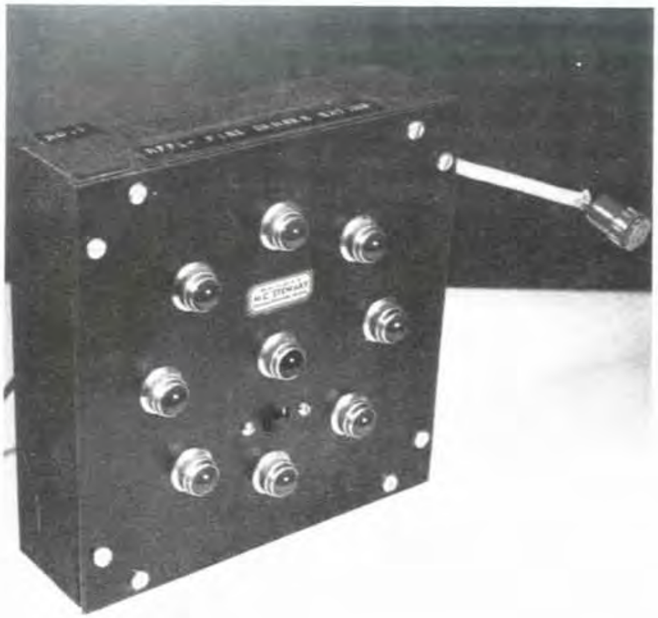
1. If a battery is attached, remove and discard it.
2. Loosen corner screws (F) and remove front panel (B).
3. Clean dust from interior of cabinet (A).
4. Inspect electrical connections (D) and remove any dirt or corrosion.
5. Repair loose connections, using rosin-core solder.
6. Attach a fresh 6-volt lantern battery. Spin the wind vane arrow to see if all of the indicator lamps will light.
7. If a lamp does not light, replace the bulb.
8. To replace a lamp bulb, first remove the protective lens by turning it counterclockwise. Grip the bulb with a short piece of rubber tubing and also turn counterclockwise. The replacement bulb should be GE #46, or its equivalent, and have a blue bead just below the filament. Be sure to reinstall the protective lens.
9. After installing each new lamp bulb, spin the wind vane arrow. If the lamp still fails to light, check for breaks and shorts in wires and connecting cables (section 31.1).
10. When all lamps will light, fasten the front panel.

Periodic Maintenance—

1. The passage of current through the contacts retards both the buildup of corrosion and the accumulation of dust particles and oil film on the contact surfaces. Therefore, it is suggested that the indicator lamp switch be left "on" throughout the day and turned "off" only at night.
2. Whenever the lamps become dim, replace the battery.

31.5 Other Windspeed and Direction Systems

Wind systems measuring direction and speed with generator-type sensors often employ sealed units requiring little routine maintenance. They may, however, require factory service if problems arise. Follow the manufacturer's instructions for maintenance of such instruments.



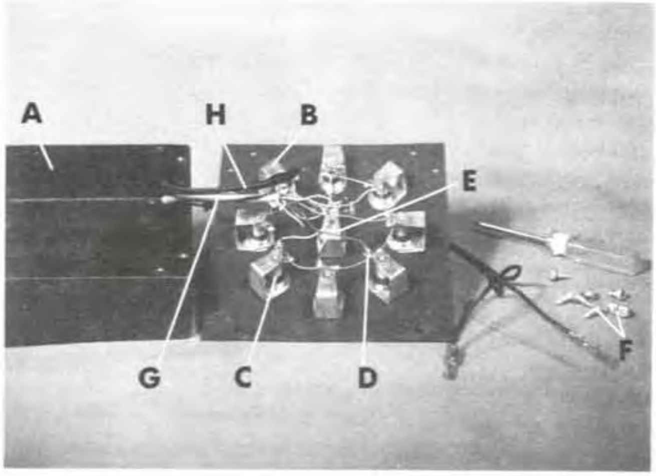


Figure 31.17—Stewart wind direction system—wind indicator dial: A, cabinet; B, indicator panel; C, lamp socket; D, lamp socket terminal; E, anemometer flasher unit; F, front panel screws; G, multiple conductor cable; H, battery cable.

CHAPTER 32. PRECIPITATION GAUGES

Maintenance requirements for the various nonrecording precipitation (or "rain") gauges (section 9.1) are generally similar. Thus, while the maintenance instructions here refer primarily to standard 8-inch gauges, the general principles also apply to small-orifice gauges. Recording rain gauges, conversely, have differing maintenance requirements depending on type, make, and model. Wherever possible, the manufacturer's instruction manual should be consulted before any major maintenance is attempted on recording gauges.

32.1 Nonrecording Rain Gauges

STANDARD 8-INCH (AND OTHER) NONRECORDING GAUGES

Nonrecording rain gauges are perhaps the easiest of all manual-type weather instruments to maintain. Nevertheless, the few simple requirements listed below should be followed for accurate measurement of precipitation.

Annual Maintenance—

1. Carefully check both the measuring tube and the overflow cylinder for leaks and dents. Repair or replace these components as necessary.
2. Check the rim or knife edge of the collector. It should be perfectly round (except for the wedge-shaped gauge) and free of nicks, dents, and other irregularities. Repair or replace as necessary.
3. Thoroughly clean the inside of the measuring tube, using hot water and a brush.
4. Check condition of the measuring stick. Clean if necessary, using soap and water. Replace stick if markings are badly faded. Markings on wooden stick may be temporarily restored with a pencil.
5. On plastic gauges that have etched graduations, renew the markings if necessary. This can be done by using the techniques described for thermometers (section 30.2).

Periodic Maintenance—

1. Check the rain gauge support to make sure that it is sound, plumb, and firmly anchored to the ground. Repair or adjust as necessary.
2. Keep the top of the gauge level, making sure that the collector is correctly seated. Check periodically with a carpenter's level set in various directions across the top of the collector (fig. 32.1). If necessary, adjust the gauge support.
3. Keep the overflow cylinder and measuring tube free of dirt and debris. Do not allow debris to collect in the funnel. Empty the measuring tube after each measurement.
4. Clean the measuring stick, as necessary, to maintain readability of the markings and precipitation waterline; wash with soap and water. (See annual maintenance, step 4.)

Figure 32.1—Checking the level exposure of a standard rain gauge (Forest Service type).

To prevent a possible oily film that sheds water from the stick, making waterline indistinct, do not touch the graduated part of measuring stick with the hands. Always hold the stick at its upper end.

5. During freezing weather, remove the funnel and measuring tube to prevent ice damage and to properly collect snowfall.

Weighing Scales—No regular maintenance is specified. As a precaution, however, avoid weighing amounts that are in excess of scale capacity. For the scale shown in figure 9.3, this capacity is about 40 pounds (with corresponding precipitation reading of 22 inches for an 8-inch-diameter gauge). Replace torn, scratched, or wornout decals (giving readings in inches) on the face of the scales. This replacement may require removal of the pointer. Upon refastening, use solder to prevent the pointer from accidentally becoming loose.

32.2 Recording Rain Gauges

UNIVERSAL WEIGHING GAUGE

Maintenance requirements of the weighing-gauge pen, pen arm assembly, chart drive assembly, and clock movement are identical to those already described for similar components of the hygrothermograph (section 30.5).

General Maintenance—(Refer to fig. 32.2.) The following maintenance should be performed at the end of each season's use (at a fire-weather station), or every 6 months if the gauge is operated year-round. Refer to the manufacturer's instrument manual for detailed instructions.

1. Remove the collector and outer case. Clean all moving parts thoroughly, using instrument-cleaning solvent applied with a soft brush. Do not use solvents that attack painted surfaces.
2. Check the linkage system, weighing spring, and other moving parts for wear and other evidence of binding or excessive friction.
3. Lubricate sparingly the bearings of all moving parts—except the chart drive assembly—with a light, nongumming instrument oil.
4. Scrub the inside and outside surfaces of the bucket to remove accumulated dirt, grime, and corrosion. Replace the bucket if leakage has occurred.
5. Check the level of fluid in the dash pot (I). Add necessary dash pot fluid to bring the level to within one-fourth inch of the top of the dash pot. Dash pot fluid is available from most instrument suppliers or directly from the manufacturer.

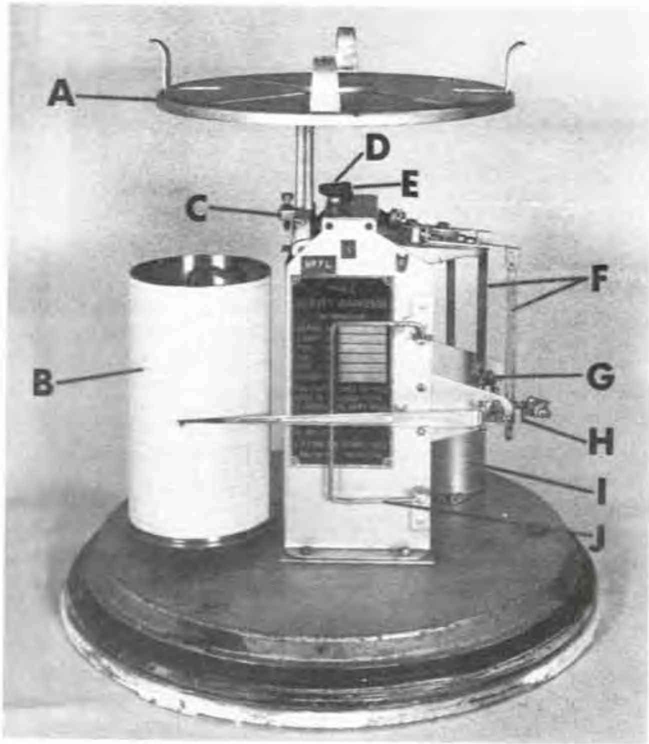


Figure 32.2—Universal weighing precipitation gauge—weighing and recording assembly: A, weighing platform; B, chart drive assembly; C, stop screw; D, spring adjustment screw; E, pen adjustment thumbscrew (red); F, linkage assembly; G, magnification bar (first traverse); H, magnification bar (second traverse); I, dash pot; J, pen lifter.

Figure 32.3—Calibration weights for Universal weighing gauge.

6. Check the weighing gauge for accuracy by placing specified amounts of water in the bucket or using calibration weights. These weights (fig. 32.3) are available from the gauge manufacturer or distributor. Detailed testing instructions are given below.
7. Refer to section 30.5 for general maintenance requirements for pen, pen arm assembly, chart drive assembly (B), and clock mechanism.

Calibration—Before checking the gauge accuracy and attempting any recalibration, perform the following checks and tests:

1. Check the chart installation. The chart must be firmly seated against the flange along the lower edge of the chart drum (B).
2. Check the chart drum. It must be properly seated on its spindle. The external gears must be meshed.
3. Make certain that there are two spacing washers between the base of the gauge and the large stationary gear at the base of the spindle.
4. Check the mechanical condition of the gauge. Look especially for points of excessive friction or binding in the linkage. Also look for possible spider webs restricting the linkage.

After the above items have been checked, proceed to check the existing calibration as follows:

5. Place the bucket on weighing platform (A).
6. Set the pen to the zero line on the recording chart, using the red knurled thumbscrew (D).
7. Add water or calibration weights to the bucket, in equivalent 1.00-inch rainfall increments. When using water, place exactly 29.0 ounces in the bucket for each inch of rain in the standard, 8-inch-diameter orifice,

Universal gauge. (Bendix-Friez Model 775CS requires 72.5 ounces for each inch of rain.) As many as 12 increments should be employed, for gauges with 12-inch (dual traverse) charts.

8. Observe the precipitation amount shown on the chart after each water or weight increment has been added.

A need for instrument recalibration is indicated if the results show chart errors exceeding 0.5 percent of the full scale (manufacturer's specification), or 0.01 inch per 1.00-inch chart increment on a 12-inch (dual traverse) chart.

9. If excessive gauge errors are indicated by a test done with water, repeat the procedure to be sure that the amounts of added water have been exactly those required.

If during the test there is insufficient or nonuniform motion of the pen over the first 1 or 2 inches of the chart, but correct or uniform motion occurs thereafter, the weighing spring is probably worn or damaged. The spring can be checked further by observing its action when the empty bucket and weights are added to the weighing platform. After the bucket and a weight (or 1.00-inch equivalent water) are added, the spring should have started to open. If no space can be observed between each effective coil, the spring should be replaced.

Recalibration should not be attempted without the detailed instructions and schematic diagrams provided by the manufacturer. These are contained in the instrument manual (for Bendix-Friez gauges) or are available from the manufacturer by request (for Belfort gauges).

TIPPING BUCKET GAUGE

Specific maintenance requirements will vary, depending on model. For example, some models do not have a water storage reservoir. The manufacturer's instrument manual should be consulted for detailed information on maintenance and calibration.

Annual Maintenance—(Refer to figure 32.4.)

1. Discontinue the use of a tipping bucket rain gauge in freezing weather unless the instrument contains a heating unit.
2. Check the collector rim (A). It should be perfectly round and free of nicks, dents, and other irregularities. Repair or replace as necessary.
3. Clean the water storage reservoir and check for leaks.
4. Remove and clean the collector (B). Clean the exposed moving parts, using a soft brush and instrument-cleaning solvent. Be sure to use a cleaner that does not attack painted surfaces.
5. Check all parts for wear; replace if necessary.
6. Check the tipping bucket (C) action. Eliminate any binding that occurs.
7. Lubricate sparingly the pivots of the bucket and the V bearing in the bucket support bracket. Use a light, nongumming instrument oil.
8. Do not attempt to adjust position of the calibration stop screws (D) located in the support bracket unless complete calibration instructions are available. Calibration is set at the factory and usually does not require modification unless the instrument has been subjected to very rough handling.

Figure 32.4—Tipping bucket precipitation gauge: A, collector rim ("knife edge"); B, collector; C, tipping bucket; D, calibration stop screw; E, measuring tube (for gauge with reservoir); F, cable to recorder.

Periodic Maintenance—

1. Keep the collector free of debris.
2. At least monthly, carefully clean the tipping bucket to remove any existing dirt or debris. Use a clean cloth.
3. Wipe the bucket pivots and support bracket V bearing monthly with an oiled cloth.
4. Check the pivot adjustment screws to make certain that the bucket is centered and that there is no excessive end play.
5. If the gauge has a water storage reservoir, check the recorded precipitation with a stick measurement of the amount drained into the measuring cylinder (E). Clean the drain cock with a cloth and check for possible dripping.
6. Check the mercury or reed switch to be sure it is functioning; inspect the magnet to be sure it has not lost its strength.

Recorder Maintenance—Whether a chart or digital recorder is used with a tipping bucket gauge, maintenance generally consists of checking electrical components and connections and the recording mechanism (and pens, if used). Instructions analogous to those in sections 30.5, 31.1, and 31.3 will apply. Refer to the appropriate instrument manual for specific maintenance requirements.

CHAPTER 33. FUEL MOISTURE EQUIPMENT

33.1 Fuel Moisture Sticks

A fuel moisture stick (set of dowels) should be discarded after one season's use; more often where the stick weathers rapidly, even though corrections for aging are applied (Deeming and others 1977; Harrington 1983). Although there is no annual maintenance, the following simple precautions should be practiced to obtain accurate measurements during a stick's period of use.

1. Keep the stick clean, because dirt, oil, and dust add to the weight and can interfere with normal moisture changes of the sticks. Prior to each weighing, dust the stick with a soft, clean paint brush. Do not brush the stick if it is wet, however; wait until it is dry.
2. Cover hands with clean gloves or use a clean cloth or piece of hard-finish paper to pick up the stick for weighing. Bare hands can contaminate the stick with oil and dirt.
3. Keep mud off the stick. A properly installed duff bed will prevent mud from splashing onto the stick during heavy rain. If the stick does become mud splattered, allow the mud to dry and then brush off (do not rub in) the dirt.
4. Keep the metal hook in place at the end of the stick, because its weight is included in the 100-gram dry weight of the stick. Similarly, guard against scratches, chips, or breaks. If they occur, replace the stick with a new one.

33.2 Fuel Moisture Scales

When properly installed in a weatherproof shelter, a fuel moisture scale requires minimal maintenance. Primarily, this consists of annual cleaning and periodic calibration checks. The following paragraphs give specific maintenance instructions for the scales most often used for fire-weather or fire-danger rating purposes.

THE FORESTER SCALE

The instructions for this scale (Forester Model 9X100 or Bendix-Friez Fuel Moisture Scale) refer to figure 33.1.

Annual Maintenance—

1. Disassemble the scale and clean all parts, using a nonflammable instrument-cleaning solvent.
2. Check the beam (E) for straightness; if bent, repair or replace it.
3. Check the wire hook (J) at end of the beam. It should be straight, well formed, and able to swing freely.
4. Clean and check the bearing hole on the front (C) and rear (D) pivot plates; if excessively worn, replace pivot plates.
5. Check the beam pivot shaft (F), which must be straight; if bent or excessively worn, repair or replace it.
6. Reassemble the scale and mount it in shelter. Check first the shelter and then the scale for level installation. Both must be square and plumb.
7. Check adjustment of the scale components. The sliding weight (I) must be movable by moderate hand pressure; adjust if necessary by turning the setscrew

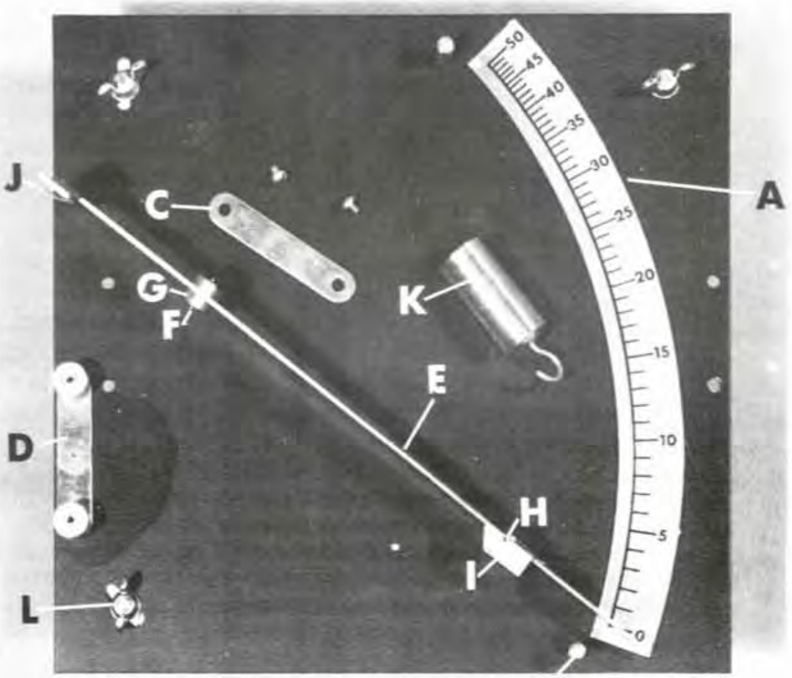


Figure 33.1—Forester scale: A, backplate with calibrated scale; B, beam stop plug; C, front pivot plate; D, rear pivot plate; E, beam; F, beam pivot shaft; G, beam pivot shaft spacer; H, sliding weight setscrew; I, sliding weight; J, beam link or hook; K, 100-gram test weight; L, mounting bracket wing nut.

(H) on top of the sliding weight. Set the sliding weight at the "100" mark on the beam and hang the 100-gram test weight on hook (J); pointer should indicate zero on the graduated arc scale. If the pointer does not indicate zero, loosen wing nuts (L) and adjust the entire backplate (A) upward or downward. Do not adjust the pointer to zero by moving the sliding weight, as this changes the reference ovendry weight of the fuel stick.

Periodic Maintenance—

1. Dust the scale with a soft brush whenever a buildup of dirt is visible.
2. Occasionally check both the shelter and scale for level and plumb installation.
3. Prior to each use of the scale, check the calibration with test weight (K). Make only very fine adjustments with the sliding weight (see annual maintenace item 7).

REGION 6 SCALE

This scale is almost identical to the Forester scale, except that it has no sliding weight on the beam. Maintenance instructions, except for calibration, are those given above for the Forester scale. To calibrate, hang the 100-gram weight on hook at end of the beam. If the pointer does not read zero, loosen the wing nuts that hold the backplate to the mounting plate; then turn the scale on the upper right-hand bolt until the pointer reads zero. Tighten the wing nut and check the pointer again. If necessary, repeat the procedure until a zero reading is obtained.

FORESTER (CHISHOLM) PORTABLE SCALE

To check this scale (fig. 33.2) for calibration, hang the 100-gram test weight on the loop (C), hold the scale level, and see if the pointer (D) reads zero on the scale (A). If the pointer does not read zero, loosen the nut (H) at weight end of the scale beam shaft (E) and adjust the weight (F) until a zero reading is obtained. Tighten the nut and recheck. Always be sure to hold the scale level.

WILLIAMS POCKET SCALE

The primary maintenance requirement of this sturdy, compact instrument (fig. 33.3) is periodic cleaning. Apply instrument-cleaning solvent and use a toothbrush to scrub away accumulated dirt, especially from the threads on the balance beam (D) and handle (A).

The central knife edge (E) of the scale is spring loaded to protect it from damage and is adjusted to move freely under the screw heads. The adjustment, which has been set correctly at the factory, never needs to be changed.

The scale's cover (B) also serves as a 100-gram test weight. Therefore, do not engrave on it, stick plastic marking tape on it, or otherwise alter its original weight.

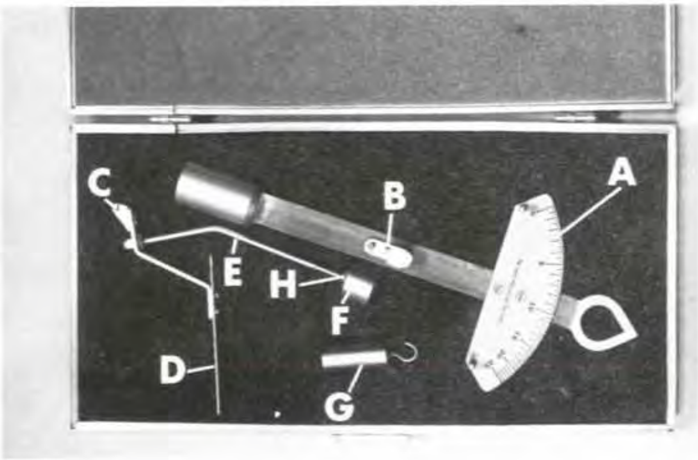


Figure 33.2—Forester (Chisholm) portable fuel moisture scale: A, scale; B, scale beam support bracket; C, fuel stick suspension loop; D, pointer; E, scale beam shaft; F, scale beam weight; G, 100-gram test weight; H, scale beam weight adjustment nut.

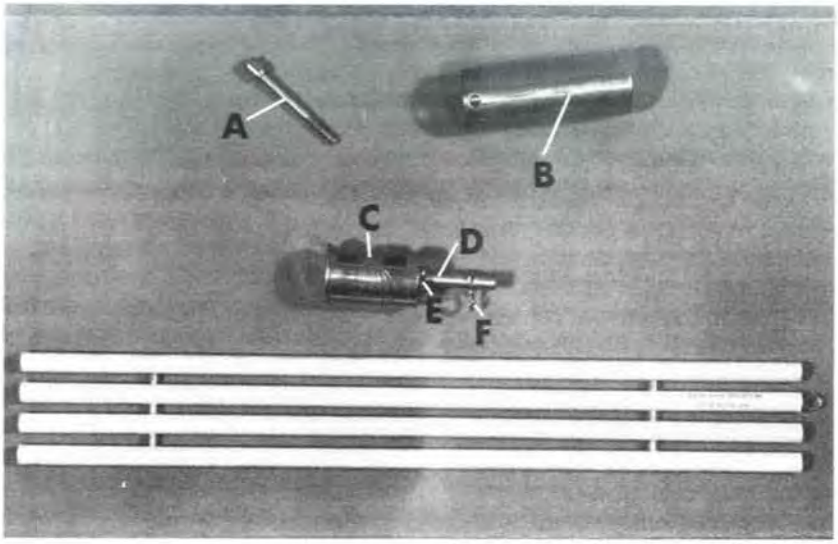


Figure 33.3—Williams Pocket Firestick Moisture Scale: A, handle with locking screw; B, cover and 100-gram test weight; C, balance weight; D, balance beam; E, knife edge; F, hook.

TRIPLE BEAM BALANCE

Annual Maintenance—(Refer to figure 33.4.)

1. Dust thoroughly with a soft, clean brush. Wash top of platform (A) if necessary.

2. Remove the bearing cover plates (E and F). Clean the bearings with blasts of dry air if possible. On older models it may be necessary to use a toothbrush to remove stubborn dirt.

3. Clean any accumulated debris from the magnet faces located in the balance cup (B). Press a piece of Scotch tape against the magnet face to pick up attracted material that might interfere with the damping vane.

4. Reinstall the bearing plates, being careful not to damage the bearings or dull the knife edges.

5. Check the knife edges, particularly on older models; if dull, the scale will respond sluggishly. Sharpen or replace dull knife edges.

Periodic Maintenance—

1. Remove dust from top of platform before each use.

2. Periodically check the scale's balance, because the balance position can be changed slightly if foreign material accumulates on the platform beams. Perform this check on a flat and level surface.

With an empty pan and all the weights at zero, the pointer should oscillate the same number of divisions above and below the center (zero) line and eventually come to rest at zero. Tap bearing cover very lightly, to prevent pointer from stopping prematurely.

If the scale does not balance, turn the knurled adjusting knobs (two knobs act together as lock nuts on older models). Screw the knobs outward if the pointer position is low; screw inward if the pointer is high. When proper adjustment is obtained, lock the nuts tightly together and then recheck the pointer.

3. Check the zero balance whenever the scale is moved, because it will be affected by a change in levelness of the working surface.

HARVARD BALANCE

Maintenance instructions for the Harvard balance (fig. 33.5) are similar to those for the triple beam scale.

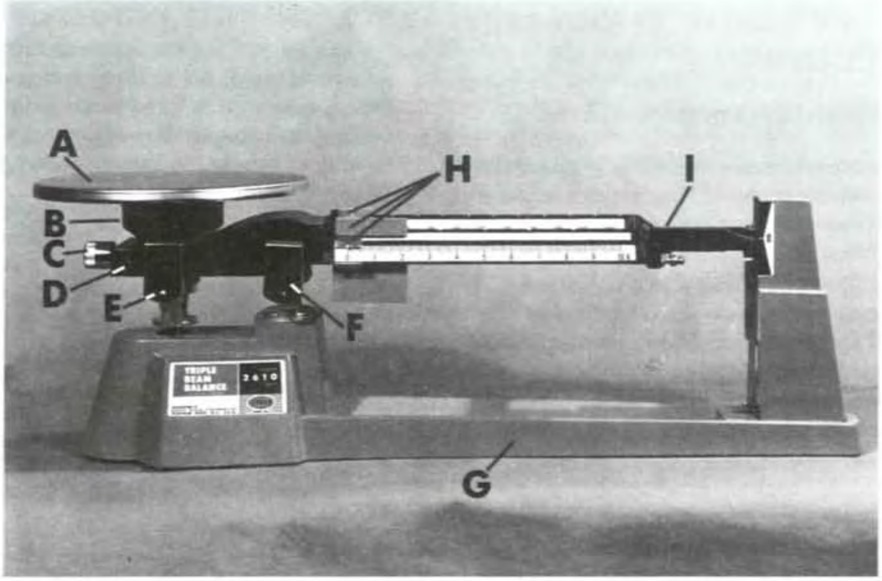


Figure 33.4—Triple beam balance: A, platform; B, balance cup; C, knurled adjustment knob; D, friction plate; E and F, bearing covers; G, base; H, poise (sliding weights); I, beam.

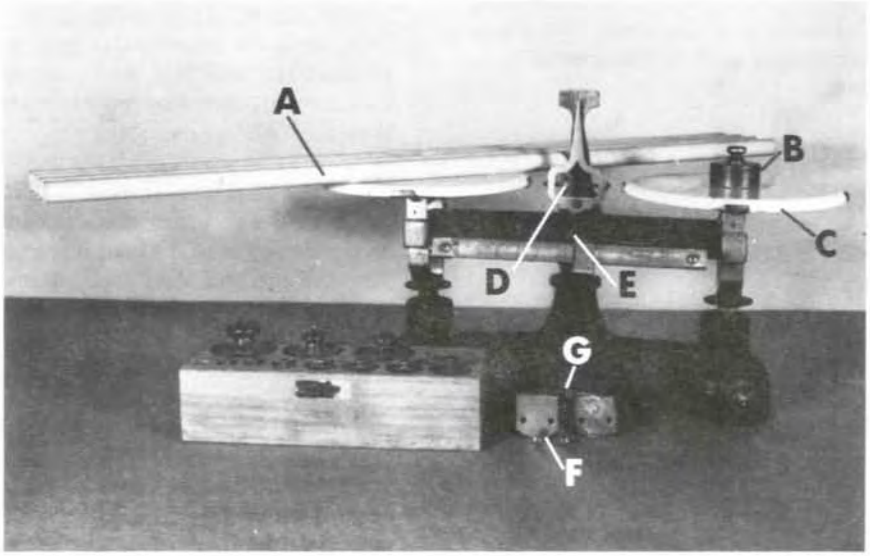


Figure 33.5—Harvard balance: A, ½-inch fuel sticks; B, 100-gram weight; C, pan; D, knurled adjustment knob; E, main bearing; F, main bearing cover plate; G, lock.

CHAPTER 34. PYRANOMETERS AND SUNSHINE RECORDERS

34.1 General Maintenance

Detailed maintenance instructions for these specialized instruments are beyond the scope of this handbook; refer to manufacturers' manuals. In general, pyranometers (including pyranographs) and electrical-type sunshine recorders require regular calibration checks. Various methods of pyranometer calibration are described by the World Meteorological Organization (1983), using the sun or artifical, laboratory sources of radiation. These methods employ comparisons with either a standard reference instrument or a similar, previously calibrated pyranometer.

Instruments should be checked occasionally for level mounting. Pyranometers and the Campbell-Stokes sunshine recorder should be inspected daily and cleaned or cleared, as necessary, of dust, moisture, or snow on their various surfaces. Use soft tissue for wiping and drying the glass dome or sphere; moisten the tissue for dust or dirt removal. Remove ice or frozen snow from the glass very gently, with the aid of a small amount of de-icing fluid. Also check pyranometers daily for possible condensation within the glass dome and to be sure that the sensing surfaces are still black. If condensation is persistent, examine the seal around the base of the dome. If the seal requires repair, use a substance such as epoxy resin or rubber sealing compound.

CHAPTER 35. EVAPORATION STATION EQUIPMENT

35.1 Evaporation Pan and Accessories

EVAPORATION PAN

Periodic Maintenance—Inspect the pan carefully for leaks at least once every month. Note on observation forms the date on which any leak was discovered and the date on which the leak was repaired; this may allow correction of affected data.

Clean the pan as often as necessary to keep it free from sediment, scum, or oil films. Empty the pan by siphoning or bailing the water out. *Never* try to lift and empty the pan while it still contains more than a few gallons of water (corresponding depth about one-half inch).

To discourage the growth of algae, add small amounts of copper sulphate to the water. If already present, algae must be removed by a thorough cleaning of the pan.

Winter Storage—During the months when freezing conditions preclude evaporation measurements, empty, clean, and store the pan. It is best to store the pan indoors. If, however, the pan is left in place outdoors, it should be turned bottom side up and secured to its wooden support with strong rope.

STILLING WELL AND GAUGE

Stilling well maintenance is minimal, requiring periodic cleaning of the stilling well and removal of any sediment. Likewise, a fixed-point gauge, affixed inside a stilling well, requires only periodic cleaning. The point should, of course, be kept in its original condition.

Hook Gauge—Maintenance consists primarily of cleaning and occasional lubrication (and correct reassembly). Oil the threads on the gauge stem lightly about twice each year with one drop of low-viscosity machine oil. Carefully remove any excess oil with a clean cloth, to prevent oil contamination of the water surface. Before oiling, clean the gauge thoroughly with kerosene or a similar commercial petroleum-base solvent.

For correct reassembly after cleaning the hook gauge, the threads of the stem and adjusting nut must be properly matched. To achieve this match, turn the adjusting nut counterclockwise until the top of the nut coincides with one of the graduations on the stem. The index line on the ring of the spider (fig. 12.3) should then coincide with the zero mark on the circular scale. If it does not coincide, unscrew the adjusting nut and reassemble the gauge by matching the alternate combination of threads.

35.2 Supplemental Instruments

TOTALIZING ANEMOMETER

Refer to the anemometer maintenance instructions in sections 31.1 and 31.2, with particular reference to the totalizing anemometer models (Belfort, Friez, and WeatherMeasure models).

SIX'S WATER THERMOMETER

Check the accuracy of the Six's thermometer at least once every month. To do this, remove the thermometer from the pan and place it in the instrument shelter, with the bulb near the center. After allowing enough time for the Six's thermometer to dry and stabilize at air temperature, compare its current reading with the current reading of the standard minimum thermometer (or, preferably, the dry bulb thermometer). Differences should not exceed 1.0 °F.

Additional maintenance procedures, concerning cleaning, restoring of worn markings, and rejoining separated mercury columns, are similar to those described in section 30.2. In rejoining a separated column, do not remove the thermometer from its mount. In the repair method employed at least initially, hold the thermometer mount horizontally by its edges near the bulb, with the U-tube pointing outward, and swing it rapidly downward. Repeat as necessary, taking care not to strike any object.

CHAPTER 36. SOIL TEMPERATURE/ SOIL MOISTURE PLOT AND EQUIPMENT

36.1 Maintenance of Soil Plot

Sod-covered plots should be clipped or mowed to maintain a uniform height of 2 to 3 inches. No irrigation should be applied except as necessary to start the cover before the observational season has begun. If, to preserve the cover, it is necessary to irrigate during severe drought, soil temperatures and moisture observed during that period should be noted as nonrepresentative.

Bare soil plots should be kept free from weeds and other vegetative cover at all times. Except where it may be harmful to the environment, chemical treatment may be preferred to the use of a hoe; this treatment is longer lasting and causes less change to soil structure. Deep cultivation should be avoided but shallow raking to avoid heavy crusting after precipitation is recommended. If chemicals are used, some precautions are necessary in their selection, rate and method of application, and time of application (U.S. Department of Commerce 1972). Local weed control experts should be consulted.

Snow cover should remain in a natural, undisturbed state. As much as possible, the plot should be located away from obstructions that could promote either local drifting or scouring of snow cover by the wind.

36.2 Soil Thermometers

No specific maintenance instructions for soil thermometers are given by the NWS (U.S. Department of Commerce 1972). The heads or recorders of mercury-in-steel and electrical thermometers must, however, be kept protected inside a suitable shelter. To maintain easy readability, mercury-in-glass thermometers will require periodic dusting or cleaning of exposed stems; worn scale markings should be renewed (section 30.2).

36.3 Soil Moisture Meters

Specific maintenance instructions for soil moisture meters should be obtained from the manufacturers' instrument manuals. Batteries operating the readout devices should be checked regularly and replaced as necessary. Periodic calibration checks are recommended, preferably done in a laboratory with a prepared set of standard soils having a known moisture content (World Meteorological Organization 1983). Electrical resistance blocks, particularly gypsum blocks, tend to deteriorate in the soil and may require eventual replacement.

PART 3. AUTOMATIC WEATHER STATIONS (AWS) AND REMOTE AUTOMATIC WEATHER STATIONS (RAWS)[1]

CHAPTER 37. GENERAL FEATURES OF AUTOMATIC AND REMOTE AUTOMATIC STATIONS

37.1 Characteristics of Stations

Automatic Weather Stations (AWS) and Remote Automatic Weather Stations (RAWS) are similar in many ways. Both types of stations are self-contained, electronically operated systems requiring, after initial programming, no human intervention in the observation and processing of weather data. Both types can be placed in remote locations. Major differences occur in the normal means of data transmission and retrieval, which often may limit the remoteness of an AWS site if real-time data are required.

As previously mentioned (section 2.3), the designation RAWS has been assigned to the specific automatic weather stations in operational use by United States government agencies. A distinguishing characteristic of RAWS is the automatic transmission of data via satellite, the system's primary communications medium. The use of a satellite enables station siting at locations that would be too remote for use of other forms of telemetry, such as radio or telephone. However, RAWS units can be equipped to communicate via radio or telephone where this is desirable and feasible. With these options, data may be obtained either automatically or upon user's interrogation, often in addition to the satellite transmission. Many AWS models also enable radio or telephone transmission of data, while others are employed primarily for delayed retrieval of data stored on-site.

The stations are typically battery powered. Some AWS installations can be operated with AC power where this power is available. Batteries used in RAWS units and some AWS units are recharged via solar panels.

Depending on the site and system, AWS data may be obtained on a current or daily basis by locally connected analog or digital devices, computer, or printer; or via radio or telephone links to a central office. Delayed data, covering periods of 1 to 2 months or longer, can be obtained via cassette tapes, strip charts, or solid-state storage packs retrieved from the AWS site.

A RAWS unit can be installed at any ground site, with two major restrictions: There must be an unobstructed line of sight from the RAWS antenna to the satellite, and there must be enough sunlight to maintain the battery charge via solar panels. From a practical standpoint, the site should also be readily accessible, for both installation and maintenance, by ground transportation wherever possible. A RAWS is not necessarily distant in location. Many units are installed near agency offices such as ranger stations, to replace manual weather stations.

RAWS units presently employed by United States government agencies—the Bureau of Land Management, the Forest Service, and the National Park Service—are almost exclusively those manufactured by Handar, and discussion in future chapters refers to these particular units. (A few older units made by LaBarge remain in use.) The adopted RAWS system reflects the sensor standards and other specifications that the above agencies have agreed upon.

The present standard RAWS is the Handar model 540A (H-540A) (a successor to the original H-530). Handar units operating via a nonsatellite link may also serve as AWS. Automatic systems from other manufacturers (chapter 44 and appendix 7) are also suitable for various data acquisition needs. Details concerning these systems will follow the details given (in chapters 38 through 43) for RAWS.

APPLICATIONS

Automatic-type stations (AWS and RAWS) have become a reliable, cost-effective means of obtaining routine or operational fire-weather data. These stations can provide needed data from previously untapped remote areas. They also may replace, and have replaced, many traditional manual-type stations. The acquired data are used by fire management personnel for presuppression, suppression, fuels management, and air quality (smoke management) applications. Stations are available in portable form for monitoring weather conditions near wildfires and prescribed burns.

The acquired data are also used by engineering, watershed management, and soils personnel, particularly during periods of intense precipitation. Additional data applications include timber management (scheduling of tree planting; timing of aerial spray operations; maintenance and closures of forest roads) and weather and flood forecasting by the National Weather Service. Special sensors can be added to further meet users' data needs.

The data can provide climatological baselines and also serve various research areas. These areas include acid rain and other problems affecting environmental quality.

37.2 Sensors

The sensors at automatic-type stations (AWS and RAWS) are electronic, or electronically operating, versions of those at manual stations. With the possible exception of rain gauges, the sensors are typically mounted on a tower or mast, with cable connections to an electronics enclosure (termed a data collection platform in a RAWS system). There, the raw sensor outputs (voltages or pulses) are conditioned into usable form. Further processing converts analog signals (in which the output voltage varies on a continuous scale) into digital information.

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[1] The information in chapters 39-43 is adapted mainly from a manual written by Phillip A. Sielaff and other members of the RAWS Support Facility at BIFC (USDI BLM, Raws Support Facility 1987).

At RAWS operated for fire-weather (fire management) purposes, sensors normally measure wind direction and speed, air temperature and relative humidity, fuel temperature, and (except at some portable stations) precipitation. Fuel moisture usually is not measured with a sensor at these stations but, instead, is calculated from other measurements (section 38.1). A barometric pressure sensor is employed at some RAWS by the BLM (section 39.2).

Additional sensors available for other resource management or monitoring purposes include those for soil moisture and temperature, solar radiation, evaporation, and stream water level. As part of a "Super" RAWS system tested in 1988, sensors have been developed for measuring cloud heights and visibility and for detecting thunderstorms (USDA FS 1988). This additional sensor complement has possible application in the area of smoke management.

Temperature and humidity sensors are housed in a solar radiation shield, which at RAWS is a naturally ventilated type—dependent on wind movement. In standard RAWS units acquired prior to 1988, this shield has been in the form of a vane orienting into the wind. The shield in portable RAWS units has been in the form of three stacked, overlapping cups, and this type is now supplied with all RAWS units. Various AWS systems employ a similar cup (or "pagoda") shield, a cylindrical multiplate shield, or a shield of flat, spaced rectangular plates. Relatively expensive force-ventilated (motor aspirated) radiation shields are also available for AWS systems—at locations with AC power.

37.3 Data Processing and Storage

Central to an automatic station is a microprocessor that controls various functions including the input, storage, and output of data. At RAWS, the processed hourly sensor data are stored temporarily until their transmission, at 3-hourly intervals, to the satellite and a downlink computer. In many AWS systems, users can individually program the sensor-scanning and data-recording intervals, the units of measurement, computations from the data, and other instructions. The programming can be done on-site with a small keypad programmer (which is an integral part of "data logger" systems) or remotely through an interfaced computer.

The physical arrangement and separation of electronics components varies among AWS systems. Some models have a compact electronics package that occupies a single enclosure. These models include data loggers (with an integrated electronics configuration) and compact modular units consisting of several basic cards. For example, a single card will provide signal conditioning for all analog sensor inputs. Other AWS systems employ a larger assemblage in the form of single-function modules, including a variety of individual signal conditioning modules plugged into a rack. These and the microprocessor may be located indoors. The modular approach, although requiring more hardware in its "building-block" concept, is claimed to provide greater flexibility and easier troubleshooting maintenance.

The processed data or excess-capacity data are commonly transferred from an AWS system's internal memory to storage on cassette tape. The on-site use of cassette recorders, however, is inadvisable in temperatures near or below freezing. Data loggers are available in which a large amount of data can be stored in solid-state modules or removable packs.

37.4 Data Retrieval

The normal mode of RAWS data retrieval (section 38.4) is via a GOES satellite downlink, usually the downlink operated by the BLM at the Boise Interagency Fire Center (BIFC). Here the RAWS data are transferred to the AFFIRMS computer, where the data are stored temporarily and NFDRS calculations are performed. The currently stored data can be accessed by individual users with a suitable computer terminal, via commercial telephone connection.

In addition, data can be accessed directly upon user's interrogation, or automatically at programmed times, from a RAWS unit equipped to transmit data via telephone or radio links. The data can be obtained in synthesized voice messages, or received by computer terminal or printer with a modem and RS232 interface.

Most AWS systems also enable data retrieval by radio or telephone in conjunction with a computer or printer. Data from a network of AWS units can be transmitted, on-call or automatically, by radio or telephone links to a central location. Where the AWS is nearby, within about 1 to 3 miles, data can be retrieved locally by a direct cable connection to a computer or printer (with RS232 interface). Direct infrared telemetry, usable within a 1-mile distance (with unobstructed view), is available in systems from at least one manufacturer (section 44.1); the range can be extended by use of repeaters. The local data can also be transmitted by radio or telephone to a central location. A voice-synthesizer option, similar to that described for RAWS, can be provided by another manufacturer.

Systems from several manufacturers besides Handar can operate via satellite communication. Another space-based method of data transmission, termed meteor-burst telemetry, is available from at least two manufacturers but is not used in RAWS systems. This method, utilizing the ionized trails of meteors to reflect radio signals (Barton 1977), is employed by the USDA Soil Conservation Service in its snow telemetry (SNOTEL) network. An advantage of meteor-burst telemetry is the operational simplicity and administrative autonomy. The data are retrieved directly by the network's central office, with no outside-agency coordination involved.

In some AWS systems, with direct cable connection, data can be displayed on digital readout panels or, in analog form, on recording charts. Data can also be recorded on cassette tape for later computer processing or printout. In other systems, data are retrieved from on-site cassette tape or solid-state storage modules. These data are then read by a computer, either directly or through an intermediary device. Further details on AWS data retrieval are given in Chapter 44.

CHAPTER 38. DESCRIPTION OF RAWS SYSTEM COMPONENTS

For description purposes, the components of a standard RAWS system (fig. 38.1) can be combined into four broad categories: (1) sensors, (2) accessories, (3) system electronics, and (4) communications options. The accessories include the tower and solar panel.

38.1 Sensors

Standard and optional sensors for RAWS systems are described in the following paragraphs. The sensors include those normally used for fire-weather observations (section 37.2) and those added for other needs.

Figure 38.1—View of standard Remote Automatic Weather Station (RAWS), showing tripod tower with sensors, solar panel, electronics enclosure (data collection platform), and GOES satellite antenna. (Photo courtesy of Handar.)

WINDSPEED

The windspeed sensor is a three-cup anemometer designed to have a low starting threshold, about 1.0 mi/h. The aluminum cup assembly, finished with black epoxy paint, is mounted on a shaft containing a permanent magnet. As the cups and shaft rotate, this produces in present Handar 540A systems a rotating magnetic field in proximity to a solid-state Hall Effect device located within the anemometer housing. The device provides a pulse output with a frequency proportional to the windspeed. In older anemometers, from Handar 530 systems, a magnet mounted on the rotating shaft activates a sealed magnetic reed switch located within the anemometer housing, producing a series switch closures with a frequency proportional to the windspeed. The anemometer is mounted on a crossarm atop the RAWS mast.

WIND DIRECTION

The wind direction sensor is an aluminum vane with a black epoxy finish. The vane is coupled to a precision, low-torque, wire-wound potentiometer. Output signal, produced as the system electronics applies a precise voltage to the potentiometer, is a voltage proportional to the wind direction azimuth. The wind vane is mounted on the same crossarm as the anemometer, at the opposite end.

AIR TEMPERATURE

The air temperature sensor is a solid-state, linear three-element thermistor and precision resistor network, potted in a shockproof 3/8-inch (outside diameter) stainless steel probe. Usually a combined air temperature/relative humidity probe is employed. The probe is housed in a radiation shield to minimize solar radiation effects. The output of the temperature sensor is a resistance proportional to the ambient temperature.

Radiation Shield—In standard RAWS units supplied prior to 1988, the radiation shield was a vane-aspirated type, orienting into the wind. Beginning in 1988, standard RAWS units are supplied with a small, pagoda-type (stacked cup) radiation shield (previously used only in portable RAWS units). With the radiation shield installed in its normal position on the RAWS tripod tower (section 40.2), the temperature (or combined temperature/relative humidity) probe is about 7 ft above the ground.

RELATIVE HUMIDITY

The relative humidity sensor is a polymer thin-film capacitor. It is usually combined with the air temperature sensor inside a single probe. Further protection is provided by a 30-micron sintered brass filter. The capacitor contains a 1-micron dielectric polymer layer, which absorbs water molecules from the air through a thin metal electrode. Similarly, it releases water molecules. Resulting capacitance changes are proportional to the relative humidity.

PRECIPITATION

The standard precipitation sensor is a tipping bucket gauge. Rain is funneled from an 8-inch-diameter collector to the tipping bucket device containing two small compartments. When 0.01 inch of rain has been collected in the exposed compartment, the bucket tips and discharges the water through an opening in the bottom of the gauge. Each tip causes a magnet to pass over a reed switch, resulting in a momentary (0.1-second) closure that produces a pulse signal. The tip also causes the other compartment to come into position, ready to fill and repeat the cycle.

The tipping bucket gauge is available in heated models (propane heated or electrically heated) for use in areas and seasons where snow and freezing temperatures may occur. The heater causes the snow (or other form of frozen precipitation) to melt and flow into and out of the tipping bucket. An Alter-type wind shield is also available to reduce precipitation loss due to wind effects around the gauge orifice.

A RAWS unit can, alternatively, employ a potentiometer weighing gauge for precipitation measurements where snow occurs. A charge of antifreeze is added to the weighing gauge bucket.

FUEL TEMPERATURE

The fuel temperature sensor is similar to that described for air temperature. It is imbedded within an 8-inch by ³/₄-inch ponderosa pine dowel, which simulates a 10-hour timelag fuel. The sensor stick is mounted on an adjustable metal arm. It is positioned in direct sunlight on the south side of the RAWS tower, 10 to 12 inches above the ground plane. The stick is attached to the arm with a coated cable clamp, which also insulates the stick from the arm.

FUEL MOISTURE

Largely as an economy measure, RAWS operated by the BLM, FS, and NPS do not usually employ the sensor available for measuring fuel moisture (10-hour timelag). Instead, this parameter is calculated through AFFIRMS or an identical computer program in the Forest Service DG system, based on a model by Deeming (1983). This model uses hourly observations of relative humidity, precipitation, and fuel stick temperature. The fuel moisture sensor is necessary at RAWS units where the data are not sent through AFFIRMS or the DG system.

The Handar fuel moisture sensor, exposed with the fuel temperature sensor in a Ponderosa pine dowel, is similar to the relative humidity sensor described above. The characteristic moisture diffusion and wood geometry permit the measured stick moisture to be converted directly to stick weight and, thus, the 10-hour fuel moisture percentage.

SOIL TEMPERATURE AND SOIL MOISTURE

As optional RAWS instrumentation, the soil temperature and moisture sensor elements are combined in a single probe. The probe has a magnesium tip and nickel-plated brass shaft separated with a Delrin spacer. The temperature sensor is a thermistor, whose output is a resistance proportional to the temperature. The moisture sensor is a Galvanic type, which measures the soil moisture (percentage of soil weight) as a function of Galvanic potential between the probe tip and the probe body. This potential is amplified and supplied as an output.

The probe should be installed in soil free of large rocks. The tip can be pressed into the soil at depths varying from about 4 inches to 20 inches. To prevent erroneous Galvanic potential readings, care must be taken that no part of the probe contacts other metal objects or power sources. The probe should be located at least 10 ft from any metal objects, such as the tower legs.

SOLAR RADIATION

The solar radiation sensor is a pyranometer employing a silicon photovoltaic detector. Its output measures the direct solar radiation plus the diffuse (sky) radiation. The instrument is not sensitive to the full solar spectrum as compared with a standard Eppley thermopile-type pyranometer, but when properly calibrated its specified accuracy is within 5 percent under most conditions of natural daylight. The response time is extremely fast, less than 1 millisecond full-scale.

BAROMETRIC PRESSURE

The barometric pressure sensor employs an aneroid diaphragm from which the air has been evacuated. The diaphragm's motion, expansion or contraction due to atmospheric pressure changes, moves a mechanically connected contact across a precision potentiometer. The output is a resistance proportional to the atmospheric pressure. The sensor is mounted inside the electronics enclosure (the data collection platform). Caution must be exercised during installation, as the sensor is fragile. It must be mounted in an exactly vertical position.

VISIBILITY

The visibility sensor, developed for the "Super" RAWS sytem, is a forward-scatter type capable of determining visibilities in the range from less than one-fourth mile to 10 miles. Employing a transmitted beam of light, it measures the amount of light scattered by suspended small particles. The sensor includes a day/night detector that signals the RAWS system electronics for correct processing of the sensor output.

BATTERY VOLTAGE

Battery voltage, routinely reported to indicate possible charging problems, is obtained from a monitor within the data collection platform. The monitor produces a signal that is proportional to the voltage.

38.2 Accessories

TOWER ASSEMBLY

The standard RAWS tower assembly (fig. 38.1) consists of the basic tripod structure, a mast, guy wires, and the electronics enclosure (Warren and Vance 1981). The structure is designed from 2-inch and 2.25-inch aluminum pipe for strength and light weight. The mast, which is two-piece and detachable, extends 20 ft above the ground plane when the adjustable tripod feet are in their center position. The mast can be easily lowered away from the tower, allowing direct access to the sensors mounted at the top of the mast. The guy wires are an integral part of the mast and do not require removal during the raising or lowering of the mast. The electronics enclosure is weatherproof to prevent moisture problems and is accessible from within the basic tower structure.

SOLAR PANEL; BATTERIES

The RAWS power source ordinarily consists of two gel-cell batteries, in the electronics enclosure, connected in parallel and charged by a solar panel with regulators. The solar panel is positioned on a horizontal member of the tower. It is placed atop the west tower leg for maximum southerly exposure and solar charge. Operating power is 11 to 14 volts.

38.3 System Electronics

DATA COLLECTION PLATFORM

The RAWS system electronics consists of a basic data acquisition and transmission package, termed the data collection platform (DCP), which includes a meteorological interface board ("met" board) and a microprocessor. The board (also termed a card) provides the capability to interface the various sensors and condition their analog or digital inputs into a format that can be processed. The microprocessor controls the power, timing, input, storage, and output. In earlier RAWS systems (Warren and Vance 1981), the signal conditioning and sensor interface required a chassis separate from the DCP. Each sensor had its own module plugged into its own signal conditioning card.

The DCP accepts the analog or digital sensor data at the programmed times, converts data from analog to digital as necessary, and stores the digitized data in memory for subsequent retrieval and data transmission. The DCP is programmable to receive and process the sensor data at a specified time interval—normally hourly—and to transmit the stored data every 3 hours. Therefore, although the data acquisition rate can be varied, each data transmission normally contains three data samples from each sensor. The programming is done via keyboard and liquid-crystal display provided in the programming set, which is mounted in an attache case. The DCP is installed in the electronics enclosure mounted on the tower. The term data collection platform is often used to denote both the electronics package and its enclosure.

Technical details, including those of programming, are found in the manufacturer's operating and service manual.

38.4 Communications

SATELLITE COMMUNICATION

Transmission and reception (retrieval) of RAWS data are ordinarily accomplished by way of a Geostationary Operational Environmental Satellite (GOES), positioned above the earth's equator (Warren and Vance 1981). The basic GOES data collection system consists of the remote weather stations, the satellite transponder, and a satellite downlink. Downlinks are located at Wallops Island, VA, and at the BLM's direct readout ground station, Boise, ID (at BIFC).

The RAWS data are transmitted to the satellite by an antenna mounted on the RAWS tower and connected by cable to the DCP. Exact data collection and transmission times (minutes past the hour) differ between RAWS units. These times are assigned by the National Environmental Satellite Data Information Service (NESDIS), Silver Spring, MD. Each RAWS unit (or platform) also transmits on an assigned channel frequency. When the 3-hourly transmit time is reached, the transmitter is turned on, and the sensor data that were stored in the DCP memory are transmitted.

The RAWS data downlinked at Wallops Island are sent to the Central Data Distribution Facility (CDDF), Camp Springs, MD. There the data are stored for at least 24 hours, for dissemination to individual data users via dedicated or commercial telephone lines. The data downlinked at BIFC are transferred to the AFFIRMS computer, where these data are stored temporarily. AFFIRMS performs NFDRS calculations from the 1300 l.s.t. data and later archives the 1300 data in the NFWDL. The AFFIRMS computer is the primary source for current (past 24 hours) RAWS data retrieval by individual users.

Retrieval of Data by Users—The currently stored RAWS data can be accessed by individual users through commercial telephone connection with AFFIRMS. This can be accomplished via telephone modem interfaced with any suitable computer terminal or computer/printer. In the Forest Service's Data General computer system, the telephone connection is made automatically as part of the RAWS menu selection. Specific data retrieval instructions are given in appendix 6. Should AFFIRMS or the BIFC downlink be out of service, the user has the option of retrieving the data directly from NESDIS (appendix 6); again, any suitable terminal may be employed.

OTHER COMMUNICATIONS OPTIONS

In addition to the standard satellite transmission, a RAWS can be equipped to transmit data by a user's direct interrogation, where feasible, via telephone links and radio link systems (which require lines of sight between links, including repeaters). Voice synthesizers are available (for Handar 540A units) for both telephone and VHF-radio readout of the RAWS data. These convert the data directly into audible voice messages and are thus convenient for field use, making a data terminal or printer unnecessary. To initiate a query, the user sends a tone code signal to the weather station. This turns on the transmitter and the station transmits the most current data.

Tone Activated Talking Module—For obtaining synthesized voice messages, the tone activated talking module (TATM) provides an alternative to wiring a radio directly to a DCP. The TATM, produced at BIFC, was designed to provide the user with a virtually maintenance-free system that does not require frequent replacement of batteries. Its electronics include two gel-cell batteries, which are kept charged through a connection to its own solar panel. The TATM is installed in an enclosure at the RAWS site, linked to the DCP and a Handar radio speech synthesizer board. The RAWS can be programmed for voice-only or voice/satellite simultaneous operation.

In use, depending on the type of speech synthesizer card in the DCP, a single or multiple tone is entered onto the operator's radio keypad. This radio signal is received by the TATM, which forwards the tone to the DCP. The DCP then sends the weather data back to the TATM, which transmits the data in a synthesized voice output back to the operator.

38.5 Portable Remote Automatic Weather Stations

Both portable and "very portable" remote automatic weather stations are available for temporary field use, and such stations are being developed further (Warren 1987a,b). These units employ the same sensors, electronics, measurement routines, and communications options as the standard RAWS; components are, thus, interchangeable. The complement of sensors, however, usually excludes a rain gauge. The temperature/relative humidity sensor is exposed in a small, pagoda-type radiation shield (adopted in 1988 for all RAWS units).

The portable stations are by definition lighter in weight and more compact for transport than the standard RAWS. The reduced weight and size is accomplished largely by differences in tower structure. In the regular portable model ("P-RAWS") (fig. 38.2), the tower consists only of the tripod support legs plus the 20-ft mast. The very portable model (termed "Micro-RAWS" by the manufacturer) (fig. 38.3) uses its fiberglass carrying case as the support for a collapsible mast that extends to only 6 ft. The carrying case measures 29 inches square by 16¾ inches deep, and the complete station package weighs 123 lb. Although the 6-ft mast height is well below the 20-ft standard, it is reasoned that the wind observed at 20 ft is in fact often used to estimate the wind closer to the surface where fires tend to move.

Figure 38.2—A portable RAWS, without satellite antenna. (Photo courtesy of Handar.)

Figure 38.3—A "very portable" RAWS ("Micro-RAWS"). (Photo courtesy of Handar.)

CHAPTER 39. CLASSES OF RAWS DEPLOYMENT

The Bureau of Land Management RAWS Program is based on the deployment of four classes of stations (USDI BLM, RAWS Support Facility 1987). The same classification has been adopted by the Forest Service (USDA FS, Pacific Northwest Region 1988). This deployment scheme facilitates centralized support, maintenance, management, and administration, while providing the flexibility and mobility required to meet the needs of fire and resource managers.

39.1 Classification

The following is a brief description of each deployment class:

CLASS I

Class I denotes those RAWS that are permanent, year-round installations, receiving highest maintenance priority. These stations may have additional sensor complement and increased sensor capability, because their data may be used in many sensitive day-to-day management decisions.

RAWS in this class comprise the BLM's 75-mile dedicated grid network. As of July 1987, there were 93 BLM stations in this class, deployed in 11 western States.

CLASS II

Class II denotes those RAWS positioned by the local fire and resource managers. These systems will be standard fire-weather configurations and semi-permanent, operating only during the "normal fire season" unless otherwise needed. Depending on prevailing fire conditions, they will have either primary or secondary maintenance priority.

As of July 1987, there were 174 BLM stations in this class, deployed in 10 western States.

CLASS III

Class III denotes those RAWS available for control burn studies, prescribed burning, special projects, and any additional project work as required. These units will be deployed on a temporary basis. After use, they are returned to the home cache or reassigned to another site or project. They will have secondary maintenance priority unless otherwise required.

The BLM's Class III units are cached at BIFC. Users of these units are responsible for all cost associated with installation and removal, rehabilitation, and repair.

CLASS IV

Class IV denotes RAWS that are essentially the same as those in Class III, with the exception that these systems use a radio communications medium, employing the National Radio Support Cache UHF/VHF frequencies. They will communicate in either synthesized voice or via an RS232 terminal. These systems are used for the same purposes as Class III, but they are also used in project-fire operations.

As of 1987, there were 30 planned BLM stations in Classes III and IV combined.

39.2 Configurations by Class

This section lists the measurements (or sensors) specified for each of the above RAWS classes. RAWS units, when purchased by the BLM, will have the capability of handling the additional sensors listed for resource management. Purchase of these sensors, however, depends upon the programmed funding.

CLASS I (PERMANENT SITES)

Standard Sensor Complement—

1. Precipitation (tipping bucket gauge).
2. Windspeed.
3. Wind direction.
4. Wind gusts—speed and direction.
5. Air temperature.
6. Relative humidity.

7. Fuel temperature.
8. Battery voltage.
9. Barometric pressure (optional).
10. Fuel moisture (measured or computed).

Additional Sensors, Depending on Resource Management Needs—

1. Soil temperature.
2. Soil moisture.
3. Stream water level.
4. Air pollution.

CLASS II (FIRE WEATHER, SEMIPERMANENT SITES)

Standard Sensor Complement—

1. Precipitation (tipping bucket gauge).
2. Windspeed.
3. Wind direction.
4. Wind gusts—speed and direction.
5. Air temperature.
6. Relative humidity.
7. Fuel temperature.
8. Battery voltage.
9. Fuel moisture.

Additional Sensors, Depending on Needs of Resource Management—

1. Soil temperature.
2. Soil moisture.
3. Weighing gauge precipitation.

Barometric pressure may be desirable at some sites.

CLASSES III AND IV (TEMPORARY SITES)

These two classes utilize the same sensor complement as Class II. Barometric pressure may be desirable at some Class III sites.

CHAPTER 40. INSTALLATION PROCEDURES, STANDARD RAWS SYSTEMS

40.1 Installment Considerations

RAWS installation within the BLM is done by experienced personnel from the centralized RAWS Support Group at BIFC. This group also can provide technical support and advice for Forest Service RAWS installation. The work scheduling seeks to utilize the assistance of local expertise from the area where a station will be located. All of the site selection standards (section 2.5), originally developed for manual fire-weather stations, should govern RAWS siting. Installation of RAWS units can take increased advantage of favorable sites due to the unmanned nature of the stations.

Local personnel should place their RAWS units where their actual fire and resource management needs exist. Placing the stations in remote areas tends to reduce public encounter and the risk of possible vandalism, but they should be located away from general view. They should be accessible for maintenance by ground vehicle wherever possible. The RAWS Field Support Group has 4-wheel-drive support vehicles, all-terrain vehicles, and snow machines, which provide access to most locations. Locations accessible only by helicopter are discouraged, because the flight time is extremely expensive. Where a RAWS must be transported via helicopter, it will also have to be maintained via helicopter.

RAWS installations typically employ either the standard fire-weather 20-ft tripod tower (fig. 38.1) or the Rohn-type guyed tower (fig. 40.1), which may be 20, 30, or 40 ft in height. The BLM at present uses only the 20-ft tripod tower; the USFS uses both types.

40.2 The Tripod Tower Installation

The positioning of the tower is very important. Proper positioning will minimize the installation time and also facilitate maintenance.

1. Assemble the basic tripod in accordance with manufacturer's instructions. Position the tower as shown in figure 40.2, with the north leg in a northerly direction.

2. Using a pocket transit or compass, and correcting for the local magnetic declination, sight across the east and west legs and correctly orient the tower. For example, at Boise, ID, with a magnetic declination of +19°, the tower would be aligned when sighting across the east and west legs at 251° (270° minus 19°).

3. After the tower has been aligned, level it using two torpedo levels. Placing the levels on the lower horizontal cross arms, ensure that the tower is level on all three sides.

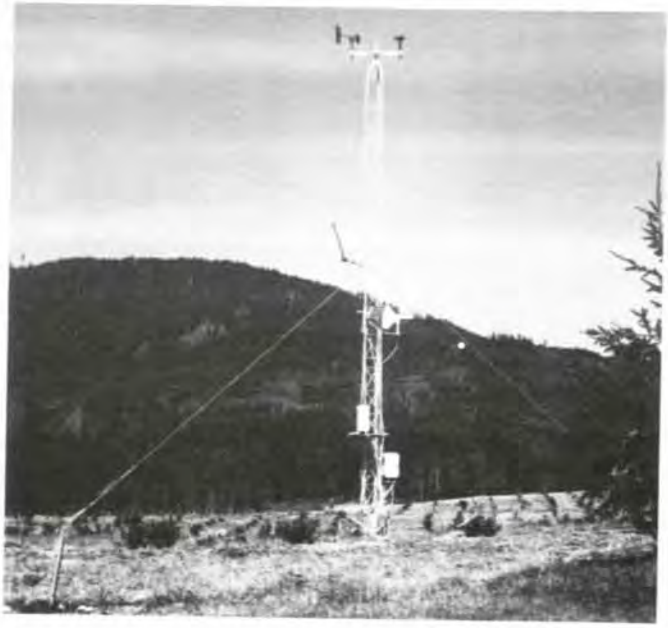

Figure 40.1—A RAWS installation on 30-ft Rohn-type tower. (Photo courtesy of Handar.)

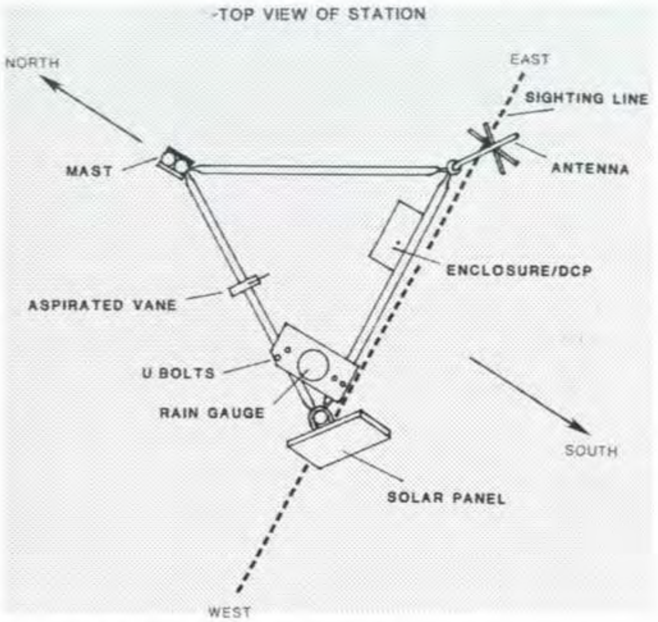

Figure 40.2—Diagram showing correct positioning of standard RAWS tripod tower and components. Radiation shield (with air temperature/relative humidity probe) may, alternatively, be located on south side of tower (on east-west crossarm). (Adapted from USDI BLM, RAWS Support Facility 1987.)

4. Once leveled, the tower can be staked to the ground as a precaution. Staking the legs prevents the tower from being moved accidentally during the installation process and during future maintenance visits, in addition to preventing possible blowdown by wind. Where the ground does not allow staking, a good alternative is to place cyclone fencing over the ends of the tower legs and feet, weighted down with rocks.

With the tripod tower correctly oriented and leveled, the remaining installation proceeds as follows:

WINDSPEED/WIND DIRECTION CROSSARM ASSEMBLY

The windspeed/wind direction (WS/WD) crossarm assembly is mounted on top of the mast. The mast is mounted to the north leg of the tower (fig. 40.2).

1. Before the mast is assembled, the WS/WD cable must be run through the center of the crossarm collar and down the center of the mast's upper and lower halves.

2. With the cable installed, assemble the two mast sections, making sure that the guy attachment tabs ("ears") align.

3. Next, fasten the mast on the north leg of the tower; make sure once again that the guy ears are properly located.

4. Finally, attach the mast support wire to the mast. This wire will support the mast in a near horizontal position for installing and servicing the WS/WD sensors. For proper installation of the WS/WD sensors, the mast and WS/WD crossarm must first be leveled, as described in step 5.

5. With the mast down (attached to the support wire), one person positions it horizontally using a torpedo level. With the mast in this position, the other person levels the WS/WD crossarm using another torpedo level. The mast should now appear like a "T" when viewed in the horizontal plane. Leveling the mast in this manner permits easy alignment and calibration of the WS/WD sensors.

WIND DIRECTION SENSOR

As a result of the procedure for orienting and leveling the entire tower structure, the WD sensor can be aligned for correct azimuth by use of a torpedo level. The WD sensor employs an alignment pin to indicate the electrical contact position corresponding to 180 degrees azimuth.

With the alignment pin and sensor arrow both in place, the WD sensor is leveled in the vertical position, the arrow pointing upward. When the mast is raised (after the WS sensor is installed), due to the tower positioning the WD sensor is aligned with true south.

The alignment should be verified during the forced-scan data checkout procedure (section 42.2). Be sure that the alignment pin is removed from the sensor after alignment is achieved.

WINDSPEED SENSOR

To install the WS sensor, the lower tubular base of the sensor is leveled with the mast in a horizontal plane. A torpedo level should be placed on the tubular base during the leveling process, as the cup portion of the sensor may not be perfectly square with the base.

The entire mast group is now mechanically aligned. After the WS and WD sensors are checked (as in section 42.2), the mast group will be elevated to the operating position and the remaining sensor complement installed.

SOLAR PANEL

The solar panel is mounted on the upper east-west crossarm of the tower, above the west leg. This provides the southerly exposure necessary for attaining the maximum possible solar charge for the RAWS system. The panel should be placed at the same angle as the elevation angle of the antenna (see manufacturer's instructions). This angle provides the best overall charging rate for year-round operation.

TIPPING BUCKET RAIN GAUGE

The tipping bucket gauge is mounted on the west corner of the tower, near the juncture of two upper crossarms, using the mounting bracket supplied by the manufacturer. With the base thus 6 ft above the ground, the gauge orifice will be $7^{1}/_{2}$ ft above the ground. The gauge should be leveled using the attached leveling indicator. In connecting the sensor cable, the two wires may be connected to either terminal without regard to polarity.

Alternatively, the gauge can be mounted off the tower, particularly where a better exposure can be obtained to reduce wind effects or obstructions. In such cases, the gauge is mounted in a firmly anchored support; the orifice may be placed about 4 ft above the ground, close to the standard height at manual weather stations.

AIR TEMPERATURE/RELATIVE HUMIDITY SENSOR

The air temperature/relative humidity (AT/RH) sensor, installed in the radiation shield, is usually mounted on an upper crossarm of the tower and thus is located about 7 ft above the ground. The Bureau of Land Management (USDI BLM, RAWS Support Group 1987) specifies mounting on the crossarm between the west and north legs of the tower. But the sensor placement can be modified, if necessary, to obtain unobstructed exposure to the prevailing wind at the site. The Forest Service favors placing the sensor on the south side of the tower—between the west and east legs.

An exposure height of 5 ft, comparable with that at manual weather stations, may be desired but could adversely affect the open exposure (and natural ventilation) of the sensor on the tripod tower. The additional 2-ft height should not make much difference, particularly where nearby brush raises the effective ground surface. At year-round stations in areas where snow depths can approach or exceed the 7-ft level, the sensor should be mounted above the standard height, possibly on the mast.

To ensure proper operation, the sensor should be leveled vertically with a torpedo level, whether the sensor is housed in a vane-aspirated radiation shield or a pagoda-type shield.

FUEL TEMPERATURE SENSOR

The fuel temperature sensor (or the fuel moisture/fuel temperature sensor, where used) is mounted, with the supplied hardware, on an arm off the lower east-west crossarm. This places the sensor on the south side of the tower, unobstructed from sunshine.

The sensor is installed 10 to 12 inches above the ground, above a representative fuel bed. Discretion should be used during station installation so as not to destroy the natural fuel bed at the site. If representative fuel is absent in the immediate area, a bed containing such fuel must be constructed.

SOIL MOISTURE/SOIL TEMPERATURE SENSOR

The soil moisture/soil temperature (SM/ST) sensor can be installed almost anywhere around the RAWS site. The only qualification is that it should be at least 10 ft from any metal object, such as a tower leg. The moisture sensor operates through the galvanic action of the soil, and any metal causes deviations in the data. Depending on user requirements, the sensor can be installed at any depth from 4 to 20 inches.

In advance of the installation, a soil sample must be taken from the depth at which the sensor will function, because a complex series of calibration curves must be established for each site (see manufacturer's instructions). To install the sensor:

1. Sink a pilot hole to within 1 inch of the sampling depth, by driving a standard ½-inch grounding rod into the earth.
2. Remove the grounding rod and place the SM/ST sensor in the pilot hole. Tap the sensor lightly into the remaining 1 inch of undisturbed soil. To avoid damage to the sensor, do not hammer or apply force.

BAROMETRIC PRESSURE SENSOR

The barometric pressure sensor is installed in the data collection platform (referring here to the electronics enclosure). It must be mounted in an exactly vertical position. The sensor is fragile and should be handled carefully. When ordering, it is important to include the elevation of the RAWS site, since the individual sensors are supplied for operation within specific elevational (or corresponding atmospheric pressure) ranges.

After the sensor is installed, a copy of its accompanying calibration document should be retained at the maintenance facility for future calibration requirements.

ANTENNA

The antenna should be assembled in accordance with the manufacturer's instructions. It is then mounted atop the east leg of the tower.

The antenna should be properly aligned for azimuth and elevation angle, using the tables that accompany the RAWS unit. Although not actually critical, antenna alignment can be particularly important during marginal transmission periods that occur in winter.

Antennna alignment is accomplished by use of a compass and inclinometer together with the above tables. All azimuth readings from these tables are in true headings and require corrections for magnetic declination, as described for the tower installation earlier in this section. After the alignment for azimuth, the inclinometer is used to adjust the antenna's elevation angle.

DATA COLLECTION PLATFORM

The data collection platform (DCP) normally is mounted, using the supplied hardware, on the south side of the tower between the upper and lower east-west crossarms. It should be about 18 inches from the east leg and 12 inches up from the lower crossarm (fig. 38.1). This position ensures that all cables can be installed without undue stresses upon them. In the Forest Service, Pacific Northwest Region, however, the DCP has been installed underground in an aluminum enclosure. This out-of-sight installation provides protection against possible vandalism and also against the elements at year-round stations.

After mounting the platform:

1. Route all cables from their respective sensors to the DCP. Take care to provide strain relief, wherever this is required, to prevent cable damage. Wrap the cables around the crossarms en route to the DCP and provide enough slack at both ends to permit a drip loop for moisture drainage.
2. Secure all cable to the tower, using cable ties.
3. Inspect all cables and make sure that rubber O-rings are used at both ends to create watertight seals.

The RAWS unit is now ready for systems checkout before operation (see section 42.2).

40.3 Rohn Tower Installation

Installation of the Rohn tower is similar to that of the tripod tower (section 40.2). Once again, care should be taken during the positioning of the triangular tower base (fig. 40.3), aligning it as described for the tripod.

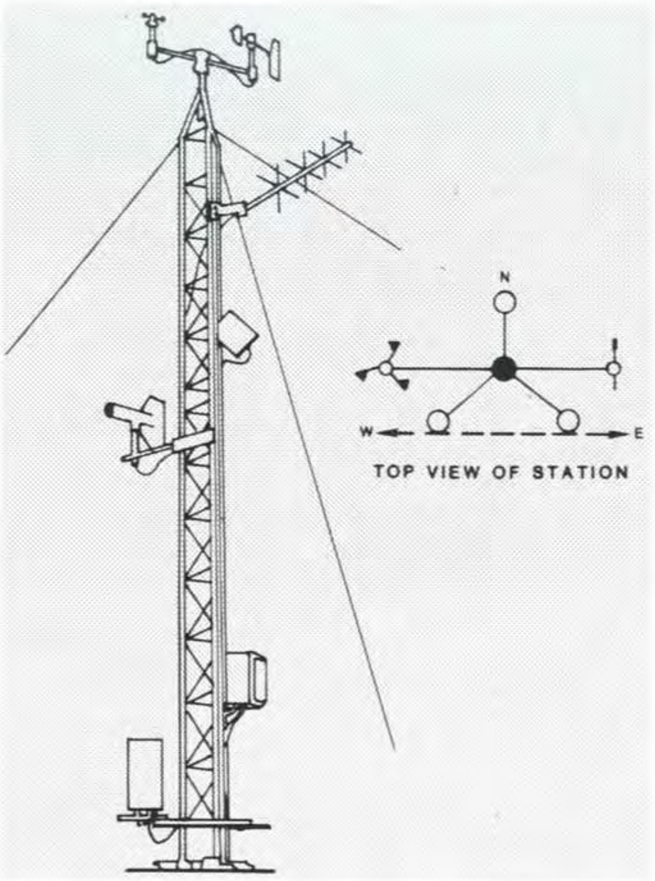

Figure 40.3—Diagram showing correct alignment of Rohn-type tower base. (From USDI BLM, RAWS Support Facility 1987.)

After the tower is in place, the WS/WD crossarm assembly is installed parallel to the east-west side of the tower. The WS and WD sensors are then installed, using the torpedo level and alignment pin.

All remaining sensors should be installed following the manufacturer's instructions, paying attention to guidelines as described in section 40.2.

CHAPTER 41. RAWS SENSOR STANDARDS

41.1 Sensor Standards (Tripod Tower Installation)

The following specifications, employed by the Bureau of Land Management and the Forest Service, summarize the standard sensor heights (above ground), sensor capabilities, and types of measurement (form of reported data).

RAIN GAUGE (TIPPING BUCKET)

Mounting height, orifice	7.5 ft (tower mount); 4 to 5 ft in off-tower mount
Range/Resolution	00.00 to 99.99 inches/0.01 inch
Accuracy	0.01 inch at rainfall rate up to 2 in/h
Type of measurement	Continuous

WINDSPEED

Mounting height	20 ft
Range	0 to 150 mi/h
Accuracy	±0.25 mi/h or 2 percent
Type of measurement	10-minute average

WIND DIRECTION

Mounting height	20 ft
Range	0 to 359 degrees
Accuracy	±2 degrees
Type of measurement	10-minute average

WIND GUST (SPEED AND DIRECTION)

Mounting height	20 ft
Range	Same as above
Accuracy	Same as above
Type of measurement	Instantaneous (1-second value)

AIR TEMPERATURE

Mounting height	7 ft (in shield, tripod tower); may vary in other mounts
Range	–58 to +122 °F
Accuracy	±0.2 °F
Type of measurement	Instantaneous

RELATIVE HUMIDITY

Mounting height	7 ft (in shield, tripod tower); may vary in other mounts
Range	0 to 100 percent
Accuracy	At 0 to 80 percent, ±2 percent; at 80 to 100 percent, ±5 percent
Type of measurement	10-minute average (Handar 540A)

FUEL TEMPERATURE

Mounting height	10 to 12 inches
Range/Accuracy	–58 to +122 °F/Same as for air temperature
Type of measurement	Instantaneous

FUEL MOISTURE

(Fuel moisture sensors are usually not deployed; see section 38.1)

Mounting height	10 to 12 inches
Range	0 to 25 grams
Accuracy	±10 percent of indicated value
Type of measurement	Instantaneous

BAROMETRIC PRESSURE

Mounting height	Varies with the height of DCP enclosure
Range	Varies according to site elevation
Resolution	0.01 inch
Accuracy	±0.3 percent of range span (mostly ±0.02 inch)
Type of measurement	Instantaneous

SOIL TEMPERATURE

Mounting depth	4 to 20 inches
Range/Accuracy	–58 to +122 °F/Same as for air temperature
Type of measurement	Instantaneous

SOIL MOISTURE

Mounting depth	4 to 20 inches
Range/Resolution	2 to 30 percent/Soil-dependent
Type of measurement	Instantaneous

41.2 Transmitted Sensor Data

All updating of sensor data coincides with the DCP's assigned minute for the GOES transmission. For example, if the assigned minute at a station is 45 minutes past the hour (GOES transmissions at 0245, 0545, 0845 GMT, etc.), all updating is done at 45 minutes past each hour. Those sensors that provide 10-minutes averages will average for the period between 35 and 45 minutes past each hour. Those sensors that provide continuous measurement give data (totals or extreme values) covering all of the previous hour. All other data are the instantaneous values at the update time.

CHAPTER 42. SCHEDULED RAWS MAINTENANCE

42.1 Preventive (Field) Maintenance: Outline of Schedule

SCHEDULE BY STATION CLASS

The following schedule, by RAWS class, is recommended (USDA FS, Pacific Northwest Region 1988):

Class I— Stations will have a regularly scheduled preventive maintenance program with the following minimum requirements:

1. Annual visits—for calibration and certification of system. During these visits, RAWS unit will be inspected visually, physically, and electronically (see section 42.2 for details). Visual inspection will include attention to possible vandalism or other damage, and to any deviations from the specified installation. All findings and data will be recorded and documented in a continual maintenance data base at the support facility.
2. Daily "watchdog" (data monitoring) services will be performed on all sensors to detect any irregular sensor outputs or tendencies that indicate problems may exist (see section 43.1). Results will be synopsized and documented for data base management and systems administration.

Class II—Stations will have a regularly scheduled preventive maintenance program during the annual operational period.

1. Annual visit—in early spring or at start of operational period—for calibration and certification. At this time, RAWS unit will be inspected visually, physically, and electronically, as described for Class I stations. All findings and data will be recorded and documented in a continual maintenance data base at the support facility.
2. Daily watchdog services will be performed during the operational period on all sensors to detect any irregular sensor outputs or tendencies that indicate problems may exist. Results will be synopsized and documented for data base management and systems administration.

Class III—These stations tend to receive greater abuse than those in the first two classes and thus require the following maintenance attention:

1. Calibration and certification usually before the beginning of use period. The RAWS unit will be inspected visually, physically, and electronically. All findings and data will be recorded and documented in a continual data base at the support facility.
2. A watchdog service will be performed after installation and DCP programming to verify sensor outputs with respect to calibration specifications, etc.
3. The relatively frequent transport and reinstallation of these RAWS units calls for rigorous inspection and maintenance. Check, in particular, for any irregularities pertaining to the sensors, cables, and hardware.
4. Scheduled RAWS site inspections should be relatively frequent, particularly at locations easily accessible to the public.

Class IV—Maintenance is identical to that described for Class III. In addition, check the radio transmission equipment.

42.2 Preventive Maintenance by BLM Field Support Group

The BLM's RAWS Field Support Group, headquartered at BIFC, conducts the preventive maintenance program for all of the Bureau's RAWS systems (another responsibility of this group is described in section 43.2). Its services are also available to Forest Service RAWS, on contract.

BLM preventive maintenance is done basically through annual visits to all station sites. The sites are visited either in early spring (Class II stations) or by early fall (Class I stations) for calibration and certification of all equipment. During these visits, each station is inspected visually, physically, and electronically. All findings and data are recorded and documented in a continual maintenance data base at the central RAWS Support Facility at BIFC.

FIELD EQUIPMENT AND REQUIREMENTS

The field support crews assigned to the RAWS Support Facility consist of two persons. These crews carry complete sets of spare parts for each type of RAWS in operation. The support vehicles are four-wheel drive and equipped for use on rough terrain. All-terrain vehicles, snow machines with freight sleds, and specialized trailers are also available to support the RAWS Program year-round.

The following is a list of tools, test equipment, and other items carried by the support crews:

1. 9/16-inch combination wrench
2. 1/2-inch combination wrench
3. Crescent wrench
4. Pliers
5. Set of Allen wrenches
6. Side cutters
7. Phillips screwdriver
8. Straight slot screwdriver
9. Torpedo levels (two)
10. Set of nut drivers
11. 9/16-inch deep-well socket
12. 1/2-inch deep-well socket
13. Ratchet
14. Knife
15. Small sledgehammer
16. Cable ties
17. Electrician's tape
18. Locktight
19. In-line wattmeter/dummy load
20. Volt-ohmmeter
21. Battery load tester
22. Belt weather kit
23. Altimeter
24. Compass
25. Magnetic declination charts
26. Inclinometer
27. Time cube (radio receiver tuned to WWV)
28. DCP programmer/test set
29. Station information
30. Padlock

Survival Equipment— Each field support crew maintains winter and summer survival equipment. In addition, each individual in the crew maintains a personal winter and summer survival kit. The combined equipment provides the necessary protection for field personnel in extreme and adverse environments. The equipment is incorporated into four kit levels:

I. *Two-person survival kit*, enclosed in a waterproof bag, for all-terrain vehicle or snowmobile travel away from the support vehicle. This kit contains: three-man backpack tent, two large canteens, mess kit, six meals, two flashlights with batteries, four spare batteries, camp ax, flare gun with red and white flares, 25-ft nylon rope, first-aid kit, emergency handheld radios with spare batteries, snow saw, and snow shovel.

II. *Support-vehicle survival kit*, which remains in the vehicle. This kit contains: two sleeping bags, 25-man first-aid kit, wooden matches, lantern, Coleman-type stove, "C" rations (one case), and spare keys (for site and vehicles).

III. *Individual survival kit*, issued to each field crew member. This kit contains: whistle, signal mirror, sleeping bag, space blanket, knife and sharpening stone, individual first-aid kit, matches in waterproof case, 15-ft nylon rope, individual canteen, one meal of long-range patrol rations, tube tent, and backpack.

IV. *Individual foul-weather gear*, issued to each field crew member. The gear consists of: field jacket with liner, parka, pants, mukluks with liners, mittens, face mask, helmet with visor, goggles with amber and gray lenses, rain suit, polypropylene thermal undergarments, and duffel bag.

VISUAL AND PHYSICAL INSPECTIONS

Upon arrival at a RAWS site, the field crew makes a thorough visual inspection of the station. The inspection includes checking for structural failures or damage (or vandalism), sensor damage, cable integrity and covering, and corrosion problems. Sites not protected by fencing are particularly subject to damage from roaming wildlife and livestock. Tower orientation and leveling should also be checked at this time.

After the visual inspection is completed, a physical inspection follows. During this process, each sensor is checked and verified against the BLM sensor standards (section 41.1). Irregularities and failures should be documented, and suspect sensors should be replaced after the complete system checkout. The physical inspection consists of the following steps:

1. Check cables at both ends for O-ring serviceability.
2. Check the cables to make certain that they are securely fastened.
3. Check the batteries for leakage and corrosion, and test their condition with load tester.
4. Check antenna and cable for physical serviceability.
5. Disassemble, inspect, and clean the entire tipping bucket rain gauge. Reassemble and then verify and record (V/R) the rain gauge calibrator measurements.
6. Check output of the solar panel with volt-ohmmeter (VOM) and clean as necessary.
7. V/R the GOES channel number.
8. V/R the barometric pressure mechanical limits.
9. V/R the software revision of the data collection platform (DCP).
10. V/R the revision of the met board (H-530 units).
11. V/R all serial numbers of the sensors, antenna, solar panel, and DCP for site record documentation.
12. Document all problems and irregularities for future resolution.
13. V/R the antenna alignment.
14. V/R the windspeed sensor ice skirt diameter (either 1¾ inches or 2 inches).

ELECTRONICS INSPECTION

After the physical inspection is completed, a thorough operational and electrical checkout is performed. The DCP programmer/test set will be used throughout the test/check (T/C) process to verify and calibrate all individual functions of the RAWS unit.

Primary Sensor Checkout—To aid in this check, the belt weather kit (BWK) should be used and all measurements recorded. The BWK measurements will be used for general comparison purposes only.

1. With the test set connected to the DCP, observe and record the latest data for all sensor inputs.
2. Compare the latest sensor data with current BWK measurements and note any irregularities. Lower windspeeds can be expected from the BWK wind meter, normally exposed closer to ground.
3. Using the test set, initialize a forced scan for additional "real time" sensor data. If sensor problems are encountered, replace the suspect sensors and retest. At this time, any sensors marked for replacement in the preceding physical inspection should be changed.

4. Perform a final sensor scan and again verify data against current BWK measurements. If standards are met, the main sensor portion of the checkout is complete.

Check of DCP and Associated Electronics Equipment—

1. Connect the in-line wattmeter/dummy load to the DCP and force a transmission. While transmitting, check and record the transmitter's power output.
2. Remove the dummy load from the wattmeter and connect the antenna cable to the system with the wattmeter in line.
3. At some point during the remaining system checkout, observe and record the forward and reflected power of the transmitter during the assigned transmission time. This check verifies that the antenna system meets the electronic standards for the system.

Additional Electronic Checks—

1. Check the barometric pressure sensor's electrical (high and low) limits.
2. Check the soil moisture/soil temperature sensor's programmed calibration values (high and low limits).
3. Verify that the current program in the DCP is the correct version with correct sensor requirements (quantity, parameters, averaging time, etc.). Reset the tipping bucket accumulation to 00.02 inch.
4. Check the next transmission time and verify that it coincides with the assigned National Environmental Satellite Service transmission time.
5. Check the starting measurement time to verify that it is correct for the desired data scans.
6. **Check and verify any other parameters of the program, data, and sensors, or pertinent conditions of the RAWS, in preparation for returning the system to the operational mode.**
7. Return the RAWS system to the "RUN" mode and remove the programmer/test set.
8. Remove any remaining test equipment from the system if all systems checks have been completed (antenna system and charging systems).
9. Make sure that all documentation is complete and ready for compilation upon return from the field.

The entire RAWS system has now been checked out according to the BLM's RAWS standards. Before leaving the site, the field crew should make sure that all support equipment has been inventoried, stowed, and secured; also, that the site is left environmentally sound.

42.3 Depot Repair Facility—Maintenance, Calibration, and Repair

The BLM's RAWS Depot Repair Facility is responsible for all repair, calibration/certification, modification, standards, and overall data administration for the Bureau's RAWS program. These Depot services are available to RAWS programs of other agencies. Beginning in 1988, Depot services have been contracted for all Forest Service RAWS.

The Depot Repair Facility maintains a centralized rotatable pool of RAWS component parts and modules. This pool permits rapid turnaround of priority maintenance items for the field user. Defective modules are then repaired and returned to the centralized pool for future use.

TEST EQUIPMENT

The following is a list of test equipment required to perform the above services at the Depot Repair Facility:

1. Humidity meter calibrator, Model HMK-11
2. Hewlett-Packard (HP) 6227B power supplies
3. Racal Dana digital multimeter 4003
4. HP 740B DC standard/differential voltmeter
5. HP 3311A function generator
6. Textronix 7834 storage oscilloscope
7. Pro Log PROM programmer
8. Prometrics EPROM eraser
9. Wind tunnel
10. HP 8901A modulation analyzer
11. HP 8555A spectrum analyzer
12. Motorola T-1012A power supplies
13. Transistor/FET tester
14. Motorola S-1350A wattmeters
15. Windspeed/wind direction test fixtures
16. Hermeticity tester
17. Handar 545A programmer/test set
18. Handar 526 programmer/test set
19. LaBarge RMS-100 programmer #1286
20. LaBarge RMS-200 programmer #1289
21. Megger

DEPOT PREVENTIVE MAINTENANCE STANDARDS

The BLM's Depot Repair Facility performs annual preventive maintenance and calibration/certification of all RAWS equipment. Maintenance instructions for the individual sensors and other components follow:

Instructions—

Tipping bucket precipitation—Disassemble, clean, and check all connections, and verify incremental closure. Using the precipitation gauge calibrator, run 1.5 liters of water through the collector and ensure that the recording device (either the DCP or the tipping bucket counter) reads 54 counts, ±2 counts.

Windspeed—Check for damage of cups and ice skirt, and check free movement of bearings. Change sensor every 2 years.

Wind direction—Check for damage of arrow (pointer and tail), and check free movement of bearings. Change every 2 years.

Air temperature/relative humidity—Change every year.

Fuel temperature—Check for deterioration and cracking of the wooden fuel stick. Change every 3 years.

Fuel moisture/fuel temperature—(Not in standard use.) Change every year.

Soil moisture/soil temperature—Check for corrosion of the sensor tip. Change every 3 years.

Antenna—Check for broken or bent elements and for proper alignment; check connectors for corrosion. Use the wattmeter for electrical operation checkout.

Cables—Check for cracking, deterioration, corrosion, proper routing, and secure attachment. Make sure that O-rings are installed on all connectors.

Tower—Check for structural damage, proper alignment, and leveling.

Data collection platform (DCP)—Check for damage. Check security of mounting and make sure that all cables are properly connected. Check batteries for corrosion and for proper output, using a load tester. Change DCP every 3 years.

DEPOT SENSOR OVERHAUL STANDARDS

The Depot Repair Facility uses these instructions for overhauling RAWS equipment:

Instructions—

Tipping bucket—Disassemble. Inspect for corrosion and mechanical wear and damage. Check and align the contact closure mechanism for proper operation. Assemble. Run the operational test-and-check (T/C).

Windspeed—Change bearings. Check the reed switch (used in older, H-530 systems) for proper alignment and operation, using the hermeticity tester. Assemble. Run operational T/C in the wind tunnel at 1.5, 5, and 10 mi/h. Proper readings will be within ±0.5 mi/h of the actual speeds. Check Hall Effect device (in H-540A systems) by applying 12 VDC, turning anemometer cups, and observing the pulse output.

Wind direction—Change bearings. Check potentiometer and replace as required. Install mechanical locking pin. For Handar sensors, apply 3.60 VDC using the voltage standard and adjust the pot for a reading of 1.80 VDC, ±0.01 VDC.

For Met One sensors, apply 3.60 VDC using the voltage standard and adjust the pot for a reading of 1.70 VDC, ±0.01 VDC. Remove the locking pin, rotate the top counterclockwise, and reinstall the locking pin; be sure not to overshoot the alignment point. Reading should now be 1.90 VDC, ±0.02 VDC.

Air temperature/relative humidity (AT/RH)—Using the Model HMK-11 humidity calibrator, apply 12.5 VDC at a current reading of 2.5 ma, ±0.5 ma. Calibrate the RH sensor at the 12 percent and 75 percent levels. After calibration, the RH sensor should read within ±3 percent of the ambient room relative humidity.

Using an ohmmeter and published calibration curve, calibrate the AT sensor at various temperature settings. The resistance must correspond to the standard within ±75 ohms.

Check bearing on aspirated-vane radiation shield and replace as necessary.

Fuel temperature—Check the fuelstick for weathering and other damage; replace as necessary. Check and calibrate the thermistor, using an ohmmeter and published calibration curve as described for AT.

Fuel moisture/fuel temperature—Check the fuelstick for weathering and serviceability. Weathering of stick is more critical here than when stick is used for measurement of fuel temperature alone. Replace as necessary. Calibration procedures are the same as those described (above) for AT/RH.

Soil moisture/soil temperature—Check the unit for cracked case and bent or damaged probe. The sensor is calibrated against known standards.

Cables—Inspect all cables for serviceability, clean and check all connectors for corrosion and O-ring installation, and then check all connections with a Megger. Replace as necessary.

Antenna—Clean the connections and check elements; replace as necessary. Connect antenna to a DCP and, with a wattmeter in line, check for proper power output and a reflected-power/forward-power ratio of 0.1 or less.

Data collection platform—A number of checks and adjustments are required, as listed:

1. Verify that the DCP has the latest, updated software installed.
2. Adjust all voltages from the power supply and regulator (adjust regulator output for 13.8 VDC on the H-540A DCP and 14.3 VDC on the H-530).
3. Align all cards and verify the revision number of the met board.
4. Adjust the R-F power output for 10 watts; adjust modulation and frequency as necessary.
5. Run and monitor the complete unit for at least 5 days in the environmental test chamber with a full complement of sensors.

Documentation—A maintenance record is kept for each sensor and DCP that is repaired and calibrated by the RAWS Depot Facility. These records are kept on file by serial number and used by the Depot staff for spotting systematic problem areas that may have impact on the entire RAWS program. The documentation also is helpful in working with manufacturers to improve product quality.

CHAPTER 43. BREAKDOWN RAWS MAINTENANCE

43.1 Definition; Monitoring

Breakdown maintenance involves the identification and correction of failures in RAWS systems or components. Various methods, both automated and manual, are used by the BLM's RAWS Support Group in monitoring the operations of the complete RAWS network. The Bureau's Direct Readout Ground Station (DRGS) has automated software that does a surveillance (or "watchdog") routine on various systems parameters. These parameters are performance related and give accurate indications of how a system is functioning. If problems are identified, corrective measures and processes are initiated.

Beginning in 1988, the watchdog service has been contracted for all Forest Service RAWS.

PERFORMANCE MONITORING SPECIFICATIONS

The following paragraphs list the performance monitoring specifications that are used in the above surveillance. The BLM uses the NOAA/NESDIS GOES DCP standards as the basis for all performance standards.

Any modification of these standards is the result of proven field experience in the actual working environment. The modified standards will always be stricter than the original ones.

Data Recovery—Data recovery from all Class I RAWS systems will be 95 percent or greater year-round. For Class II systems, the Class I specifications hold for the normal fire season. As described here, data recovery conists of two categories (or levels): (1) data recovery from the RAWS unit through the satellite to the DRGS at BIFC and (2) data recovery from the DRGS to the user requesting the data. If data loss occurs, regardless of cause (missing transmissions, faulty characters, etc.), users will be notified and data base documentation will be made.

The first recovery level (95 percent) is determined mainly by atmospheric conditions and satellite operating parameters. Normally this recovery level ranges from a low of 95 percent to a high of 98.5 percent, averaging 97.8 percent. **NOTE:** This data loss does not occur at NOAA/NESDIS, where there are multiple receiving antennas and satellites to counter the above anomalies.

The second recovery level (99.8 percent) is determined by the quality of the data transmission lines, the AFFIRMS, and the RAWS systems failure rate.

Faulty (Bad) Characters/Parity Errors—From the BLM's experience over past years, sporadic parity errors or bad characters are most uncommon. When they occur, they are usually attributed to adverse weather conditions. Therefore, any appearance that is excessive and occurs outside such conditions will be treated as a problem.

Transmitter Performance—

Transmitter power (EIRP)—The range of received power from the DCP is 40-50 dbm.

Transmitter modulation—The range for modulation is from –5 db to –9 db, with –6 db the optimum reading.

Transmitter frequency—The permissible variance is ±400 Hz. Because of the year-round use of most of the BLM's DCP units, the Bureau attempts to maintain a standard of ±250 Hz before the start of winter to allow for cold-weather shifts. The BLM also specifies a maximum daily variance of 150 Hz on all DCP's.

Transmitter timing—NESDIS allots each transmitter a time window of 60 seconds, every 3 hours, in which to transmit. The BLM's standard for transmitter stability specifies that, once initialized, the start of transmission shall at no time vary by more than 2 seconds. Any unexplained slippage will be treated as a problem.

DATA MONITORING

A second vital responsibility of the RAWS Support Group is to monitor and analyze the meteorological data from all BLM maintained RAWS systems. Through the watchdog routine, these data are screened daily for any irregular sensor outputs or tendencies that indicate possible problems. The data are abstracted and documented for data base management and systems administration.

Guidelines—The following rudimentary guidelines are used in the watchdog screening and in followup manual checking of data:

Precipitation—There should be no intermittent loss or reduction in the cumulative total.

Windspeed—Look for a realistic changing pattern, noting particularly any long periods of time with an unchanging windspeed.

Wind direction—Look for a realistic changing pattern, noting particularly any long periods of time with an unchanging wind direction.

Air temperature/fuel temperature (AT/FT)—The two temperatures should run closely together during nighttime hours, with the FT rising about 15 to 20 degrees or more above the AT during sunny daylight hours. Look for normal diurnal variations, taking into consideration occurrences of precipitation, cold front passages, etc.

Relative humidity—Look for realistic changes in the hourly values, considering both the air temperature and occurrence of precipitation. Also be aware of the possible effects of site location, altitude, and aspect (and other local factors) on relative humidity.

Battery voltage—Note diurnal variations in the battery charging rate. Pay particular attention to voltage readings above 13.5 volts or below 12.0 volts. During winter months, watch the charging rates more closely, as chilled batteries and snow cover on solar panels can result in system failure.

Barometric pressure—Readings from L-100, L-200, and H-530 systems will appear too low, because the data are raw and have no elevation correction added. Upon request, this correction for elevation can be done automatically at the BIFC downlink. Barometric pressure from H-540A systems should be near 31.00 (inches). For all readings, pressure changes should generally be gradual and show hourly continuity in trends, which may also reverse. Rapid, irregular pressure changes can occur (as during thunderstorm activity) but are uncommon.

Soil moisture—Readings usually will not exceed 30 percent. Changes will generally be slow, particularly at greater sensor depths.

Soil temperature—Readings will generally change slowly, particularly at greater sensor depths. Winter readings may reach the freezing point, particularly at smaller depths.

43.2 Field Work

As a followup to the above screening process, the RAWS Field Support Group schedules field trips. The scheduling aims toward making the most efficient use of available time and personnel. While performing the field work, the crew adheres to all of the previously described RAWS standards and procedures (section 42.2).

CHAPTER 44. AUTOMATIC WEATHER STATIONS, NON-RAWS

Automatic Weather Stations (AWS) are similar in many ways to the RAWS just described. Major differences occur in the means of data transmission and retrieval, which often may limit the remoteness of AWS sites (section 37.1). Like RAWS, many AWS systems can automatically transmit data in real time. Several of the AWS manufacturers also have an option for satellite telemetry, which is the communications mode generally identified with RAWS.

A variety of data retrieval methods or options is found among available AWS systems. For some applications, particularly in research, the data are primarily obtained on a delayed basis. In such cases, the data are usually stored on cassette tape (where temperatures are above freezing) or in solid state modules. Depending on the number of weather parameters and the observational frequency, 1 to 2 months of data, or more, can be stored. The data are then transferred to a computer for readout. Some AWS accumulate the data in analog form, via strip chart recording. For real-time data retrieval, many AWS can be interrogated or programmed to automatically transmit via telephone lines or radio links; over short distances, they can be linked by direct cable connection.

As previously mentioned (section 37.1), the BLM, FS, and NPS now deploy only Handar systems in their RAWS programs (although a few older LaBarge units remain in operation). And these systems—particularly the portable units, not using satellite communication—may also serve as AWS. But individual choice may rule in selecting automatic equipment for various applications (section 37.1) outside of U.S. government fire-weather or fire-danger monitoring. Different systems may be deemed most suitable and economical by different users in other resource management or research applications.

Besides Handar, more than a dozen manufacturers in the United States offer automatic weather data acquisition systems. Some of these makes are available in two or more models, with the differences involving arrangement of the electronics package, the form of power supply, data storage, portability, etc. Many of these systems employ sensors from other manufacturers, who specialize in certain types of equipment. The following sections will describe the range of available equipment, including variations in sensor characteristics and specifications as detailed in manufacturers' literature.

44.1 Data Collection and Transmission

Table 44.1 shows some of the variety of automatic weather station (or data acquisition) systems available in the United States. The Handar RAWS systems are included. The information has been compiled from company literature, which varies in its technical detail. System features most subject to ambiguity or misinterpretation have therefore been omitted. Several companies may unintentionally be missing from the listing, which is not all-inclusive and is not intended for any particular endorsement.

Installations of some of the data-logger or compact AWS systems, with their sensor arrays, are shown in figures 44.1 through 44.6.

Table 44.1—Summary of automatic weather station features; basic station characteristics and methods or options of data collection and retrieval: (1) company (two-letter abbreviation),[1] (2) model or series number, (3) type of system or electronics configuration (M, modular; C, compact or compact modular; L, data logger), (4) power source (DC, battery; AD, battery or AC line; AC, AC line); s denotes solar panel available, (5) number of sensor inputs or modules, single ended analog plus digital, standard and/or maximum (m), (6) external, on-site data storage option, denoted by X (CH, strip chart recorder; TA, cassette tape; SS, solid state module or large internal memory—denoted by i), (7) data transfer or communications option, denoted by X (TA, cassette tape or 9-track tape—denoted by n; CH, strip chart; AM, analog meter; DM, digital meter; C/P, computer or printer through RS232 interface; T, telephone; R, radio link; S, satellite),[2] (8) specified lowest operating temperature (Temp.) of system, °F (excluding on-site tape recording); e denotes option for –40 or lower; p, specification for microprocessor (signal conditioners –4 °F)

(1) (2)	(3)	(4)	(5)	(6)			(7)								(8)
				Storage			Transfer/Communications								
Company, Model	Type	Power	Inputs	CH	TA	SS	TA	CH	AM	DM	C/P	T	R	S	Temp.
BF, 7031 Data Logger	L	DC	10			i					X	X	X		
CB, 21X Micrologger	L	DCs	20		X	i	X				X	X	X	X	–13e
CR7X	C	DCs	32		X	i	X				X	X	X	X	–13e
CR10	L	DCs	14		X	X	X	X			X	X	X	X	–13e
CT, EWS	C	ADs	6	X	X		n				X				–4e
IMP-850	L	(Same as CB, 21X Micrologger)													
Modular System	M	AC	6m		X		n				X				–4e
Remote System	M	ADs	16m					X			X	X	X	X	–40
EV, Easy Data Mark 3	L	DCs	8,16m								X	X	X		
HA, 540A RAWS	C	DCs	15		X						X	X	X	X	–4e
Portable (P-RAWS)	C	DCs	15		X						X	X	X	X	–4e
Micro-RAWS	C	DCs	15			i					X	X	X	X	–4e
550A Hydrologger	L	DCs				i	X				X	X			
560A Hydrol. RAWS	C	DCs	15		X						X	X	X	X	–4e
KH, 50AM100 (WEDOS)	M	AC	5,11m		X					X	X	X			
LI, LI-1200S	L	AD	4			i					X				–13
MO, Met Set 3D	L	AD	6,12+m		X						X				
Met Set 3M	L	DC	9			i	X				X	X			
Met Set 3S	C	(information incomplete)												X	
Met Set 4B	C	ADs	6m	X							X				
MP, MPH-700	C	ADs	20m			X					X	X	X	X	
OD, Easy Logger	L	DCs	16			X					X	X	X		–22
SM, Compulogger 6500	L	DCs	4,11m		X	i	X				X	X	X		–22
Modular	M	ADs	10m		X						X	X	X		–40
1046 Selectronic	C	AD	6,10m					X		X	X				
5081 Self-Reportng	C	DC	6,20m	X									X		
5240 Portable FW	C	DCs	7								X	X	X		
TE, Series 3000	M	AD	7					X	X	X	X				
TG, MicroMet	L	DCs	5,10m	X	X						X	X	X		
Series 21	M	AD	7m							X	X		X		–4
VS, MILOS 200	C	ADs	32m		X	X	X	X		X	X	X	X	X	–40
MIDAS	M	AC									X	X	X		
WT, Macro 20	L	DCs	20		X	X				X	X	X	X		–13
M733	M	AD	11m				X	X	X	X	X	X	X		+32p

[1]Company identifications are:
BF, Belfort Instrument Company
CB, Campbell Scientific, Inc.
CT, Climatronics Corp.
EV, Environdata Australia Pty. Ltd. (distrib. by John W. Kennedy Consultants)
HA, Handar
KH, Kahl Scientific Instrument Corp.
LI, Li-Cor, Inc.
MO, Met One, Inc.
MP, Meteophysics Corp.
OD, Omnidata International, Inc.
SM, Sierra-Misco, Inc.
TE, Texas Electronics, Inc.
TG, Teledyne Geotech
VS, Vaisala Inc.
WT Weathertronics, Division of Qualimetrics, Inc.

[2]Additional communications options: CB (all three systems) and VS, meteor-burst telemetry; SM (Compulogger), infrared telemetry; WT (M733), voice synthesizer for T and R. Data from data logger systems and CR7X may also be retrieved on-site from digital (LCD) display on the integral programmer or field terminal.

Figure 44.1—Automatic weather station using CR10 data logger (Campbell Scientific, Inc.), for recording windspeed and direction (Met One sensors 014A and 024A), temperature, relative humidity, and solar radiation (Li-Cor sensor on angled mounting arm). Installation (in senior author's yard) shows size difference between Gill multiplate radiation shield (R.M. Young Co.) and cotton-region type shelter. (Photo by Arnold I. Finklin.)

Figure 44.2—Climatronics Electronic Weather Station (EWS), with on-site multiplex strip chart recorder. (Photo courtesy of Climatronics Corp.)

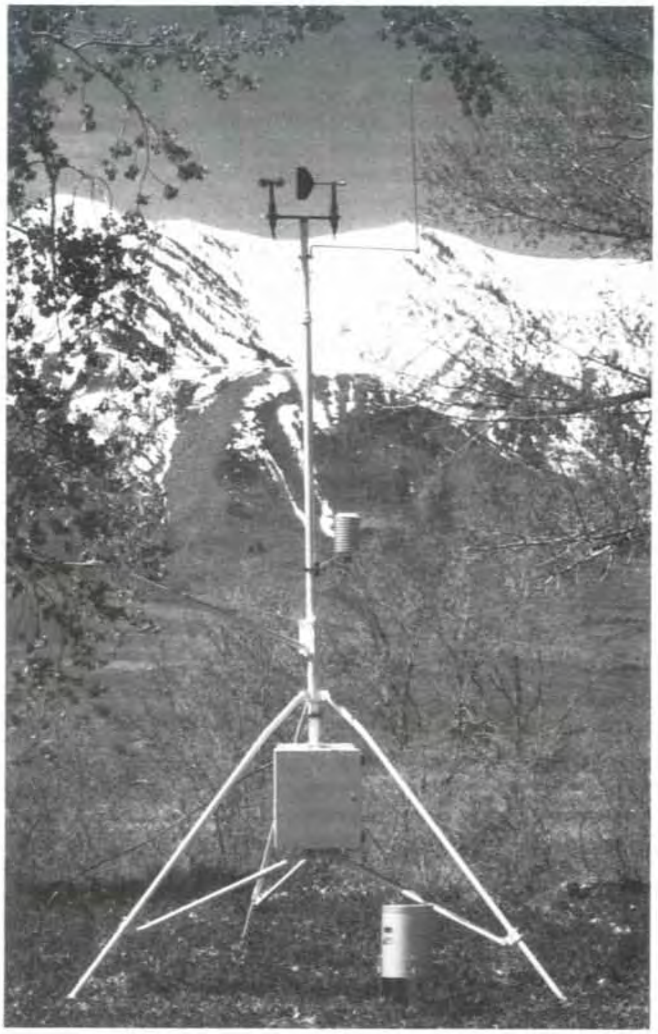

Figure 44.3—Easy Logger recording system (Omnidata International, Inc.), with Wind Sentry (R.M. Young Co.) anemometer and wind vane, tipping bucket rain gauge (Sierra-Misco, Inc., model 2501), Gill multiplate radiation shield (R.M. Young Co.) housing temperature and relative humidity probe (Phys-Chemical Research Corp.), and pyranometer (Li-Cor). (Photo courtesy of Omnidata International, Inc.)

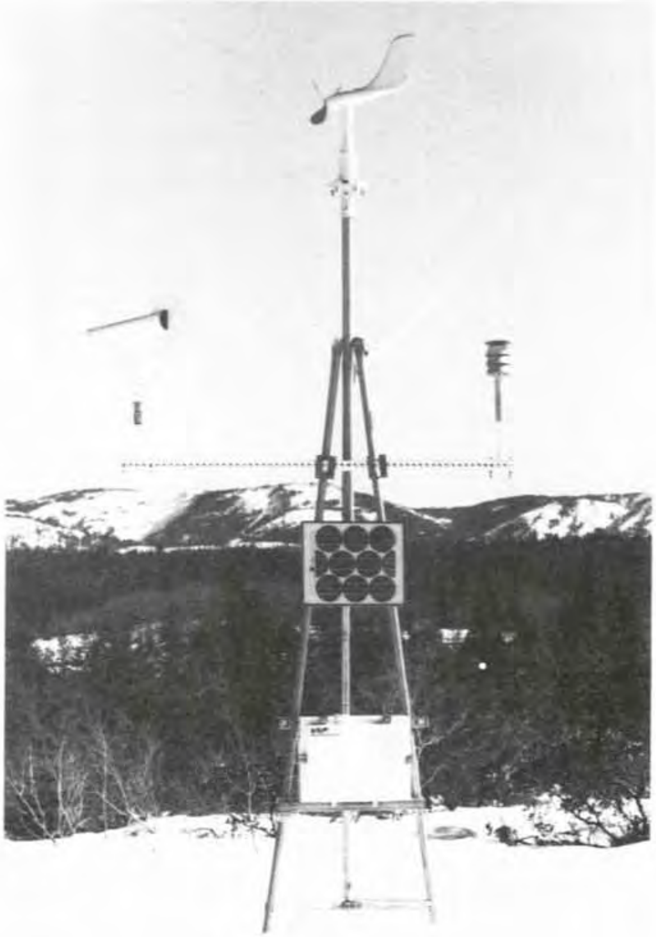

Figure 44.4—Weathertronics automatic weather station, with Skyvane wind sensor, and vane-type and pagoda-type radiation shields for temperature and/or humidity probes. (Photo courtesy of Qualimetrics, Inc.)

Figure 44.5—CompuLogger (Sierra-Misco, model 6500) data collection system, with infrared transmitter and basic sensors; temperature/relative humidity probe is mounted in flat-plate radiation shield. (Photo courtesy of Sierra-Misco, Inc.)

Figure 44.6—Typical sensor array used in Texas Electronics (series 3000) modular meteorological system. (Photo courtesy of Texas Electronics, Inc.)

44.2 Sensors

The stations or systems just listed are generally available with a standard complement of between four and seven sensors. As with RAWS and manual fire-weather stations, the most basic sensors are those for wind direction, windspeed, temperature, relative humidity (or dewpoint), and precipitation. The AWS systems with seven sensors typically add sensors for solar radiation and barometric pressure. Other options are available, as indicated in table A7.1 (appendix 7).

Among the various company offerings of AWS systems, there is much similarity in the design and specifications of some of the sensors. Many of the companies employ at least one or two types of sensors made by other manufacturers; this is particularly true for precipitation (measured by tipping bucket gauge) and solar radiation. The greatest variety is found in the wind sensors, which, more than other sensors, vary in their appearance, their construction materials, and (particularly for anemometers) their type of transducer. A discussion of the basic sensors available for automatic stations follows.

WINDSPEED AND WIND DIRECTION

The windspeed sensors are mostly three-cup anemometers, but some are three- or four-blade propellers mounted on an airplane-shaped body that includes a vertical tailfin for measuring wind direction. Six-cup anemometers (in a staggered, two-tier array), six-blade propellers, and "U-V-W" anemometers (three separate propellers mounted to measure horizontal and vertical wind vectors) are also available for specialized needs; likewise, bivanes (bidirectional wind vanes) are available for measurement of both azimuth and elevation angle. Only the three-cup and simple propeller anemometers will be discussed here.

Anemometers—Almost without exception, the three-cup anemometers are made of aluminum (or anodized aluminum), stainless steel, or a form of dark-colored plastic. Most are designed to be corrosion-resistant and to measure or withstand winds of at least 100 mi/h. The plastic cups are the most corrosion-resistant and are said to discourage possible ice buildup. Plastic can, in time, undergo changes due to ultraviolet (UV) radiation, but the employed formulations are stabilized against UV. The construction, together with the type of transducer employed, will affect the sensitivity and durability of the instrument.

Five types of windspeed transducers are available for use in AWS systems. These are (1) AC generator, (2) DC generator, (3) magnetic reed switch, (4) light chopper (or photochopper), and (5) high frequency, nonoptical tachometer. (A Hall Effect device is used in RAWS, section 38.1.) The generator anemometers tend to be durable, but some models have relatively high starting speeds, 2.0 mi/h or higher. Generator output is either a linear DC voltage proportional to the windspeed or an AC sine wave voltage signal with a frequency directly proportional to windspeed. Some of the AC generators have a brushless design that should add to their durability.

The magnetic reed switch is activated by a magnet attached to the bottom of the anemometer shaft. As the cups and shaft rotate, the magnet produces a series of contact closures with a frequency proportional to the windspeed. With the magnet extending across the shaft diameter, there are two contact closures for each full rotation.

The light-chopper anemometer shaft is directly coupled to a slotted disc, which, when rotated, interrupts a light beam produced by an infrared LED. The interrupted signal is detected by a photo-sensitive transistor located on the opposite side of the disc. Output is a pulsed frequency proportional to the windspeed. Anemometers of this type have a rather low starting speed.

Similar in principle to the light chopper is a high-frequency tachometer employing a slotted disc that rotates between a high frequency oscillator transmitter and a receiver. Output is a 12-V square wave with a frequency proportional to the windspeed. Compared with the light chopper, this tachometer has a lower power requirement and may be more maintenance-free.

Wind Vanes—The tail portion of wind vanes available for AWS systems is generally constructed of either aluminum or a plastic formulation. Magnesium and foam are also used; the foam may have an aluminum or plastic skin.

Most of the vanes are coupled to a potentiometer. With constant excitation voltage applied to the potentiometer, signal output is proportional to the azimuth position of the vane. The potentiometers are either wirewound or made of conductive plastic; a hybrid type is wire-wound with a conductive plastic coating. Some models have a direction (azimuth) range from 0 to 540° which is useful for strip chart recorders or averaging circuits; the discontinuity at north (360°) is eliminated.

One precision vane model incorporates a digital optical encoder transducer, termed a "resolver," which eliminates the contacting parts of potientiometer-type instruments. It utilizes two signal inputs—a reference sine wave and a sine wave whose phase relationship to the reference varies proportionally with the wind azimuth. Output is two sine waves, whose phase difference is numerically equal to the azimuth. Another vane has an optoelectronic transducer employing infrared LED's and phototransistors; these are mounted on six orbits on each side of a code disc attached to the vane shaft. Wind direction is indicated by the six-bit pulse code received by the phototransistors.

Table 44.2 summarizes the features of various anemometers and wind vanes used in AWS systems, based on manufacturer specifications. (The RAWS sensors, furnished by Handar, are also included.) Although the table seeks to give a thorough listing, inadvertant omissions are bound to occur. Distance constant is defined as the length of airflow passage required for an anemometer to respond to 63 percent of a sharp change in speed. Lower values are characteristic of sensitive anemometers. Damping ratio, specified for vanes, is a constant calculated from the relative amount of overshoot on two successive swings (half cycles) of a decaying oscillation. Higher ratios, such as 0.4 to 0.6, are associated with sensitive vanes; low values, such as 0.2 or 0.3, with rugged-duty vanes (Mazzarella 1985).

Table 44.2—Summary of wind sensors available for automatic weather stations: (1) manufacturer (two-letter abbreviation),[1] (2) model number of anemometer-and-vane set or anemometer/vane, (3) anemometer type (ACG, AC generator; DCG, DC generator; RSW, magnetic reed switch; LCH, light chopper; HTA, high frequency tachometer, non-optical; HLE, Hall Effect); anemometers are 3-cup except for propeller denoted by prefix P, (4) construction material (Mat.) of cups or propeller (ALU, aluminum or anodized aluminum; SST, stainless steel; PLA, plastic of any type), (5) specified maximum recording speed (Max.), miles per hour (mi/h), (6) starting threshold speed, (7) Speed accuracy (Accur.), full scale, plus or minus indicated mi/h or percent (whichever is greater at observed speed, when both are shown), (8), distance constant (DC), (9) type of vane transducer (P, potentiometer of type: ww, wire-wound; cp, conductive plastic; pw, plastic coated wire-wound; or tf, thin film. RES, resolver (see text); OPE, optoelectronic/code disc), (10) material (Mat.) of vane tail (ALU, aluminum or anodized aluminum; MAG, magnesium; PLA, plastic of any type; FGP, fiberglass reinforced plastic; FOM, foam, with aluminum (a) or butyrate (b) skin), (11) direction accuracy (Accur.), plus or minus, degrees azimuth, (12) damping ratio (DR). Information from company literature; blank spaces, not specified

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
				Anemometer					Vane		
Company, Model		Type	Mat.	Max., mi/h	ST, mi/h	Accur., mi/h/pct.	DC, ft	Type	Mat.	Accur., deg.	DR
BF,	123 Aerovane	PDCG	PLA	100	3.8	1/	15	P	FGP	2	
	1022S/D	LCH	SST	80	0.5	/1	5	P	MAG	4	0.4
	1074	LCH		125	0.75	1/1.5	18	Ptf		4	0.55
CM,	011-4/012-16	LCH	PLA	90	0.6	0.2/1	5	P	PLA	3	0.4
	optional							P	FOM	3	0.6
CT,	F460	LCH	PLA	125	0.5	0.2/1	5	P		2	0.4
	optional		SST	(same)			8				
	Mark III	LCH	ALU	125	1	0.3/1.5	15	P	MAG	3	0.5
	optional	SST	(same)				8	P	PLA		
	Wind Monitor (RY 05103 design)	ACG	PLA	100	2	0.2/1	11	Pcp	PLA	2	0.23
	optional		(same)		1		4				0.4
HA,	430A/431A	HLE	ALU	150	1	0.3/2	15	Pww	ALU	2	
KH,	03BM040/050	DCG		100		1/				2	
MO,	010B/020B	LCH	PLA	125		0.2/1	5	P	PLA	3	0.5
	optional		ALU		(same)		15		ALU		
	013/023	RSW	ALU	150	1.5	0.3/2	15	Pww	ALU	10	0.3
	014A/024A	RSW	ALU	100	1.0	0.3/1.5	15	Pww	ALU	5	0.25
	optional		PLA		(same)		5				0.4
RY,	12002	DCG	PLA	70	1.0		8	Pcp	PLA		0.51
	12005	DCG	PLA	110	1.0		8	Pcp	ALU		0.34
	12102D	LCH	PLA		0.7		8				
	03001 Sentry	ACG	PLA	112	2.5		8	Pcp	PLA		0.2
	05103 Monitor	PACG	PLA	134	1.3		9	Pcp	PLA		0.25
	05305 Mon.-AQ	PACG	PLA	90	0.9		9	Pcp	FOM	-	0.45
	05701 Mon.-RE	PACG	PLA	70	0.5		3	Pcp	PLA		0.65
SM,	1036HM	ACG	PLA	100	1	/1	10	P		5	0.5
	1005DC/1010	DCG	PLA	100	0.75	/1	7	Pww	PLA	2	0.4
	1005LED	LCH	PLA	100	0.5	/1	5				
	1005C	RSW	PLA	100	1	/1	8				
	optional	SST							SST		
	1016 Propvane (RY 05103 Wind Monitor)	ACG	PLA	134	1.6		10	Pcp	PLA		0.23
TE,	TV-110-L2	LCH	ALU	100	1.0	/2	22				
	TV-102/TD104	DCG	ALU	100	2.0	/2	22	Ppw	ALU	4	0.36
	TV-114	ACG	ALU	100	2.0	/2	22				
TG,	WS-201			200	<2	1/2	5	Pcp		3	0.2
	optional										0.4
	1500 Series	LCH	PLA	90	0.6	0.2/1	5	RES	FOMa		0.6
VS,	WAA/WAV15	LCH	PLA	150	0.8	0.2/2	5	OPE	ALU	3	0.4
WT,	2010/2005	HTA	PLA	100	0.6	0.2/1	5	Pww	ALU	2	0.4
	2011	DCG	PLA	100	1.0	(same)					
	2012	RSW	PLA	100	0.6	(same)					
	2030/2020	LCH	SST	100	0.5	0.2/1	5	Pww	FOMb	2	0.4
	2031	DCG	SST	100	1	(same)					
	2032	RSW	SST	100	0.5	(same)					
	2100 Skyvane	PHTA	FGP	200	2	1/3	6	Pww	FG	2	
	2102	PDCG	FGP	(same)							
	2106	PACG	FGP	(same)							

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[1] See table 44.1 footnote for company identifications; in addition:
CM, Climet Instruments Company
RY, R.M. Young Company.

TEMPERATURE AND HUMIDITY

Temperature—Temperature sensors available from the above companies employ either a platinum resistance device, thermistor, or thermistor-and-resistor network. The platinum resistance sensors from at least three of the companies are made in a four-wire configuration; this design automatically compensates for possible lead resistance error. Thermistors may contain two or three elements. Models for soil or water temperature measurement are specified by four companies. Most sensors for air temperature are encased in a stainless steel probe about 4 to 6 inches long. The air temperature sensor is generally available with the relative humidity sensor in a single probe.

Various temperature ranges are available from some companies. Specified ranges for the platinum resistance sensors include –50 to +50 °C (–58 to +122 °F) or higher; three-element thermistors, –50 to +50 °C (–58 to +122 °F); two-element thermistors, –30 to +50 °C (–22 to +122 °F). Specified accuracy of these sensors is mostly between 0.1 and 0.3 °C (0.2 and 0.5 °F).

Relative Humidity—Many of the relative humidity sensors are a thin-film capacitor type, employing a 1-micron dielectric polymer layer. This layer absorbs water molecules from the air through a thin metal electrode, causing capacitance change proportional to the relative humidity. Output from the probe electronics is a DC voltage that is linear from 0 to 100 percent relative humidity. Accuracy is specified as within ±3 percent, full-scale, by four companies in their literature. But this may not hold true under actual field conditions. Another company specifies ±3 percent accuracy only in the 10 to 90 percent relative humidity range and ±10 percent from 90 to 100 percent relative humidity.

Hysteresis (calibration shift) during a 0 to 80 to 0 percent relative humidity excursion is specified in the various catalogs as only ±1 or 2 percent; during a 0 to 100 to 0 percent excursion, between ±2 and 5 percent. Response time of the humidity element is very fast, specified as low as 1 second to reach 90 percent of a relative humidity change at a temperature of 20 °C (68 °F). The sensor, however, is usually protected with a sintered brass or stainless steel filter, increasing the response time to about 30 seconds.

A few other types of relative humidity sensors are offered. A relatively inexpensive sensor, manufactured by Phys-Chemical Research Corporation and available from both Campbell Scientific and Omnidata, employs a sulfanated polystyrene sensing element. This has an electrically conducting surface layer that adsorbs water molecules. Changes in relative humidity cause the surface resistance to vary.

Another sensor, from Texas Electronics, employs a hygroscopic inorganic sensing element; its expansion and contraction positions the suspended core of a linear variable differential transformer (LVDT). The processed LVDT output signal is directly proportional to relative humidity. A sensor made by Hygrometrix, available from Campbell Scientific and Climatronics Corporation, employs a composite of organic and inorganic crystals. These sense moisture by the hygromechanical stress of cellulose crystal structures acting upon a pair of silicon strain gauges connected as a half Wheatstone bridge. A sensor from Climet uses a hygromechanical arch that bends as the relative humidity varies. The arch and two strain gauges operate in a bridge circuit. Specified accuracy of these three sensors varies from ±2 to 5 percent. As with the thin-film capacitor, however, larger errors may occur under actual field conditions.

Several companies offer sensors for dewpoint temperature in addition to, or instead of, those for relative humidity. A lithium chloride dewcell is most commonly employed in these sensors. Specified accuracy of measured dewpoint is typically within ±2 or 3 °F over a range from –20to +85 °F.

Radiation Shields, Naturally Ventilated—The air temperature and relative humidity probes, singly or combined, are housed in solar radiation shields available from all of the companies. Naturally ventilated shields, which depend upon wind movement, come in several designs. The most expensive is the vane-aspirated shield, which turns on a set of ball bearings and orients the probes into the wind (at windspeeds of 2 mi/h and higher). The probe is mounted within two concentric tubes. This shield has been employed at standard RAWS installations (fig. 38.1), though it is now being replaced (section 38.1). The vane shield is constructed of aluminum with a reflective white epoxy or enamel finish on exterior surfaces. It is available from Climet, Met One, Sierra-Misco, and Qualimetrics/ Weathertronics.

R. M. Young Company provides a cylindrical multiplate shield, consisting of 12 white opaque thermoplastic plates. The stacked, overlapping plates form a cylinder that is 5 inches in diameter and 7 inches high. This shield is also carried by Sierra-Misco and Qualimetrics/ Science Associates and is utilized in Campbell Scientific and Omnidata AWS systems (figs. 44.1 and 44.3). A similar but larger shield, of fiberglass-reinforced polyester, is made by Vaisala. A pagoda-type shield, consisting of three stacked anodized aluminum cups and a disc roof, is available from Climatronics, Qualimetrics, and Texas Electronics (TE) (figs. 44.2, 44.4, and 44.6). TE provides a separate, four-cup shield for a relative humidity sensor. Other wind-ventilated shields include a shield comprised of four flat rectangular plates (two above and two below the inserted probe) from Sierra-Misco (fig. 44.5), a small hemispherical-dome shield from Kahl, and an open design comprised of two flat discs (a large upper disc and a small lower disc) from Belfort.

Specifications as to radiation error affecting temperatures are not given for all of these shields. The error can reach at least 2 to 3 °F—similar to that inside a standard wooden shelter at manual stations—under conditions of strong sunshine combined with wind less than 2 mi/h; such error may occur particularly at sun angles perpendicular to sloping shield surfaces. An error of only 0.2 °F is specified for the vane shield at windspeeds above 2 mi/h (when the vane should be oriented into the wind). A more modest specification (under strong radiation conditions) is given for a plate-type shield, error about 0.6 °F at 7 mi/h.

Power-Aspirated Radiation Shields—Shields aspirated by a blower are available from most of the above companies. These shields are relatively expensive and require AC power, generally about 10 to 20 watts, to operate the blower motors. In most models, the sensor portion of the shield employs two concentric, downward facing air-intake tubes. This housing is constructed of white-painted aluminum (with blackened interior surfaces) or white thermoplastic material. Belfort models employ a silvered glass thermos for the sensor housing. The blower, situated at the opposite end of a horizontal, boom-type connecting tube (except vertically above the sensor area in the Met One model), draws air past the sensor at specified rates between 10 and 20 feet per second. Specified maximum radiation errors are between 0.1 and 0.4 °F. An inexpensive shield from Sierra-Misco employs a solar-powered fan. The fan is operated by a photovoltaic cell mounted on this short, horizontal tubular shield.

PRECIPITATION

A tipping bucket gauge is used as the precipitation sensor in most AWS systems. Output is a momentary electrical contact closure for each increment of precipitation. This increment, 0.01 inch (between 0.1 mm and 1 mm in metric models), fills one of the bucket compartments, causing the bucket to tip and activate a switch. The switch may be the mercury type or the newer magnetic reed or mercury-wetted reed type. The water is drained through the base of the gauge after each tip, and thus the gauges have an unlimited operating capacity. Where retention of the rainfall for analysis is desired, Sierra-Misco can provide a collection assembly that houses containers. Alternatively, any suitable container may be placed beneath a gauge. Tipping bucket gauges as ordinarily supplied do not function in snowfall and freezing weather. Continued operation under these conditions requires models equipped with heaters. The heaters are either electrical, requiring AC power, or propane-operated; they are effective down to about –20 °F. Weighing gauges (from Belfort) providing potentiometer output can also be used; antifreeze solution is added for winter operation.

Gauges are available with orifice diameters ranging from 6 inches to 12 inches. Most common are the 8-inch gauges; these range in height from 15 to 24 inches. The tipping bucket is constructed of brass or stainless steel and the funnel is anodized aluminum. The funnel usually has a debris screen to prevent leaves, bugs, bird droppings, and other matter from plugging the funnel opening or entering the bucket mechanism. Screening may also be provided at the base openings from which water is drained.

Gauges with a mercury switch have a specified accuracy within 1 percent at precipitation rates up to 1 or 2 in/h. Error may increase to 6 percent (deficiency) at a precipitation rate of 6 in/h. Greater accuracy is specified for gauges with a magnetic reed switch, within 1 percent at rates up to to 3 in/h; within 3 percent at 6 in/h.

SOLAR RADIATION

Pyranometers, used for measurement of global (total direct and diffuse) radiation, are available in three basic types: black-and-white thermopile, black-surface thermopile, and photovoltaic silicon cell. The thermopile types are more sensitive and cover a much wider solar spectrum range than the photovoltaic type, but they may be over five times higher in price.

Black-and-white pyranometers have a circular receiving surface consisting of wedge-shaped sectors coated alternately black and white. The Eppley design has 6 sectors; the Qualimetrics/Weathertronics star pyranometer has 12 sectors. Thermocouples are imbedded in each sector to produce a thermopile. When exposed to solar radiation, the black and white surfaces develop a temperature difference producing a voltage proportional to the solar radiation. With its highly transparent glass dome, the instrument responds to a wavelength spectrum from 0.28 to 2.80 microns, as specified for the Eppley pyranometer; 0.3 to 3 microns response is specified for the star pyranometer. Sensitivity, expressed in the sensor output, is 11 microvolts and 15 microvolts, respectively, per watt per square meter. Response time for a 66 percent change is about 4 seconds.

The thermopile models with a heat-absorbing black receiving surface have spectral-response and response-time characteristics similar to those of the black-and-white pyranometers. Sensitivity may also be similar, with 10 microvolts and 17 microvolts (per above units) specified for two models.

The relatively inexpensive silicon cell pyranometers respond to radiation only in the spectral range from 0.35 to 1.15 microns. The silicon cell converts this energy directly into electrical energy. Sensitivity (voltage output) is about 70 microvolts (per above units). Response time is extremely fast, less than 1 millisecond, due to the fact that the instrument is light sensitive, not heat sensitive as in the case of thermopile pyranometers. Silicon cell pyranometers are factory calibrated against a standard black-and-white pyranometer, compensating for the silicon cell's limited spectral response. Absolute accuracy of instantaneous values is specified to be within 5 percent under most conditions of natural daylight; accuracy over a daily period may be within 3 percent.

All of the pyranometers have a linear response, within 1 percent deviation, within the observable range from 0 to 2 langleys per minute (0 to 1,400 watts per square meter). Temperature dependency in thermopile models is slight, with ±1 or 1.5 percent constancy from –20 to +40 or +50 °C (–4 to +104 or +122 °F). Temperature dependency may be greater in silicon cell pyranometers.

Shadow rings are available for use with pyranometers for applications requiring the separate direct-radiation and diffuse (sky)-radiation components. Use of the ring prevents direct solar radiation from reaching the pyranometer, and thus only the diffuse radiation is measured. To measure the direct radiation, a second, identical pyranometer is exposed without a shadow ring. The direct radiation will be the difference between the two instrument readings.

BAROMETRIC PRESSURE

Several types of barometric (atmospheric) pressure transducers are available for AWS systems. These may incorporate several stacked aneroid cells (bellows), a capsule, or what is termed a solid-state pressure transducer. In a bellows-type design from Kahl Scientific, Sierra-Misco, and Texas Electronics, the bellows sensor is directly coupled to the core of a linear variable differential transformer (LVDT). The core moves up or down as the bellows expand or contract in response to changes in atmospheric pressure. No physical contact is made between the core and transformer, provided that the instrument is vertically aligned, thus eliminating friction. Output is a voltage proportional to the pressure. In another design, available from Belfort, Climet, and Teledyne Geotech, the bellows are mechanically linked to a precision potentiometer; output is a resistance proportional to the pressure.

A capsule-type sensor deforms in proportion to the atmospheric pressure and generates a capacitance signal proportional to the pressure sensed. As the pressure increases, electrodes on the inside surface of the capsule are moved closer together, thus increasing the capacitance; the capacitance is detected by a built-in integrated cicuit and converted to a voltage output. A solid-state sensor from Qualimetrics/Weathertronics employs a piezoresistive diaphragm (a diaphragm with implanted resistors) that responds to the pressure. Built-in integrated circuits process the signal and produce a voltage output proportional to the pressure. The capsule and solid-state sensors can be mounted in any position.

The various sensors can be ordered or field adjusted for measurement ranges that enable use at altitudes as high as 6,000 ft to more than 10,000 ft. The span of barometric pressure within a selected measurement range may vary from 3 to 6 inches of mercury. Specified accuracy among models ranges from 0.01 inch to 0.03 inch, with greatest precision in an expensive capsule model. Most sensor models can be installed outdoors in a protected enclosure, with minimum operating temperatures varying from 0 to –40 °F. The bellows-LVDT sensors from Texas Electronics and Kahl Scientific, however, are intended for indoor installation, with operating ranges down to only +32 to 40 °F.

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APPENDIX 1. ABRIDGED OBSERVATIONAL INSTRUCTIONS FOR MANUAL FIRE-WEATHER STATIONS

A1.1 Temperature and Humidity

READING THERMOMETERS

1. Avoid parallax error when reading liquid-in-glass thermometers. A straight line from the observer's eye to the meniscus or index should form a right angle with the thermometer stem and scale.

2. 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.

MAXIMUM AND MINIMUM THERMOMETERS

Standard Liquid-in-Glass Thermometers—The procedure for reading and setting the standard maximum and minimum thermometers, mounted in a Townsend Support, is given in the following steps (refer to fig. 23.2). Record all temperatures to the nearest degree Fahrenheit.

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, with moderate force) until its reading, in the vertical position, will not go lower. Always start the spin from this position. Record the final reading as the "set maximum" reading.

   b. 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.

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.

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 and current (or set minimum) thermometer readings 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.

Recording of Maximum and Minimum Temperatures—When taking observations at the basic 24-hour observation time, remember that the maximum temperature recorded for today cannot be *lower* than the minimum temperature read yesterday. Nor can it be lower than the set maximum thermometer reading of either yesterday or today. 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.

PSYCHROMETER READINGS

For fire-weather observations, the psychrometer (dry bulb and wet bulb thermometer) readings are usually recorded to the nearest degree. Be sure to use the correct psychrometric tables, as designated for the station elevation.

STANDARD ELECTRIC FAN PSYCHROMETER

Basic Operating Procedures—The basic operating procedure for the electric (battery-operated) fan psychrometer, mounted in an instrument shelter, is as follows:

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

2. *Wet the wick*—Saturate with clean, distilled or other 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 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 column 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.

Observations in Freezing Weather—During freezing weather, the water on the wet bulb wick should be completely frozen with a thin coating of ice before an observation is begun. To allow this ice coating to form, when the wick is initially dry, wet the wick about 15 minutes prior to the observation time.

Ventilate the thermometers until the wet bulb reaches a steady temperature below 32 °F; read first the wet bulb and then the dry bulb.

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.

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.

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.
6. Wind the clock (where this is required). If the chart drive is battery operated, check to make sure that the chart drive (clock or motor) is running. Listen for an audible sound. Replace batteries if chart motion has stopped since the previous visit or if a replacement is due. If, however, the chart motion has stopped but the chart drive is running, check to see if the gears are binding or meshing too tightly.

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.
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.
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 in the nibs, 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 the 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. Make necessary adjustments (refer to sections 23.5 and 30.5).

Make a time-check mark on the traces, lightly deflecting each pen *downward*; a 1/8-inch vertical line is generally sufficient. Do not deflect the humidity pen arm upward, as this may apply damaging force on the hairs. Write the actual time near the pen mark or on the observation form. Make any necessary adjustment of pen position.

A1.2 Wind

AVERAGE WINDSPEED

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 (miles per hour); a 0.5 decimal is raised to the next integer. Wherever possible, correct the observed windspeeds as specified in the instruction manual furnished by the anemometer's manufacturer.

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

ONE-SIXTIETH-MILE CONTACTING ANEMOMETER

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 dial.
4. Obtain the 10-minute average windspeed in mi/h by placing a decimal point in front of the final digit read on the 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 mi/h by placing a decimal point in front of the final digit read on the 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.

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. Hold the anemometer in an open, representative location. When using instruments that show instantaneous windspeed, obtain an average speed by mental estimate or by recording the speeds at fixed intervals during the observation.

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. Hold the instrument about midway from either end, taking care not to block the two holes at the bottom or the pinhole on the top stem.
2. Observe motion of the white ball in relation to the left (low) scale. If ball remains within the range between 2 and 9 mi/h, read from the left scale. If ball is rising to near 10 mi/h, cover the opening at top of stem with index finger 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.

A1.3 Precipitation

NONRECORDING GAUGES

Timely Measurement of Precipitation—To prevent possible loss by evaporation, measure and record rainfall as soon as possible after its ending when using nonstandard, small-orifice gauges. A supplemental early-morning measurement 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.

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

STANDARD 8-INCH GAUGE

The following operating instructions apply to both the large-capacity and smaller-capacity (Forest Service) standard 8-inch-diameter rain gauges.

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 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 it is seated 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 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. Only the uter (overflow) can is exposed. When snow (or rain) then curs, measure the precipitation as soon as possible after has ended; refer to section 25.1 for details.

RECORDING GAUGES: UNIVERSAL WEIGHING GAUGE

Daily Precipitation Measurements—Precipitation amounts between successive observations are obtained directly from the recording chart, subtracting the previous reading of the pen trace from the current reading. First, 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, noting date and time.

To change a chart, for ordinary warm-season (fire-season) operation:

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 emove through access door. Remove chart, noting the te and "time off." Prepare a new chart, noting station name, date, and "time on."
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 A1.1.)
5. Wind the clock (where this is required), but do not overwind. (See hygrothermograph instructions, section A1.1.)
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 slighty 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 upon the pen should be sufficient to start this w. If necessary, remove pen from chart and draw a ece 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.

Operation During Freezing Weather—For operation during the snow season (and freezing weather), remove (by rotation) the funnel attached at the bottom of the collector; store in a convenient place. Place an antifreeze solution in the bucket (see section 25.2).

MEASUREMENT OF SNOWFALL AND SNOW DEPTH

Snowfall—Snowfall, the depth of newly fallen snow or ice pellets (sleet), should be measured concurrently with the snowfall water content—measure as soon as possible after the snow has ended, to avoid errors from possible 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.

Use the rain gauge measuring stick, or a sturdier ruler if necessary; record to the nearest tenth of an inch, reading the actual linear distance on the stick, taking an average from several measurement spots. When a grass surface is used, be sure that the stick is pushed only to the bottom of the snow layer—not lower into the grass blades. Refer to section 25.4 for further details.

Snow Depth—Total depth of snow lying on the ground can be measured with the rain gauge measuring stick or a longer, sturdier stick; several spots are sampled. Snow stakes may be required in areas with heavy snow cover. Record to the nearest inch.

A1.4 Fuel Moisture

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 $1/2$-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. 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 paintbrush; if wet, shake off any free moisture.
3. *Weigh the stick*—Using its hook, hang the stick on the scale arm. 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 (see fig. 26.3).

4. *Replace the stick*—Remove the stick from the scale and return it to the wire rack. 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 but is much easier to use if it is hung on a post, tree, etc. To operate:

1. *Check the scale*—Make sure that 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 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 (see 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 i cover (100 grams) on hook; any deviation from 100 gra must be included as an adjustment in the final moisture calculation (step 6).
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. 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 (see fig. 26.7).
7. *Replace the stick*—(See Forester scale instructions.)

APPENDIX 2. PSYCHROMETRIC TABLES

TA No. 454-0-1E
10-63

U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU

RELATIVE HUMIDITY
and
DEW POINT TABLE

Pressure 30 Inches of Mercury

For use at elevations between 0 and 500 feet above sea level
(In Alaska use at elevations between 0 and 300 feet above sea level)

Values in the body of the table are relative humidities (in percent) and dew points (in deg. Fahr.), with respect to water, for indicated values of wet and dry bulb temperatures in degrees Fahrenheit.

HOW TO USE THE TABLE

Locate at the top of the column the reading corresponding to the wet bulb temperature. Locate at the left side of the table the reading corresponding to the dry bulb temperature. Follow down the column under the wet bulb temperature, and across from the dry bulb temperature; at the intersection of these two columns will be found the relative humidity (%) in black and the dew point (°F.) in red.

USCOMM-WB-DC

WET BULB TEMPERATURES

DRY BULB TEMPERATURES

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
30	-31 6	-12 15	-1 25	+6 35	11 45	16 56	20 66	24 77	27 88	30 99																														
31		-21 8	-8 18	+1 27	6 37	13 47	18 57	22 68	25 78	28 89	31 99																													
32		-48 2	-16 11	-4 20	+4 30	10 39	15 49	19 59	23 69	26 79	29 89	32 100																												
33			-31 5	-12 14	-1 23	+6 32	12 41	17 51	21 60	24 70	28 80	30 90	33 100																											
34				-22 8	-7 16	+2 25	9 34	14 43	18 52	22 62	26 71	29 81	32 90	34 100																										
35				-47 2	-16 10	-4 19	+5 27	11 36	16 45	20 54	24 63	27 72	30 81	33 91	35 100																									
36					-30 5	-11 13	0 21	+7 29	13 38	18 47	22 55	25 64	28 73	31 82	34 91	36 100																								
37						-21 7	-6 15	+3 23	9 31	15 40	19 48	23 57	26 65	29 74	32 82	35 91	37 100																							
38						-42 2	-14 10	-2 18	+6 25	12 33	17 42	21 50	25 58	28 66	31 74	33 83	36 91	38 100																						
39							-27 5	-9 12	+1 20	8 28	14 35	19 43	22 51	26 59	29 67	32 75	34 83	37 92	39 100																					
40								-18 7	-4 15	+4 22	11 30	16 37	20 45	24 52	27 60	30 68	33 76	35 84	38 92	40 100																				
41								-36 3	-12 10	-1 17	+7 24	13 32	18 39	22 46	25 53	29 61	31 68	34 76	37 84	39 92	41 100																			
42									-23 5	-7 12	+3 19	10 26	15 33	20 40	23 47	27 54	30 62	33 69	35 77	38 84	40 92	42 100																		
43									-49 1	-15 8	-2 14	+6 21	12 28	17 35	21 41	25 48	28 55	31 62	34 70	36 77	39 85	41 92	43 100																	
44										-29 4	-9 10	+2 17	9 23	14 29	19 36	23 43	26 49	29 56	32 63	35 70	37 78	40 85	42 92	44 100																
45											-18 6	-4 12	+5 19	11 25	16 31	21 37	24 44	28 51	31 57	34 64	36 71	39 78	41 85	43 93	45 100															
46											-35 2	-11 8	0 14	+7 20	13 26	18 32	22 39	26 45	29 52	32 58	35 65	37 72	40 79	42 86	44 93	46 100														
47												-22 5	-6 10	+3 16	10 22	16 28	20 34	24 40	27 46	31 53	33 59	36 66	39 72	41 79	43 86	45 93	47 100													
48												-45 1	-14 7	-2 12	+6 18	13 24	18 29	22 35	26 41	29 47	32 54	35 60	37 66	40 73	42 79	44 86	46 93	48 100												
49													-27 3	-8 9	+2 14	9 20	15 25	20 31	24 37	27 42	30 48	33 54	36 61	39 67	41 73	43 80	45 86	47 93	49 100											
50														-17 5	-3 10	+5 16	12 21	17 27	21 32	25 38	29 44	32 49	35 55	37 61	40 68	42 74	44 80	46 87	48 93	50 100										
51														-33 2	-11 7	+1 12	8 17	14 23	19 28	23 34	27 39	30 45	33 50	36 56	39 62	41 68	43 74	45 81	47 87	49 93	51 100									
52															-21 4	-5 9	+4 14	11 19	17 24	21 29	25 35	29 40	32 46	35 51	37 57	40 63	42 69	44 75	46 81	48 87	50 94	52 100								
53															-42 1	-13 6	-1 11	+8 16	14 21	19 26	23 31	27 36	30 41	33 47	36 52	39 58	41 64	43 69	45 75	47 81	49 87	51 94	53 100							
54																-25 3	-7 8	+3 12	11 17	16 22	21 27	25 32	28 37	32 42	35 48	37 53	40 59	42 64	44 70	47 76	49 82	50 88	52 94	54 100						
55																-57	-15 5	-2 9	+7 14	13 19	18 24	23 28	27 33	30 38	33 43	36 49	39 54	41 59	43 65	46 70	48 76	50 82	51 88	53 94	55 100					
56																	-29 2	-8 7	+3 11	10 16	16 20	21 25	25 30	28 35	32 39	35 44	37 50	40 55	42 60	45 65	47 71	49 77	51 82	53 88	54 94	56 100				
57																		-17 4	-3 8	+6 13	13 17	18 22	23 26	27 31	30 36	33 41	36 45	39 50	41 56	44 61	46 66	48 71	50 77	52 83	54 88	55 94	57 100			
58																		-33 2	-10 6	+2 10	10 14	16 19	21 23	25 28	28 32	32 37	35 42	38 46	40 51	43 56	45 61	47 67	49 72	51 77	53 83	55 88	56 94	58 100		
59																			-19 3	-4 7	+6 12	13 16	18 20	23 24	27 29	30 33	33 38	36 43	39 47	41 52	44 57	46 62	48 67	50 72	52 78	54 83	56 89	57 94	59 100	
60																			[illegible]	[illegible]	+1 9	9 13	15 17	20 21	25 26	29 30	32 34	35 39	38 44	40 48	43 53	45 58	47 63	49 68	51 73	53 78	55 83	[illegible]	[illegible]	60 100

WET BULB TEMPERATURES

DRY BULB TEMPERATURES

	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
61	-21 3	-4 7	+5 11	12 15	18 19	23 23	27 27	30 31	34 36	36 40	39 44	42 49	44 54	46 58	48 63	50 68	52 73	54 78	56 84	58 89	59 94	61 100																														
62	-44 1	-12 4	+1 8	9 12	15 16	20 20	25 24	29 28	32 32	35 37	38 41	41 45	43 50	45 54	48 59	50 64	52 69	54 74	55 79	57 84	59 89	60 95	62 100																													
63		-23 2	-5 6	+5 10	12 14	19 17	23 21	27 25	31 29	34 33	37 38	39 42	42 46	44 51	47 55	49 60	51 64	53 69	55 74	56 79	58 84	60 89	61 95	63 100																												
64		-50 1	-13 4	0 8	+9 11	13 15	21 19	25 23	29 26	32 30	35 34	38 39	41 43	43 47	46 51	48 56	50 60	52 65	54 70	56 74	57 79	59 84	61 89	62 95	64 100																										
65			-25 2	-5 6	+5 9	12 13	18 16	23 20	27 24	31 28	34 31	37 35	40 39	42 44	45 48	47 52	49 56	51 61	53 65	55 70	57 75	59 80	60 85	62 90	63 95	65 100																									
66			-57	-11 4	0 7	+9 10	15 14	21 18	25 21	29 25	33 29	36 32	39 36	41 40	44 44	46 49	48 53	50 57	52 62	54 66	56 71	58 75	60 80	61 85	63 90	64 95	66 100																								
67				-26 2	-6 5	+5 8	12 12	18 15	23 19	27 22	31 26	34 30	37 34	40 37	43 41	45 45	47 49	50 54	52 58	54 62	55 66	57 71	59 76	61 80	62 85	64 90	65 95	67 100																							
68					-14 3	0 7	+9 10	16 13	21 17	25 20	29 24	33 27	36 31	39 34	42 38	44 42	47 46	49 50	51 54	53 58	55 63	57 67	58 71	60 76	62 81	63 85	65 90	67 95	68 100																						
69					-26 2	-6 5	+5 8	13 11	19 14	23 18	28 21	31 25	35 28	38 32	41 35	43 39	46 43	48 47	50 51	52 55	54 59	56 63	58 67	60 72	61 76	63 81	64 85	66 90	68 95	69 100																					
70						-14 3	0 6	+9 9	16 12	21 16	26 19	30 22	33 26	36 29	39 33	42 36	45 40	47 44	49 48	51 51	53 55	55 60	57 64	59 68	61 72	62 77	64 81	66 86	67 90	69 95	70 100																				
71						-26 2	-5 5	+5 8	13 11	19 14	24 17	28 20	32 23	35 27	38 30	41 34	44 37	46 41	48 45	51 48	53 52	55 56	56 60	58 64	60 68	62 73	63 77	65 81	67 86	68 90	70 95	71 100																			
72							-13 3	+1 6	10 9	16 12	22 15	26 18	30 21	34 24	37 29	40 31	43 35	45 38	47 42	50 45	52 49	54 53	56 57	58 61	59 65	61 69	63 73	64 77	66 82	68 86	69 91	71 95	72 100																		
73							-26 2	-5 4	+6 7	13 10	19 13	24 16	29 19	32 22	36 25	39 29	41 32	44 35	47 39	49 42	51 46	53 50	55 53	57 57	59 61	61 65	62 69	64 73	66 77	67 82	69 86	70 91	72 95	73 100																	
74								-13 3	+1 6	10 8	17 11	22 14	27 17	31 20	34 23	37 26	40 30	43 33	46 36	48 40	50 43	52 47	54 50	56 54	58 58	60 62	62 66	63 70	65 74	67 78	68 82	70 86	71 91	73 95	74 100																
75								-25 2	-4 4	+6 7	14 10	20 12	25 15	29 18	33 21	36 24	39 27	42 31	45 34	47 37	49 40	52 44	54 47	56 51	58 55	59 58	61 62	63 66	65 70	66 74	68 78	69 82	71 87	72 91	74 95	75 100															
76								-57	-12 3	+2 5	11 8	17 11	23 14	27 16	31 19	35 22	38 25	41 28	44 31	46 35	49 38	51 41	53 45	55 48	57 52	59 55	61 59	62 63	64 66	66 70	67 74	69 78	70 82	72 87	73 91	75 95	76 100														
77									-23 2	-3 4	+7 7	15 9	21 12	25 15	30 18	33 20	37 23	40 26	43 29	45 32	48 35	50 39	52 42	54 45	55 49	58 52	60 56	62 59	63 63	65 67	67 71	68 75	70 79	71 83	73 87	74 91	76 96	77 100													
78									-49	-11 3	+3 5	12 8	18 10	23 13	28 16	32 19	35 21	39 24	41 27	44 30	47 33	49 36	51 39	53 43	56 46	57 49	59 53	61 56	63 60	65 63	66 67	68 71	69 75	71 79	72 83	74 87	75 91	77 96	78 100												
79										-21 2	-2 4	+8 6	15 9	21 12	26 14	30 17	34 20	37 22	40 25	43 28	46 31	48 34	51 37	53 40	55 43	57 47	59 50	61 53	62 57	64 60	66 64	67 68	69 71	70 75	72 79	73 83	75 87	76 91	78 96	79 100											
80										-43	-9 3	+4 5	12 8	19 10	24 13	29 15	33 18	36 21	39 23	42 26	45 29	47 32	50 35	52 38	54 41	56 44	58 47	60 50	62 54	64 57	65 61	67 64	68 68	70 72	72 75	73 79	74 83	76 87	77 91	79 96	80 100										
81											-19 2	-1 4	+9 6	16 9	22 11	27 14	31 16	35 19	38 21	41 24	44 27	46 30	49 33	51 35	53 38	55 42	57 45	59 48	61 51	63 54	65 58	66 61	68 65	70 68	71 72	73 76	74 80	76 83	77 87	78 92	80 96	81 100									
82											-37 1	-7 3	+5 5	13 7	20 10	25 12	29 15	33 17	37 20	40 22	43 25	45 28	48 31	50 33	53 36	55 39	57 42	59 45	61 48	62 52	64 55	66 58	68 62	69 65	71 69	72 72	74 76	75 80	77 84	78 88	79 92	81 96	82 100								
83												-16 2	0 4	+10 6	17 9	23 11	28 13	32 16	35 18	39 21	42 23	44 26	47 29	50 31	52 34	54 37	56 40	58 43	60 46	62 49	64 52	65 55	67 59	69 62	70 65	72 69	73 73	75 76	76 80	78 84	79 83	80 92	82 96	83 100							
84												-31 1	-6 3	+6 5	14 7	21 10	26 12	30 14	34 17	37 19	41 22	43 24	46 27	49 29	51 32	53 35	55 38	57 41	59 43	61 46	63 50	65 53	67 56	68 59	70 62	71 66	73 69	74 73	76 76	77 80	79 84	80 88	81 92	83 96	84 100						
85													-14 2	+2 4	11 6	18 8	24 11	28 13	33 15	36 18	39 20	42 22	45 25	48 28	50 30	53 33	55 36	57 38	59 41	61 44	63 47	64 50	66 53	68 56	69 60	71 63	72 66	74 70	75 73	77 77	78 80	80 84	81 88	82 92	84 96	85 100					
86													-26 1	-4 3	+8 5	15 7	22 9	27 12	31 14	35 16	38 18	41 21	44 23	47 26	49 28	52 31	54 34	56 36	58 39	60 42	62 45	64 48	66 51	67 54	69 57	70 60	72 63	74 67	75 70	77 73	78 77	79 81	81 84	82 88	83 92	85 96	86 100				
87														-11 2	+3 4	12 6	19 8	25 10	29 13	33 15	37 17	40 19	43 22	46 24	49 27	51 29	53 32	55 34	58 37	59 40	61 42	63 45	65 48	67 51	68 54	70 57	72 60	73 64	75 67	76 70	78 74	79 77	80 81	82 84	83 88	84 92	86 95	87 100			
88														-22 1	-2 3	+9 5	17 7	23 9	28 11	32 13	36 16	39 18	42 20	45 22	48 25	50 27	53 30	55 32	57 35	59 38	61 40	63 43	64 46	66 49	68 52	70 55	71 58	73 61	74 64	76 67	77 71	79 74	80 77	81 81	83 85	84 88	85 92	87 96	88 100		
89														-45	-8 2	+5 4	14 6	20 8	26 10	30 12	34 14	38 17	41 19	44 21	47 23	49 26	52 28	54 30	56 33	58 36	60 38	62 41	64 44	66 46	67 49	69 52	71 55	72 58	74 61	75 64	77 68	78 71	80 74	81 78	82 81	84 85	85 88	86 92	88 96	89 100	
90															-17 1	0 3	+11 5	18 7	24 9	29 11	33 13	37 15	40 17	43 20	46 22	48 24	51 26	53 29	55 31	58 34	60 36	62 39	63 41	65 44	67 47	69 50	70 53	72 55	73 58	75 62	76 65	78 68	79 71	81 74	82 78	84 81	85 85	86 89	87 92	89 96	90 100

WET BULB TEMPERATURES

	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
91	-34 1	-5 2	+7 4	15 6	22 8	27 10	31 12	35 14	39 16	42 18	45 20	48 23	50 25	53 27	55 29	57 32	59 34	61 37	63 39	65 42	66 45	68 47	70 50	71 53	73 56	75 59	76 62	78 65	79 68	80 71	82 75	83 78	85 82	86 85	87 89	88 92	90 96	91 100				
92		-13 2	+3 3	12 5	19 7	25 9	30 11	34 13	37 15	41 17	44 19	47 21	49 23	52 26	54 28	56 30	58 33	60 35	62 37	64 40	66 43	68 45	69 48	71 51	73 53	74 56	76 59	77 62	79 65	80 68	82 72	83 75	84 78	86 82	87 85	88 89	89 92	91 96	92 100			
93		-26 1	-3 3	+9 4	17 6	23 8	28 10	32 12	36 14	40 16	43 18	46 20	48 22	51 24	53 26	56 28	58 31	60 33	62 36	64 38	65 41	67 43	69 46	71 48	72 51	74 54	75 57	77 60	78 63	80 66	81 69	83 72	84 75	85 78	87 82	88 85	89 89	91 93	92 96	93 100		
94			-10 2	+5 3	14 5	21 7	26 9	31 11	35 13	38 14	42 16	45 18	48 21	50 23	53 25	55 27	57 29	59 31	61 34	63 36	65 39	67 41	68 44	70 46	72 49	73 52	75 54	76 57	78 60	79 63	81 66	82 69	84 72	85 75	86 79	88 82	89 85	90 89	92 93	93 96	94 100	
95			-20 1	0 3	+11 4	18 6	24 8	29 10	33 11	37 13	41 15	44 17	47 19	49 21	52 23	54 25	56 28	59 30	61 32	63 34	64 37	66 39	68 42	70 44	71 47	73 49	75 52	76 55	78 57	79 60	81 63	82 66	83 69	85 72	86 76	87 79	89 82	90 86	91 89	93 93	94 96	95 100
96			-39	-6 2	+7 4	15 5	22 7	27 9	32 10	36 12	39 14	43 16	46 18	48 20	51 22	53 24	56 26	58 28	60 30	62 33	64 35	66 37	68 40	69 42	71 45	73 47	74 50	76 52	77 55	79 58	80 61	82 64	83 67	84 70	86 73	87 76	88 79	90 82	91 86	92 89	94 93	95 96
97				-14 1	+2 3	12 4	20 6	25 8	30 10	35 11	38 13	42 15	45 17	48 19	50 21	53 23	55 25	57 27	59 29	61 31	63 33	65 36	67 38	69 40	71 43	72 45	74 48	75 50	77 53	78 55	80 58	81 61	83 64	84 67	85 70	87 73	88 76	89 79	91 83	92 86	93 89	95 93
98				-28 1	-3 2	+9 4	17 5	23 7	29 9	33 10	37 12	40 14	44 16	47 18	49 19	52 21	54 23	57 25	59 27	61 30	63 32	65 34	67 36	68 38	70 41	72 43	73 46	75 48	77 51	78 53	80 56	81 59	82 61	84 64	85 67	87 70	88 73	89 76	91 79	92 83	93 86	94 89
99					-10 1	+5 3	14 5	21 6	27 8	32 9	36 11	39 13	43 15	46 16	48 18	51 20	54 22	56 24	58 26	60 28	62 30	64 32	66 34	68 37	70 39	71 41	73 44	75 46	76 48	78 51	79 54	81 56	82 59	84 62	85 65	86 67	88 70	89 73	90 76	92 80	93 83	94 86
100					-20 1	0 2	+11 4	19 5	25 7	30 9	34 10	48 12	42 14	45 15	48 17	50 19	53 21	55 23	57 25	60 27	62 29	64 31	66 33	67 35	69 37	71 39	73 42	74 44	76 46	77 49	79 51	80 54	82 57	83 59	85 62	86 65	87 68	89 71	90 74	91 77	93 80	94 83
101					-40	-6 2	+8 3	16 5	23 6	28 8	33 9	37 11	40 13	44 14	47 16	49 18	52 20	54 21	57 23	59 25	61 27	63 29	65 31	67 33	69 36	70 38	72 40	74 42	75 45	77 47	79 49	80 52	81 54	83 57	84 60	86 62	87 65	88 68	90 71	91 74	92 77	94 80
102						-14 1	+3 3	13 4	21 5	26 7	31 9	36 10	39 12	43 13	46 15	49 17	51 18	54 20	56 22	58 24	61 26	63 28	65 30	66 32	68 34	70 36	72 38	73 40	75 43	77 45	78 47	80 50	81 52	83 55	84 57	86 60	87 63	88 65	90 68	91 71	92 74	93 77
103						-26 1	-2 2	+10 3	18 5	24 6	30 8	34 9	38 11	42 12	45 14	48 16	50 17	53 19	55 21	58 23	60 25	62 26	64 28	66 30	68 32	70 34	71 37	73 39	75 41	76 43	78 45	79 48	81 50	82 53	84 55	85 58	87 60	88 63	89 66	91 68	92 71	93 74
104							-8 1	+6 3	15 4	22 6	28 7	33 9	37 10	40 12	44 13	47 15	50 16	52 18	55 20	57 22	59 23	61 25	63 27	65 29	67 31	69 33	71 35	73 37	74 39	76 41	77 44	79 46	80 48	82 51	83 53	85 55	86 58	88 61	89 63	90 66	92 69	93 72
105							-18 1	+2 2	12 4	20 5	26 6	31 8	35 9	39 11	43 12	46 14	49 15	51 17	55 19	56 20	59 22	61 24	63 26	65 28	67 30	69 31	70 33	72 35	74 38	75 40	77 42	79 44	80 46	82 49	83 51	85 53	86 56	87 58	89 61	90 63	91 66	93 69
106							-34	-4 2	+9 3	18 4	24 6	29 7	34 8	38 10	42 11	45 13	48 14	51 16	53 18	56 19	58 21	60 23	62 25	64 26	66 28	68 30	70 32	72 34	73 36	75 38	77 40	78 42	80 44	81 47	83 49	84 51	86 54	87 56	88 59	90 61	91 64	92 66
107								-11 1	+5 2	15 4	22 5	28 6	33 8	37 9	41 11	44 12	47 14	50 15	53 17	55 18	57 20	60 22	62 23	64 25	66 27	68 29	70 31	71 32	73 34	75 36	76 38	78 41	79 43	81 45	83 47	84 49	85 52	87 54	88 56	90 59	91 61	92 64
108								-22 1	0 2	+12 3	20 4	26 6	31 7	35 8	39 10	43 11	46 13	49 14	52 16	54 17	57 19	59 21	61 22	63 24	65 26	67 27	69 29	71 31	73 33	74 35	76 37	78 39	79 41	81 43	82 45	84 47	85 50	87 52	88 54	89 57	91 59	92 62
109								-46	-6 1	+8 3	17 4	24 5	29 6	34 8	38 9	42 11	45 12	48 13	51 15	54 16	56 18	58 20	61 21	63 23	65 24	67 26	69 28	70 30	72 32	74 33	76 35	77 37	79 39	80 41	82 43	83 46	85 48	86 50	88 52	89 55	90 57	92 60
110									-14 1	+4 2	14 3	22 5	28 6	33 7	37 8	41 10	44 11	47 13	50 14	53 15	55 17	58 19	60 20	62 22	64 23	66 25	68 27	70 28	72 30	74 32	75 34	77 36	78 38	80 40	82 42	83 44	85 46	86 48	87 50	89 53	90 55	91 57
111									-26	-1 2	+11 3	19 4	26 5	31 6	36 8	39 9	43 10	46 12	49 13	52 15	55 16	57 18	59 19	62 21	64 22	66 24	68 26	70 27	71 29	73 31	75 33	76 34	78 36	80 38	81 40	83 42	84 44	86 46	87 49	89 51	90 53	91 55
112										-7 1	+8 2	17 3	24 5	29 6	34 7	38 8	42 10	45 11	48 12	51 14	54 15	56 17	59 18	61 20	63 21	65 23	67 24	69 26	71 28	73 29	74 31	76 33	78 35	79 37	81 39	82 41	84 43	85 45	87 47	88 49	90 51	91 53
113										-16 1	+3 2	14 3	22 4	28 5	33 7	37 8	41 9	44 10	48 12	50 13	53 14	56 16	58 17	60 19	63 20	65 22	67 23	69 25	70 27	72 28	74 30	76 32	77 33	79 35	81 37	82 39	84 41	85 43	87 45	88 47	89 49	91 51
114										-31	-2 1	+11 3	19 4	26 5	31 6	36 7	40 8	43 10	47 11	50 12	52 14	55 15	57 16	60 18	62 19	64 21	66 22	68 24	70 25	72 27	74 29	75 30	77 32	79 34	80 36	82 38	83 39	85 41	86 43	88 45	89 47	91 50
115											-9 1	+7 2	17 3	24 4	29 5	34 7	39 8	42 9	46 10	49 12	52 13	54 14	57 16	59 17	61 18	64 20	66 21	68 23	70 24	71 26	73 28	75 29	77 31	78 33	80 34	81 36	83 38	85 40	86 42	87 44	89 46	90 48
116											-18 1	+3 2	14 3	22 4	28 5	33 6	37 7	41 8	45 10	48 11	51 12	54 13	56 15	59 16	61 17	63 19	65 20	67 22	69 23	71 25	73 26	75 28	76 30	78 31	80 33	81 35	83 37	84 38	86 40	87 42	89 44	90 46
117											-35	-3 1	+11 2	19 3	26 4	31 6	36 7	40 8	44 9	47 10	50 11	53 13	55 14	58 15	60 17	63 18	65 19	67 21	69 22	71 24	72 25	74 27	76 28	78 30	79 32	81 33	82 35	84 37	85 39	87 41	88 43	90 44
118												-9 1	+7 2	17 3	24 4	30 5	35 6	39 7	43 8	46 10	49 11	52 12	55 13	57 15	60 16	62 17	64 19	66 20	68 21	70 23	72 24	74 26	76 27	77 29	79 31	80 32	82 34	84 36	85 37	87 39	88 41	89 43
119												-19 1	+2 1	14 2	22 4	28 5	33 6	38 7	42 8	45 9	48 10	51 11	54 13	57 14	59 15	61 16	64 18	66 19	68 20	70 22	72 23	73 25	75 26	77 28	79 29	80 31	82 33	83 34	85 36	86 38	88 40	89 41

DRY BULB TEMPERATURES

TA No. 454-0-1D
10-63

U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU

RELATIVE HUMIDITY
and
DEW POINT TABLE

Pressure 29 Inches of Mercury

For use at elevations between 501 and 1900 feet above sea level
(In Alaska use at elevations between 301 and 1700 feet above sea level)

Values in the body of the table are relative humidities (in percent) and dew points (in deg. Fahr.), with respect to water, for indicated values of wet and dry bulb temperatures in degrees Fahrenheit.

HOW TO USE THE TABLE

Locate at the top of the column the reading corresponding to the wet bulb temperature. Locate at the left side of the table the reading corresponding to the dry bulb temperature. Follow down the column under the wet bulb temperature, and across from the dry bulb temperature; at the intersection of these two columns will be found the relative humidity (%) in black and the dew point (°F.) in red.

USCOMM-WB-DC

WET BULB TEMPERATURES

DRY BULB TEMPERATURES

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
30	-25 8	-10 17	0 27	+7 37	12 46	16 57	20 67	24 77	27 88	30 99					
31	-57 1	-19 10	-6 20	+2 29	9 38	14 48	18 58	22 68	25 78	28 89	31 99				
32		-36 4	-13 13	-3 22	+5 31	11 40	15 50	20 60	23 69	26 79	29 90	32 100			
33			-25 7	-9 15	0 24	+7 33	13 42	17 52	21 61	25 71	28 80	30 90	33 100		
34			-56 1	-18 9	-5 18	+3 26	9 35	14 44	19 53	23 62	26 72	29 81	32 91	34 100	
35				-34 4	-13 12	-2 20	+6 29	11 37	16 46	20 55	24 64	27 73	30 82	33 91	35 100
36					-24 6	-8 14	+1 22	8 31	14 39	18 48	22 56	25 65	28 74	31 82	34 91
37					-50 1	-17 9	-4 17	+4 25	10 33	15 41	20 49	24 58	27 66	30 74	32 83
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39							-21 7	-6 14	+3 21	9 29	15 37	19 44	23 52	26 60	29 67
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41								-26 5	-9 11	+1 18	8 26	14 33	18 40	22 47	26 54
42									-18 7	-4 14	+5 21	11 28	16 34	20 41	24 48
43									-33 3	-11 9	0 16	+8 23	13 29	18 36	22 42
44										-21 5	-6 12	+3 18	10 24	15 31	20 37
45										-42 2	-13 8	-1 14	+6 20	12 26	17 32
46											-25 4	-7 10	+2 16	9 22	14 28
47											-56 1	-16 6	-3 12	+5 18	11 23
48												-29 3	-10 8	+1 14	8 19
49													-19 5	-5 10	+4 16
50													-37 2	-12 7	-1 12
51														-23 4	-6 9
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36	36 100														
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43	25 49	28 56	31 63	34 70	36 78	39 85	41 92	43 100							
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45	21 39	25 45	28 51	31 58	34 65	36 72	39 78	41 86	43 93	45 100					
46	19 34	23 40	26 46	30 52	32 59	35 65	38 72	40 79	42 86	44 93	46 100				
47	17 29	21 35	25 41	28 47	31 53	34 60	36 66	39 73	41 79	43 86	45 93	47 100			
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52	-2 11	+6 15	13 20	18 25	22 31	26 36	29 41	32 47	35 52	38 58	40 63	42 69	44 75	46 81	48 87
53	-8 7	+2 12	9 17	15 22	20 27	24 32	27 37	31 42	34 48	36 53	39 58	41 64	43 70	46 76	48 82
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59			-43 1	-12 5	0 9	+8 13	14 17	19 21	24 25	28 30	31 34	34 39	37 43	39 48	42 53
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53	49 88	51 94	53 100							
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59	44 58	46 63	48 68	50 73	52 79	54 83	56 89	57 94	59 100	
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WET BULB TEMPERATURES

DRY BULB TEMPERATURES

	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65
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63		-58	-14 4	-1 7	+8 11	14 15	20 19	24 22	28 26	31 30	34 34	37 38	40 43	42 47	45 51	47 56	49 60	51 65	53 70	55 74	57 79	58 84	60 89	61 95	63 100		
64			-27 2	-7 5	+4 9	11 12	17 16	22 20	26 24	30 27	33 31	36 35	39 39	41 43	44 48	46 52	48 56	50 61	52 65	54 70	56 75	58 80	59 85	61 90	62 95	64 100	
65				-15 3	-1 7	+8 10	14 14	20 17	24 21	28 25	32 29	35 32	38 36	40 40	43 44	45 48	47 53	49 57	51 61	53 66	55 70	57 75	59 80	60 85	62 90	63 95	65 100

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66	-28 2	-7 5	+4 8	11 12	17 15	22 19	26 22	30 26	33 30	36 33	39 37	42 41	44 45	46 49	49 53	51 58	53 62	54 66	56 71	58 76	60 80	61 85	63 90	64 95	66 100				
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68		-29 2	-7 5	+4 8	12 11	18 14	22 18	27 21	30 24	34 28	37 32	40 35	42 39	45 43	47 47	49 51	51 55	53 59	55 63	57 67	59 72	60 76	62 81	63 85	65 90	67 95	68 100		
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78		-23 1	-4 4	+7 6	14 9	20 11	25 14	29 17	33 19	36 22	39 25	42 28	45 31	47 34	50 37	52 40	54 43	56 46	58 50	60 53	61 57	63 60	65 64	66 67	68 71	69 75	71 79	72 83	74 87	75 91	77 96	78 100		
79		-48	-11 3	+3 5	11 8	18 10	23 13	28 15	32 18	35 20	38 23	41 26	44 29	46 32	49 35	51 38	53 41	55 44	57 47	59 50	61 54	63 57	64 61	66 64	67 68	69 72	71 75	72 79	73 83	75 87	76 91	78 96	79 100	
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WET BULB TEMPERATURES

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93		-11 2	+4 3	13 5	20 7	25 9	30 11	34 12	38 14	41 16	44 18	47 20	49 23	52 25	54 27	56 29	58 31	60 34	62 36	64 38	66 41	68 43	69 46	71 49	72 51	74 54	76 57	77 60	78 63	80 66	81 69	83 72	84 75	85 79	87 82	88 85	89 89	91 93	92 96	93 100		
94		-21 1	-1 3	+10 4	17 6	23 8	28 10	32 11	36 13	40 15	43 17	46 19	48 21	51 23	53 25	55 28	58 30	60 32	62 34	63 37	65 39	67 41	69 44	70 47	72 49	74 52	75 55	77 57	78 60	80 63	81 66	82 69	84 72	85 76	86 79	88 82	89 86	90 89	92 93	93 96	94 100	
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97			-30 1	-4 2	+8 4	16 5	23 7	28 9	32 10	36 12	40 14	43 16	46 17	48 19	51 21	53 23	56 25	58 27	60 29	62 32	64 34	66 36	67 38	69 41	71 43	72 45	74 48	76 51	77 53	79 56	80 59	81 61	83 64	84 67	86 70	87 73	88 76	90 79	91 83	92 86	93 89	95 93
98				-11 1	+4 3	13 5	20 6	26 8	31 9	35 11	38 13	42 15	45 16	48 18	50 20	53 22	55 24	57 26	59 28	61 30	63 32	65 34	67 37	69 39	70 41	72 44	74 46	75 48	77 51	78 54	80 56	81 59	83 62	84 64	85 67	87 70	88 73	89 76	91 80	92 83	93 86	94 89
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100				-43	-7 2	+7 3	15 5	22 6	27 8	32 9	36 11	40 13	43 14	46 16	49 18	51 20	54 21	56 23	58 25	60 27	62 29	64 31	66 33	68 35	70 38	71 40	73 42	74 44	76 47	78 49	79 52	81 54	82 57	83 60	85 62	86 65	87 68	89 71	90 74	91 77	93 80	94 83
101					-15 1	+2 3	12 4	20 5	26 7	30 8	35 10	38 12	42 13	45 15	48 17	50 18	53 20	55 22	57 24	60 26	62 28	64 30	65 32	67 34	69 36	71 38	72 40	74 43	76 45	77 47	79 50	80 52	82 55	83 57	84 60	86 63	87 65	89 68	90 71	91 74	92 77	94 80
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103						-10 1	+5 3	15 4	21 6	27 7	32 8	36 10	40 12	43 13	46 15	49 16	51 18	54 20	56 21	58 23	60 25	63 27	64 29	66 31	68 33	70 35	72 37	73 39	75 41	76 43	78 46	80 48	81 50	82 53	84 55	85 58	87 60	88 63	89 66	91 69	92 71	93 74
104						-19 1	+1 2	12 3	19 5	25 6	30 8	35 9	38 11	42 12	45 14	48 15	51 17	53 19	55 20	58 22	60 24	62 26	64 28	66 29	68 31	69 33	71 35	73 37	75 40	76 42	78 44	79 46	81 48	82 51	84 53	85 56	86 58	88 61	89 63	90 66	92 69	93 72
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106							-12 1	+4 2	14 4	21 5	27 6	32 8	36 9	40 11	43 12	46 14	49 15	52 17	54 18	56 20	59 22	61 23	63 25	65 27	67 29	69 30	70 32	72 34	74 36	75 38	77 40	79 43	80 45	82 47	83 49	84 52	86 54	87 56	89 59	90 61	91 64	93 67
107							-23 1	-1 2	+11 3	19 4	25 6	30 7	35 8	38 10	42 11	45 13	48 14	51 16	53 17	56 19	58 20	60 22	62 24	64 26	66 27	68 29	70 31	72 33	73 35	75 37	77 39	78 41	80 43	81 45	83 47	84 50	86 52	87 54	88 57	90 59	91 62	92 64
108							-49	-7 1	+7 3	16 4	23 5	29 6	33 8	37 9	41 10	44 12	47 13	50 15	53 16	55 18	57 19	60 21	62 23	64 24	66 26	68 28	70 30	71 31	73 33	75 35	76 37	78 39	79 41	81 43	82 46	84 48	85 50	87 52	88 55	89 57	91 59	92 62
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111									-8 1	+7 2	16 3	23 5	29 6	33 7	37 8	41 10	44 11	48 12	50 14	53 15	56 17	58 18	60 20	62 21	64 23	66 24	68 26	70 28	72 29	73 31	75 33	77 35	78 37	80 39	81 41	83 43	84 45	86 47	87 49	89 51	90 53	91 56
112									-17 1	+2 2	13 3	21 4	27 5	32 7	36 8	40 9	43 10	47 12	50 13	52 14	55 16	57 17	60 19	62 20	64 22	66 23	68 25	70 26	71 28	73 30	75 32	76 33	78 35	80 37	81 39	83 41	84 43	86 45	87 47	88 49	90 51	91 54
113									-32	-3 1	+10 2	18 4	25 5	30 6	35 7	39 8	42 10	46 11	49 12	52 14	54 15	57 16	59 18	61 19	63 21	65 22	67 24	69 25	71 27	73 29	74 30	76 32	78 34	79 36	81 37	82 39	84 41	85 43	87 45	88 47	90 50	91 52
114										-10 1	+6 2	16 3	23 4	29 5	33 7	38 8	41 9	45 10	48 11	51 13	53 14	56 15	58 17	61 18	63 20	65 21	67 23	69 24	71 26	72 27	74 29	76 31	77 32	79 34	81 36	82 38	84 40	85 42	86 44	88 46	89 48	91 50
115										-19 1	+2 2	13 3	21 4	27 5	32 6	36 7	40 8	44 10	47 11	50 12	53 13	55 15	58 16	60 17	62 19	64 20	66 22	68 23	70 25	72 26	74 28	75 30	77 31	79 33	80 35	82 36	83 38	85 40	86 42	88 44	89 46	90 48
116										-37	-3 1	+10 2	18 3	25 4	30 6	35 7	39 8	43 9	46 10	49 11	52 13	55 14	57 15	59 17	62 18	64 19	66 21	68 22	70 24	71 25	73 27	75 28	77 30	78 32	80 33	81 35	83 37	84 39	86 41	87 42	89 44	90 46
117											-10 1	+6 2	16 3	23 4	29 5	34 6	38 7	42 8	45 10	48 11	51 12	54 13	56 14	59 16	61 17	63 18	65 20	67 21	69 23	71 24	73 26	75 27	76 29	78 30	80 32	81 34	83 36	84 37	86 39	87 41	89 43	90 45
118											-20 1	+2 1	13 2	21 3	27 5	32 6	37 .7	41 8	44 9	47 10	50 11	53 12	56 14	58 15	60 16	63 18	65 19	67 20	69 22	71 23	72 25	74 26	76 28	78 29	79 31	81 33	82 34	84 36	85 38	87 39	88 41	90 43
119											-40	-4 1	+10 2	19 3	25 4	31 5	35 6	40 7	43 8	47 9	50 11	52 12	55 13	58 14	60 15	62 17	64 18	66 19	68 21	70 22	72 24	74 25	76 27	77 28	79 30	80 31	82 33	84 35	85 36	87 38	88 40	89 42

DRY BULB TEMPERATURES

TA No. 454-0-1C

U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU

RELATIVE HUMIDITY and DEW POINT TABLE

Pressure 27 Inches of Mercury

For use at elevations between 1,900 and 3,900 feet above sea level
(In Alaska use at elevations between 1,700 and 3,600 feet above sea level)

Values in the body of the table are relative humidities (in percent) and dew points (in deg. Fahr.), with respect to water, for indicated values of wet and dry bulb temperatures in degrees Fahrenheit.

HOW TO USE THE TABLE

Locate at the top of the column the reading corresponding to the wet bulb temperature. Locate at the left side of the table the reading corresponding to the dry bulb temperature. Follow down the column under the wet bulb temperature, and across from the dry bulb temperature; at the intersection of these two columns will be found the relative humidity (%) in black and the dew point (°F.) in red.

WET BULB TEMPERATURES

DRY BULB TEMPERATURES

	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
30	-45 3	-17 12	-6 21	+2 30	8 39	13 49	17 58	21 68	24 78	27 89	30 99																														
31		-31 5	-13 14	-3 23	+5 32	10 41	15 50	19 60	22 69	25 79	28 89	31 99																													
32			-23 8	-8 17	0 25	+7 34	12 43	16 52	20 61	24 71	27 80	29 90	32 100																												
33			-43 2	-16 11	-5 19	+3 27	9 36	14 45	18 54	22 63	25 72	28 81	31 91	33 100																											
34				-29 5	-12 13	-2 21	+5 29	11 38	16 46	20 55	23 64	26 73	29 82	32 91	34 100																										
35					-21 8	-7 16	+1 23	8 31	13 40	17 48	21 57	25 65	28 74	30 83	33 91	35 100																									
36					-39 3	-15 10	-4 18	+4 26	10 33	15 42	19 50	23 58	26 66	29 75	31 83	34 91	36 100																								
37						-27 5	-10 13	0 20	+7 28	12 35	17 43	21 51	24 59	27 67	30 75	32 83	35 92	37 100																							
38						-57 1	-18 8	-6 15	+3 22	9 30	14 37	19 45	22 53	26 60	28 68	31 76	34 84	36 92	38 100																						
39							-33 3	-12 10	-2 17	+6 24	11 32	16 39	20 47	24 54	27 61	30 69	32 76	35 84	37 92	39 100																					
40								-23 6	-7 13	+2 19	8 26	14 34	18 41	22 48	25 55	28 62	31 69	33 77	36 84	38 92	40 100																				
41								-43 2	-15 8	-3 15	+5 22	11 28	16 35	20 42	23 49	26 56	29 63	32 70	34 77	37 85	39 92	41 100																			
42									-27 4	-9 11	0 17	+8 24	13 30	18 37	21 43	25 50	28 57	31 64	33 71	36 78	38 85	40 92	42 100																		
43									1	-18 7	-5 13	+4 19	10 26	15 32	19 38	23 45	26 51	29 58	32 64	34 71	37 78	39 85	41 93	43 100																	
44										-32 3	-11 9	-1 15	+7 21	12 27	17 33	21 39	24 46	28 52	30 59	33 65	36 72	38 79	40 86	42 93	44 100																
45											-21 5	-6 11	+3 17	9 23	14 29	19 35	23 41	26 47	29 53	32 59	34 66	37 72	39 79	41 86	43 93	45 100															
46											-38 2	-13 8	-2 13	+6 19	12 25	16 30	21 36	24 42	27 48	30 54	33 60	36 67	38 73	40 80	42 86	44 93	46 100														
47												-24 4	-7 10	+2 15	9 21	14 26	18 32	22 37	26 43	29 49	32 55	34 61	37 67	39 74	41 80	43 87	45 93	47 100													
48												-46 1	-15 6	-3 12	+5 17	11 22	16 28	20 33	24 39	27 44	30 50	33 56	36 62	38 68	40 74	42 80	44 87	46 93	48 100												
49													-26 3	-9 8	+1 13	8 18	13 24	18 29	22 34	26 40	29 45	32 51	34 57	37 63	39 68	41 75	43 81	45 87	47 93	49 100											
50													-57 1	-17 5	-4 10	+4 15	11 20	16 25	20 30	24 36	27 41	30 46	33 52	36 57	38 63	40 69	42 75	44 81	46 87	48 94	50 100										
51														-31 2	-11 7	0 12	+7 17	13 22	18 27	22 32	26 37	29 42	32 47	34 53	37 58	39 64	41 70	44 75	46 81	47 88	49 94	51 100									
52															-20 4	-5 9	+4 14	10 18	15 23	20 28	24 33	27 38	30 43	33 48	36 54	38 59	40 65	43 70	45 76	47 82	48 88	50 94	52 100								
53															-36 2	-12 6	-1 11	+7 15	13 20	18 24	22 29	25 34	29 39	32 44	34 49	37 54	39 60	42 65	44 71	46 76	48 82	50 88	51 94	53 100							
54																-22 4	-6 8	+3 12	10 17	15 21	20 26	24 30	27 35	30 40	33 45	36 50	38 55	41 60	43 66	45 71	47 77	49 82	51 88	52 94	54 100						
55																-42 1	-14 5	-2 9	+6 14	12 18	17 23	22 27	25 32	29 36	32 41	35 46	37 51	40 56	42 61	44 66	46 72	48 77	50 83	52 88	53 94	55 100					
56																	-25 3	-7 7	+2 11	9 15	15 20	20 24	24 28	27 33	30 37	33 42	36 47	39 52	41 57	43 62	45 67	47 72	49 78	51 83	53 89	54 94	56 100				
57																	-50 1	-15 5	-2 9	+6 13	12 17	17 21	22 25	26 30	29 34	32 39	35 43	37 48	40 53	42 57	44 62	46 67	48 73	50 78	52 83	54 89	55 94	57 100			
58																		-27 2	-8 6	+2 10	9 14	15 18	20 22	24 26	27 31	31 35	34 40	36 44	39 49	41 53	43 58	46 63	48 68	49 73	51 78	53 84	55 89	56 94	58 100		
59																			-16 4	-3 8	+6 12	12 16	17 20	22 24	26 28	29 32	32 36	35 41	38 45	40 50	42 54	45 59	47 64	49 69	51 73	52 79	54 84	56 89	57 94	59 100	
60																			-29 [illegible]	[illegible]	+2 9	9 13	15 17	20 21	24 25	28 29	31 33	34 37	37 41	39 46	41 50	44 55	46 59	48 64	50 69	52 74	53 79	55 84	[illegible]	58 95	60 100

WET BULB TEMPERATURES

DRY BULB TEMPERATURES

	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65
61	-17 4	-3 7	+6 11	12 14	18 18	22 22	26 26	29 30	33 34	35 38	38 42	40 47	43 51	45 56	47 60	49 65	51 69	53 74	55 79	56 84	58 89	59 95	61 100				
62	-31 2	-9 5	+2 9	9 12	15 16	20 20	24 23	28 27	31 31	34 35	37 39	39 43	42 48	44 52	46 56	48 61	50 65	52 70	54 75	56 80	57 85	59 90	60 95	62 100			
63		-18 3	-3 7	+6 10	12 14	18 17	22 21	26 25	30 28	33 32	36 36	38 40	41 44	43 48	45 53	47 57	49 61	51 66	53 70	55 75	57 80	58 85	60 90	61 95	63 100		
64		-32 1	-9 5	+2 8	9 11	15 15	20 18	24 22	28 26	31 29	34 33	37 37	40 41	42 45	43 49	47 53	49 57	51 62	53 66	54 71	56 75	58 80	59 85	61 90	63 95	64 100	
65			-18 3	-3 6	+6 9	13 13	18 16	23 20	27 23	30 27	33 30	36 34	39 38	41 42	44 46	46 50	48 54	50 58	52 62	54 67	55 71	57 76	59 80	60 85	62 90	64 95	65 100

	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
66	-32 1	-9 4	+2 8	10 11	16 14	21 17	25 21	29 24	32 28	35 31	38 35	40 39	43 43	45 47	47 51	49 55	51 59	53 63	55 67	57 72	58 76	60 81	61 85	63 90	65 95	66 100				
67		-18 3	-3 6	+6 9	13 12	18 15	23 19	27 22	30 25	34 29	37 32	39 36	42 40	44 43	46 47	48 51	50 55	52 59	54 63	56 68	58 72	59 76	61 81	63 86	64 90	66 95	67 100			
68		-32 1	-9 4	+2 7	10 10	16 13	21 17	25 20	29 23	32 26	35 30	38 33	41 37	43 41	45 44	48 48	50 52	52 56	54 60	55 64	57 68	59 72	60 77	62 81	64 86	65 90	67 95	68 100		
69			-17 3	-3 6	+7 9	13 12	19 15	23 18	27 21	31 24	34 27	37 31	40 34	42 38	45 41	47 45	49 49	51 53	53 56	55 60	56 64	58 69	60 73	62 77	63 81	65 86	66 91	68 95	69 100	
70			-31 1	-9 4	+1 7	10 10	16 13	21 16	26 19	29 22	33 25	36 28	39 32	41 35	44 39	46 42	48 46	50 49	52 53	54 57	56 61	58 65	59 69	61 73	63 77	64 82	66 86	67 91	69 95	70 100

	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
71	-17 3	-2 5	+7 8	14 11	19 14	24 17	28 20	31 23	35 26	38 29	40 33	43 36	45 39	47 43	49 46	51 50	53 54	55 58	57 61	59 65	60 69	62 73	64 78	65 82	67 86	68 91	70 95	71 100				
72	-30 1	-8 4	+3 7	11 9	17 12	22 15	26 18	30 21	33 24	36 27	39 30	42 34	44 37	46 40	49 44	51 47	53 51	55 54	56 58	58 62	60 66	62 70	63 74	65 78	66 82	68 86	69 91	71 95	72 100			
73		-16 3	-1 5	+8 8	15 11	20 13	24 16	28 19	32 22	35 25	38 28	41 31	43 34	46 38	48 41	50 44	52 48	54 51	56 55	58 59	59 62	61 66	63 70	64 74	66 78	67 82	69 87	70 91	72 95	73 100		
74		-28 1	-7 4	+4 6	12 9	18 12	23 14	27 17	31 20	34 23	37 26	40 29	42 32	45 35	47 38	49 42	51 45	53 48	55 52	57 55	59 59	61 63	62 67	64 70	65 74	67 78	68 83	70 87	71 91	73 95	74 100	
75			-14 3	0 5	+9 8	15 10	21 13	25 16	29 18	33 21	36 24	39 27	41 30	44 33	46 36	48 39	51 42	53 46	55 49	56 52	58 56	60 60	62 63	63 67	65 71	66 75	68 79	69 83	71 87	72 91	74 96	75 100

	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
76	-26 1	-6 4	+5 6	13 9	18 11	23 14	27 17	31 19	35 22	38 25	40 28	43 31	45 34	48 37	50 40	52 43	54 46	56 50	58 53	59 57	61 60	63 64	64 67	66 71	68 75	69 79	70 83	72 87	73 91	75 96	76 100				
77	-54	-13 3	+1 5	9 7	16 10	21 12	26 15	30 18	33 20	36 23	39 26	42 29	45 32	47 34	49 37	51 41	53 44	55 47	57 50	59 54	61 57	62 61	64 64	66 68	67 71	69 75	70 79	71 83	73 87	74 91	76 96	77 100			
78		-23 1	-4 4	+6 6	13 9	19 11	24 13	28 16	32 19	35 21	38 24	41 27	44 29	46 32	48 35	51 38	53 41	55 44	56 48	58 51	60 54	62 57	63 61	65 64	67 68	68 72	70 76	71 79	73 83	74 87	75 91	77 96	78 100		
79		-45	-11 3	+2 5	10 7	17 10	22 12	27 14	30 17	34 20	37 22	40 25	43 27	45 30	48 33	50 36	52 39	54 42	56 45	58 48	60 51	61 55	63 58	65 61	66 65	68 68	69 72	71 76	72 80	74 84	75 88	76 92	78 96	79 100	
80			-20 2	-3 4	+7 6	14 8	20 11	25 13	29 15	33 18	36 20	39 23	42 26	44 28	47 31	49 34	51 37	53 40	55 43	57 46	59 49	61 52	62 55	64 58	66 62	67 65	69 69	70 72	72 76	73 80	75 84	76 88	77 92	79 96	80 100

	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
81	-37 1	-9 3	+3 5	12 7	18 9	23 12	27 14	31 16	35 19	38 21	41 24	43 26	46 29	48 32	50 35	53 37	55 40	57 43	58 46	60 49	62 52	64 56	65 59	67 62	68 66	70 69	71 73	73 76	74 80	76 84	77 88	78 92	80 96	81 100				
82		-17 2	-1 4	+8 6	15 8	21 10	26 13	30 15	33 17	37 20	40 22	42 25	45 27	47 30	50 33	52 35	54 38	56 41	58 44	60 47	61 50	63 53	65 56	66 59	68 63	70 66	71 69	72 73	74 77	75 80	77 84	78 88	79 92	81 96	82 100			
83		-31 1	-7 3	+5 5	13 7	19 9	24 11	28 14	32 16	35 18	39 21	41 23	44 26	47 28	49 31	51 33	53 36	55 39	57 42	59 44	61 47	63 50	64 53	66 57	68 60	69 63	71 66	72 70	74 73	75 77	76 80	78 84	79 88	80 92	82 96	83 100		
84			-14 2	+1 4	10 6	17 8	22 10	27 12	31 15	34 17	37 19	40 21	43 24	46 26	48 29	50 31	53 34	55 37	57 39	59 42	60 45	62 48	64 51	66 54	67 57	69 60	70 63	72 67	73 70	75 74	76 77	77 81	79 84	80 88	81 92	83 96	84 100	
85			-26 1	-5 3	+6 5	14 7	20 9	25 11	29 13	33 15	36 18	39 20	42 22	45 25	47 27	50 30	52 32	54 35	56 37	58 40	60 43	62 46	63 48	65 51	67 54	68 57	70 61	71 64	73 67	74 70	76 74	77 77	78 81	80 85	81 88	82 92	84 96	85 100

	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
86	-11 2	+2 4	11 6	18 8	23 10	28 12	32 14	35 16	38 19	41 21	44 23	47 25	49 28	51 30	53 33	55 35	57 38	59 41	61 43	63 46	65 49	66 52	68 55	69 58	71 61	72 64	74 67	75 71	77 74	78 78	80 81	81 85	82 88	83 92	85 96	86 100				
87	-21 1	-2 3	+8 5	15 7	21 9	26 11	30 13	34 15	37 17	40 19	43 22	46 24	48 26	50 29	53 31	55 33	57 36	59 39	61 41	62 44	64 47	66 49	67 52	69 55	71 58	72 61	74 64	75 68	76 71	78 74	79 78	81 81	82 85	83 88	84 92	86 96	87 100			
88	-39	-8 2	+4 4	13 6	19 8	24 10	29 12	33 14	36 16	39 18	42 20	45 22	47 25	50 27	52 29	54 32	56 34	58 37	60 39	62 42	64 44	65 47	67 50	69 53	70 56	72 59	73 62	75 65	76 68	78 71	79 75	80 78	82 81	83 85	84 89	85 92	87 96	88 100		
89		-17 1	0 3	+9 5	17 7	22 9	27 11	31 13	35 15	38 17	41 19	44 21	47 23	49 25	51 28	53 30	56 32	58 35	59 37	61 40	63 42	65 45	67 48	68 50	70 53	71 56	73 59	74 62	76 65	77 68	79 71	80 75	81 78	83 82	84 85	85 89	87 92	88 96	89 100	
90		-30 1	-6 2	+6 4	14 6	20 8	25 10	30 12	34 13	37 15	40 17	43 20	46 22	48 24	51 26	53 28	55 31	57 33	59 35	61 38	63 40	64 43	66 45	68 48	69 51	71 54	72 56	74 59	75 62	77 65	78 69	80 72	81 75	82 78	84 82	85 85	86 89	88 92	89 96	90 100

WET BULB TEMPERATURES

	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
91	-13 2	+2 3	11 5	18 7	23 9	28 11	32 12	36 14	39 16	42 18	45 20	47 22	50 25	52 27	54 29	56 31	55 34	60 36	62 38	64 41	66 43	67 46	69 49	71 51	72 54	74 57	75 60	77 63	78 66	79 69	81 72	82 75	83 79	85 82	86 85	87 89	89 93	90 96
92	-21 1	-3 3	+8 4	16 6	22 8	27 10	31 11	35 13	38 15	41 17	44 19	47 21	49 23	51 25	54 27	56 30	58 32	60 34	62 36	63 39	65 41	67 44	69 46	70 49	72 52	73 54	75 57	76 60	78 63	79 66	80 69	82 72	83 75	84 79	86 82	87 86	88 89	90 93
93	-45	-9 2	+4 3	13 5	19 7	25 9	29 10	33 12	37 14	40 16	43 18	46 20	48 22	51 24	53 26	55 28	57 30	59 32	61 35	63 37	65 39	66 42	68 44	70 47	71 50	73 52	74 55	76 58	77 60	79 63	80 66	81 69	83 73	84 76	85 79	87 82	88 86	89 89
94		-17 1	0 3	+10 4	17 6	23 8	28 9	32 11	36 13	39 15	42 17	45 19	47 20	50 22	52 24	54 27	57 29	59 31	61 33	62 35	64 38	66 40	68 42	69 45	71 47	72 50	74 53	76 55	77 58	78 61	80 64	81 67	83 70	84 73	85 76	87 79	88 82	89 86
95		-31 1	-5 2	+6 4	15 5	21 7	26 9	30 10	34 12	38 14	41 16	44 17	47 19	49 21	52 23	54 25	56 27	58 29	60 31	62 34	64 36	66 38	67 40	69 43	71 45	72 48	74 50	75 53	77 56	78 58	80 61	81 64	82 67	84 70	85 73	86 76	88 79	89 83
96			-12 1	+3 3	12 4	19 6	24 8	29 9	33 11	37 13	40 14	43 16	46 18	48 20	51 22	53 24	55 26	57 28	59 30	61 32	63 34	65 36	67 39	68 41	70 43	72 46	73 48	75 51	76 53	78 56	79 59	81 61	82 64	83 67	85 70	86 73	87 76	89 79
97			-23 1	-2 2	+9 4	16 5	22 7	27 8	32 10	36 12	39 13	42 15	45 17	48 19	50 21	52 23	55 24	57 26	59 28	61 30	63 33	65 35	66 37	68 39	70 41	71 44	73 46	74 49	76 51	77 54	79 56	80 59	82 62	83 65	84 67	86 70	87 73	88 76
98			-44	-8 2	+5 3	14 5	20 6	26 8	30 9	34 11	38 13	41 14	44 16	47 18	49 19	52 21	54 23	56 25	58 27	60 29	62 31	64 33	66 35	68 37	69 40	71 42	73 44	74 47	76 49	77 52	79 54	80 57	81 59	83 62	84 65	85 68	87 71	88 74
99				-16 1	+1 2	11 4	18 5	24 7	29 8	33 10	37 12	40 13	43 15	46 17	49 18	51 20	53 22	56 24	58 26	60 28	62 30	64 32	65 34	67 36	69 38	71 40	72 42	74 45	75 47	77 50	78 52	80 55	81 57	83 60	84 62	85 65	87 68	88 71
100				-29 1	-4 2	+8 3	16 5	22 6	27 8	32 9	35 11	39 12	42 14	45 16	48 17	50 19	53 21	55 23	57 24	59 26	61 28	63 30	65 32	67 34	68 36	70 38	72 41	73 43	75 45	76 48	78 50	79 52	81 55	82 57	84 60	85 63	86 65	88 68
101					-11 1	+4 3	13 4	20 5	25 7	30 8	34 10	38 11	41 13	44 15	47 16	50 18	52 20	54 21	57 23	59 25	61 27	63 29	65 31	66 33	68 35	70 37	71 39	73 41	75 43	76 46	78 48	79 50	81 53	82 55	83 58	85 60	86 63	87 66
102					-20 1	-1 2	+10 3	18 5	24 6	29 8	33 9	37 11	40 12	43 14	46 15	49 17	51 19	54 20	56 22	58 24	60 26	62 27	64 29	66 31	68 33	69 35	71 37	73 39	74 42	76 44	77 46	79 48	80 51	82 53	83 56	84 58	86 61	87 63
103					-37	-6 2	+7 3	15 4	22 6	27 7	32 8	36 10	39 11	42 13	45 14	48 16	51 18	53 19	55 21	58 23	60 24	62 26	64 28	65 30	67 32	69 34	71 36	72 38	74 40	75 42	77 44	78 46	80 49	81 51	83 53	84 56	86 58	87 61
104						-13 1	+3 2	13 4	20 5	25 6	30 8	34 9	38 11	41 12	44 13	47 15	50 17	52 18	55 20	57 21	59 23	61 25	63 27	65 28	67 30	69 32	70 34	72 36	74 38	75 40	77 42	78 45	80 47	81 49	83 51	84 54	85 56	87 59
105						-24 1	-2 2	+9 3	17 4	24 6	29 7	33 8	37 10	40 11	43 13	46 14	49 16	52 17	54 19	56 20	58 22	61 24	63 25	64 27	66 29	68 31	70 33	72 35	73 37	75 39	76 41	78 43	79 45	81 47	82 49	84 52	85 54	86 57
106						-48	-8 1	+6 3	15 4	22 5	27 6	32 8	36 9	39 10	43 12	46 13	48 15	51 16	53 18	56 19	58 21	60 23	62 24	64 26	66 28	68 30	69 31	71 33	73 35	74 37	76 39	78 41	79 43	80 45	82 48	83 50	85 52	86 54
107							-16 1	+2 2	12 3	19 4	25 6	30 7	34 8	38 10	42 11	45 12	48 14	50 15	53 17	55 18	57 20	59 22	62 23	64 25	65 27	67 28	69 30	71 32	72 34	74 36	76 38	77 40	79 42	80 44	82 46	83 48	24 50	86 52
108							-28	-3 2	+9 3	17 4	23 5	29 6	33 8	37 9	41 10	44 12	47 13	49 14	52 16	54 17	57 19	59 20	61 22	63 24	65 25	67 27	69 29	70 31	72 32	74 34	75 36	77 38	78 40	80 42	81 44	83 46	84 48	86 51
109								-9 1	+5 2	15 3	21 5	27 6	32 7	36 8	40 10	43 11	46 12	49 14	51 15	54 17	56 18	58 19	60 21	63 23	64 24	66 26	68 28	70 29	72 31	73 33	75 35	77 36	78 38	80 40	81 42	83 44	84 47	85 49
110								-18 1	+1 2	12 3	19 4	25 5	30 6	35 8	38 9	42 10	45 12	48 13	51 14	53 16	56 17	58 19	60 20	62 22	64 23	66 25	68 26	70 28	71 30	73 31	75 33	76 35	78 37	79 39	81 41	82 43	84 45	85 47
111								-32	-4 1	+9 2	17 4	24 5	29 6	33 7	37 8	41 10	44 11	47 12	50 13	52 15	55 16	57 18	59 19	61 21	64 22	65 24	67 25	69 27	71 28	73 30	74 32	76 34	77 35	79 37	80 39	82 41	83 43	85 45
112									-10 1	+5 2	15 3	22 4	27 5	32 7	36 8	40 9	43 10	46 11	49 13	52 14	54 15	57 17	59 18	61 20	63 21	65 23	67 24	69 26	70 27	72 29	74 31	76 32	77 34	79 36	80 38	82 40	83 42	85 44
113									-19 1	+1 2	12 3	19 4	25 5	31 6	35 7	39 8	42 10	45 11	48 12	51 13	54 15	56 16	58 17	60 19	63 20	65 22	66 23	68 25	70 26	72 28	74 29	75 31	77 33	78 35	80 36	81 38	83 40	84 42
114									-35	-4 1	+9 2	17 3	24 4	29 5	34 7	38 8	41 9	44 10	47 11	50 13	53 14	55 15	58 16	60 18	62 19	64 21	66 22	68 24	70 25	71 27	73 28	75 30	76 32	78 33	80 35	81 37	83 39	84 40
115										-11 1	+5 2	15 3	22 4	27 5	32 6	36 7	40 8	44 9	47 11	50 12	52 13	55 14	57 16	59 17	61 18	64 20	66 21	67 23	69 24	71 26	73 27	74 29	76 30	78 32	79 34	81 35	82 37	84 39
116										-20 1	+1 2	12 2	20 4	26 5	31 6	35 7	39 8	43 9	46 10	49 11	51 12	54 14	56 15	59 16	61 18	63 19	65 20	67 22	69 23	71 25	72 26	74 28	76 29	77 31	79 32	81 34	82 36	84 38
117										-38	-4 1	+9 2	17 3	24 4	29 5	34 6	38 7	42 8	45 9	48 11	51 12	53 13	56 14	58 15	60 17	63 18	65 19	67 21	68 22	70 24	72 25	74 26	75 28	77 30	79 31	80 33	82 34	83 36
118											-11 1	+5 2	15 3	22 4	28 5	33 6	37 7	41 8	44 9	47 10	50 11	53 12	55 13	58 15	60 16	62 17	64 18	66 20	68 21	70 23	72 24	73 25	75 27	77 28	78 30	80 32	81 33	83 35
119											-21	+1 1	12 2	20 3	26 4	31 5	36 6	40	43 8	46 9	49 11	52 12	55 13	57 14	59 15	62 16	64 18	66 [illegible]	68 20	69 22	71 23	73 24	75 26	76 27	78 29	[illegible]	81 [illegible]	83 34

DRY BULB TEMPERATURES

TA No. 454-0-1B
10-63

U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU

RELATIVE HUMIDITY and DEW POINT TABLE

Pressure 25 Inches of Mercury

For use at elevations between 3901 and 6100 feet above sea level
(In Alaska use at elevations between 3601 and 5700 feet above sea level)

Values in the body of the table are relative humidities (in percent) and dew points (in deg. Fahr.), with respect to water, for indicated values of wet and dry bulb temperatures in degrees Fahrenheit.

HOW TO USE THE TABLE

Locate at the top of the column the reading corresponding to the wet bulb temperature. Locate at the left side of the table the reading corresponding to the dry bulb temperature. Follow down the column under the wet bulb temperature, and across from the dry bulb temperature; at the intersection of these two columns will be found the relative humidity (%) in black and the dew point (°F.) in red.

USCOMM-WB-DC

WET BULB TEMPERATURES

DRY BULB TEMPERATURES

	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
20	-31 9	-14 20	-5 32	+2 44	7 56	11 68	15 81	18 94																																			
21		-25 11	-11 23	-3 34	+3 46	8 58	13 70	16 82	20 94																																		
22		-46 3	-20 14	-8 25	-1 36	+5 48	10 59	14 71	18 83	21 95																																	
23			-34 6	-16 17	-6 27	+1 38	7 49	11 61	15 72	19 83	22 95																																
24				-27 9	-12 19	-3 30	+3 40	9 51	13 62	17 73	20 84	23 96																															
25				-52 2	-21 12	-9 22	-1 32	+5 42	10 53	14 63	18 74	21 85	24 96																														
26					-36 5	-16 14	-6 24	+1 34	7 44	12 54	16 65	19 75	22 86	25 97																													
27						-27 8	-12 17	-3 26	+4 36	9 46	13 56	17 66	21 76	24 87	26 97																												
28						-56 1	-21 10	-9 19	0 29	+6 38	11 48	15 57	19 67	22 77	25 87	27 98																											
29							-37 4	-16 13	-5 22	+2 31	8 40	12 49	16 59	20 68	23 78	26 88	29 98																										
30								-27 7	-11 15	-2 24	+4 33	10 42	14 51	18 60	21 70	24 79	27 89	30 99																									
31								-54 1	-20 10	-8 18	0 26	+6 35	11 44	16 52	19 61	23 71	26 80	28 90	31 99																								
32									-35 4	-15 12	-4 20	+3 28	9 37	13 45	17 54	21 63	24 72	27 81	30 90	32 100																							
33										-25 7	-10 15	-1 22	+5 30	11 39	15 47	19 56	22 64	25 73	28 82	31 91	33 100																						
34										-48 2	-18 9	-6 17	+2 25	8 32	12 40	17 49	20 57	24 65	27 74	29 83	32 91	34 100																					
35											-31 4	-13 12	-3 19	+4 27	10 34	14 42	18 50	22 58	25 67	28 75	30 83	33 92	35 100																				
36												-22 7	-9 14	0 21	+7 29	12 36	16 44	20 52	23 60	26 68	29 76	32 84	34 92	36 100																			
37												-40 3	-16 9	-5 16	+3 23	9 31	14 38	18 46	22 53	25 61	28 69	30 76	33 84	35 92	37 100																		
38													-27 5	-11 12	-1 19	+6 26	11 33	16 40	20 47	23 55	26 62	29 69	31 77	34 84	36 92	38 100																	
39													-55 1	-19 7	-6 14	+2 21	8 27	13 34	18 42	21 49	25 56	27 63	30 70	33 77	35 85	37 92	39 100																
40														-32 3	-13 10	-2 16	+5 23	11 29	15 36	19 43	23 50	26 57	29 64	31 71	34 78	36 85	38 92	40 100															
41															-22 6	-8 12	+1 18	8 25	13 31	17 38	21 44	24 51	27 58	30 64	32 71	35 78	37 85	39 93	41 100														
42															-39 2	-15 8	-3 14	+4 20	10 27	15 33	19 39	23 46	26 52	29 58	31 65	34 72	36 79	38 86	40 93	42 100													
43																-25 5	-9 10	0 16	+7 22	13 29	17 35	21 41	24 47	27 53	30 59	32 66	35 72	37 79	39 86	41 93	43 100												
44																-48 1	-17 7	-4 13	+4 18	10 24	15 30	19 36	22 42	25 48	28 54	31 60	34 66	36 73	38 80	40 86	42 93	44 100											
45																	-29 4	-10 9	0 15	+7 20	12 26	17 31	20 37	24 43	27 49	30 55	32 61	35 67	37 73	39 80	41 86	43 93	45 100										
46																		-19 6	-5 11	+3 17	9 22	14 27	18 33	22 38	25 44	28 50	31 56	34 62	36 68	38 74	40 80	42 87	44 93	46 100									
47																		-32 3	-12 8	+1 13	+6 18	12 23	16 29	20 34	24 40	27 45	30 51	32 57	35 62	37 68	39 74	41 81	43 87	45 93	47 100								
48																			-20 5	-6 10	+2 15	9 20	14 25	18 30	22 35	25 41	28 46	31 52	34 57	36 63	38 69	40 75	42 81	44 87	46 94	48 100							
49																			-35 2	-13 7	-2 12	+5 17	11 21	16 26	20 31	24 37	27 42	30 47	32 53	35 58	37 64	39 70	42 75	44 81	45 87	47 94	49 100						
50																				-22 4	-7 9	+2 13	8 18	14 23	18 28	22 33	25 38	28 43	31 48	34 53	36 59	39 64	41 70	43 76	45 82	46 88	48 94	50 100					
51																				-39 2	-14 6	-3 10	+5 15	11 20	16 24	20 29	24 34	27 39	30 44	33 49	35 54	37 60	40 65	42 71	44 76	46 82	48 88	49 94	51 100				
52																					-24 3	-8 8	+1 12	8 17	13 21	18 26	12 30	25 35	28 40	31 45	34 50	36 55	39 60	41 66	43 71	45 77	47 82	49 88	50 94	52 100			
53																					-45 1	-16 5	-3 9	+5 14	11 18	16 22	20 27	24 32	27 36	30 41	33 46	35 51	38 56	40 61	42 66	44 72	46 77	48 83	50 88	51 94	53 100		
54																						-27 3	-9 7	+1 11	8 15	13 19	18 24	22 28	25 33	29 37	31 42	34 47	37 52	39 57	41 62	43 67	45 72	47 77	49 83	51 89	52 94	[illegible]	
55																						53 1	-17 5	-4 8	+4 13	11 17	16 21	20 25	24 29	27 34	30 38	33 43	36 48	38 52	40 57	42 62	44 67	46 73	48 78	50 83	52 89		

WET BULB TEMPERATURES

DRY BULB TEMPERATURES

	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	65	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
56	-29 2	-10 6	0 10	+8 14	13 18	18 22	22 26	26 31	29 35	32 39	34 44	37 49	39 53	41 58	44 63	46 68	47 73	49 78	51 83	53 89	54 94	56 100																													
57		-18 4	-4 8	+4 12	11 15	16 19	20 23	24 28	27 32	30 36	33 40	36 45	38 49	41 54	43 59	45 64	47 68	49 73	50 79	52 84	54 89	55 94	57 100																												
58		-31 2	-10 6	0 9	+7 13	13 17	18 21	22 25	26 29	29 33	32 37	35 41	37 46	40 50	42 55	44 59	46 64	48 69	50 74	51 79	53 84	55 89	56 95	58 100																											
59			-19 4	-5 7	+4 11	11 14	16 18	20 22	24 26	28 30	31 34	34 38	36 42	39 47	41 51	43 55	45 60	47 65	49 69	51 74	53 79	54 84	56 89	57 95	59 100																										
60			-32 2	-11 5	0 9	+8 12	13 16	18 19	22 23	26 27	29 31	32 35	35 39	38 43	40 47	42 52	44 56	46 61	48 65	50 70	52 75	54 79	55 84	57 90	58 95	60 100																									
61				-19 3	-5 7	+4 10	11 14	16 17	21 21	24 24	28 28	31 32	34 36	37 40	39 44	41 48	43 52	46 57	48 61	49 66	51 70	53 75	55 80	56 85	58 90	59 95	61 100																								
62				-33 1	-11 5	0 8	+8 11	14 15	19 18	23 22	26 26	30 29	33 33	35 37	38 41	40 45	43 49	45 53	47 57	49 62	51 66	52 71	54 75	56 80	57 85	59 90	61 95	62 100																							
63					-19 3	-5 6	+6 9	11 13	16 16	21 20	25 23	28 27	31 30	34 34	37 38	39 42	42 46	44 50	46 54	48 58	50 62	52 67	54 71	55 76	57 80	58 85	60 90	62 95	63 100																						
64					-34 1	-11 4	0 8	+8 11	14 14	19 17	23 21	27 24	30 28	33 31	36 35	38 39	41 43	43 46	45 50	47 54	49 59	51 63	53 67	55 72	56 76	58 81	60 85	61 90	63 95	64 100																					
65						-19 3	-6 6	+5 9	11 12	17 15	21 19	25 22	29 25	32 29	35 32	37 36	40 40	42 43	44 47	47 51	49 55	50 59	52 63	54 68	56 72	57 76	59 81	61 86	62 90	64 95	65 100																				
66						-33 1	-10 4	+1 7	8 10	14 13	19 16	23 20	27 23	31 26	34 30	36 33	39 37	41 40	44 44	46 48	48 52	50 56	52 60	53 64	55 68	57 72	58 77	60 81	62 86	63 90	65 95	66 100																			
67							-19 3	-4 6	+5 8	12 11	17 15	22 18	26 21	29 24	32 27	35 31	38 34	40 38	43 41	45 45	47 49	49 52	51 56	53 60	55 64	56 68	58 73	60 77	61 81	63 86	64 90	66 95	67 100																		
68							-32 1	-10 4	+1 7	9 10	15 13	20 16	24 19	28 22	31 25	34 28	37 32	39 35	42 39	44 42	46 46	48 49	50 53	52 57	54 61	56 65	57 69	59 73	61 77	62 82	64 86	65 91	67 95	68 100																	
69								-18 3	-3 5	+6 8	12 11	18 14	22 17	26 20	30 23	33 26	36 29	38 33	41 36	43 39	45 43	48 46	50 50	52 54	53 57	55 61	57 65	59 69	60 73	62 78	63 82	65 86	66 91	68 95	69 100																
70								-31 1	-9 4	+2 7	10 9	15 12	20 15	25 18	28 21	32 24	35 27	37 30	40 33	42 37	45 40	47 44	49 47	51 51	53 54	55 58	56 62	58 66	60 70	61 74	63 78	64 82	66 86	67 91	69 95	70 100															
71									-17 3	-3 5	+6 8	13 11	18 13	23 16	27 19	30 22	33 25	36 28	39 31	41 34	44 38	46 41	48 44	50 48	52 51	54 55	56 58	57 62	59 66	61 70	62 74	64 78	65 82	67 87	68 91	70 95	71 100														
72									-29 1	-8 4	+3 6	10 9	16 12	21 14	25 17	29 20	32 23	35 26	38 29	41 32	43 35	45 38	47 42	49 45	51 48	53 52	55 55	57 59	59 63	60 66	62 70	63 74	65 78	66 83	68 87	69 91	71 95	72 100													
73										-15 3	-2 5	+7 8	14 10	19 13	23 16	27 18	31 21	34 24	37 27	40 30	42 33	44 36	47 39	49 42	51 46	53 49	55 52	56 56	58 59	60 63	61 67	63 71	64 75	66 79	67 83	69 87	70 91	72 96	73 100												
74										-26 1	-7 4	+4 6	11 9	17 11	22 14	26 17	30 19	33 22	36 25	39 28	41 31	44 34	46 37	48 40	50 43	52 46	54 50	56 53	58 56	59 60	61 64	62 67	64 71	66 75	67 79	68 83	70 87	71 91	73 96	74 100											
75										-52	-14 3	0 5	+8 7	15 10	20 12	24 15	28 18	32 20	35 23	38 26	40 29	43 31	45 34	47 37	49 41	51 44	53 47	55 50	57 53	59 57	60 60	62 64	64 68	65 71	67 75	68 79	70 83	71 87	72 91	74 96	75 100										
76											-24 2	-5 4	+5 6	12 9	18 11	22 13	27 16	30 19	33 21	36 24	39 27	42 29	44 32	47 35	49 38	51 41	53 44	55 47	56 51	58 54	60 57	62 61	63 64	65 68	66 72	68 75	69 79	71 83	72 87	73 91	75 96	76 100									
77											-43	-12 3	+1 5	9 7	15 10	21 12	25 14	29 17	32 19	35 22	38 25	41 27	43 30	46 33	48 36	50 39	52 42	54 45	56 48	58 51	59 55	61 58	63 61	64 65	66 68	67 72	69 76	70 80	72 83	73 87	74 92	76 96	77 100								
78												-21 2	-4 4	+6 6	13 8	19 11	23 13	27 15	31 18	34 20	37 23	40 26	43 28	45 31	47 34	49 37	51 40	53 42	55 46	57 49	59 52	61 55	62 58	64 62	65 65	67 69	68 72	70 76	71 80	73 84	74 88	75 92	77 96	78 100							
79												-36 1	-10 3	+2 5	10 7	16 9	21 12	26 14	30 16	33 19	36 21	39 24	42 26	44 29	46 32	49 35	51 37	53 40	55 43	57 46	58 49	60 52	62 56	63 59	65 62	66 66	68 69	69 73	71 76	72 80	74 84	75 88	76 92	78 96	79 100						
80													-18 2	-2 4	+7 6	14 8	20 10	24 13	28 15	32 17	35 20	38 22	41 25	43 27	46 30	48 32	50 35	52 38	54 41	56 44	58 47	60 50	61 53	63 56	65 59	66 63	68 66	69 69	71 73	72 77	73 80	75 84	76 88	77 92	79 96	80 100					
81													-31 1	-8 3	+4 5	11 7	17 9	22 11	27 14	30 16	34 18	37 21	40 23	42 25	45 28	47 31	49 33	51 36	53 39	55 41	57 44	59 47	61 50	62 53	64 56	66 60	67 63	69 66	70 70	72 73	73 77	74 80	76 84	77 88	78 92	80 96	81 100				
82													-57	-15 2	-1 4	+8 6	15 8	21 10	25 12	29 15	33 17	36 19	39 21	41 24	44 26	46 29	49 31	51 34	53 37	55 39	57 42	59 45	60 48	62 51	64 54	65 57	67 60	68 63	70 67	71 70	73 73	74 77	75 81	77 84	78 88	80 92	81 96	82 100			
83														-26 1	-6 3	+5 5	13 7	19 9	23 11	28 13	31 15	35 18	38 20	41 22	43 25	46 27	48 29	50 32	52 35	54 37	56 40	58 43	60 45	61 48	63 51	65 54	66 57	68 60	69 64	71 67	72 70	74 74	75 77	76 81	78 84	79 88	80 92	82 96	83 100		
84														-49	-12 2	+1 4	10 6	16 8	22 10	26 12	30 14	34 16	37 18	40 21	42 23	45 25	47 28	49 30	52 33	54 35	56 38	57 41	59 43	61 46	63 49	64 52	66 55	68 58	69 61	71 64	72 67	73 71	75 74	76 77	78 81	79 85	80 88	81 92	83 96	84 100	
85															-21 1	-3 3	+7 5	14 7	20 9	24 11	29 13	32 15	36 17	39 19	41 22	44 24	46 26	49 28	51 31	53 33	55 36	57 38	59 41	61 44	62 47	64 49	66 52	67 55	69 58	70 61	72 64	73 68	74 71	76 74	77 78	79 81	80 85	81 88	82 92	84 96	85 100

WET BULB TEMPERATURES

	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
86	-37 1	-9 2	+3 4	11 6	18 8	23 10	27 12	31 14	34 16	38 18	40 20	43 22	46 25	48 27	50 29	52 32	54 34	56 36	58 39	60 42	62 44	63 47	65 50	67 53	68 56	70 59	71 62	73 65	74 68	76 71	77 74	78 78	80 81	81 85	82 89	83 92	85 96	86 100				
87		-17 2	-1 3	+8 5	15 7	21 9	26 11	30 13	33 15	36 17	39 19	42 21	45 23	47 25	50 28	52 30	54 32	56 35	58 37	60 40	61 42	63 45	65 48	66 50	68 53	69 56	71 59	72 62	74 65	75 68	77 71	78 75	79 78	81 82	82 85	83 89	85 92	86 96	87 100			
88		-29 1	-6 2	+5 4	13 6	19 8	24 10	28 12	32 13	35 15	38 17	41 20	44 22	46 24	49 26	51 28	53 31	55 33	57 35	59 38	61 40	63 43	64 45	66 48	67 51	69 54	71 56	72 59	73 62	75 65	76 68	78 72	79 75	80 78	82 82	83 85	84 89	86 92	87 96	88 100		
89			-13 2	+1 3	10 5	17 7	22 9	27 11	31 12	34 14	37 16	40 18	43 20	46 22	48 24	50 27	53 29	55 31	57 33	58 36	60 38	62 41	64 43	65 46	67 49	69 51	70 54	72 57	73 60	75 63	76 66	77 69	79 72	80 75	81 78	83 82	84 85	85 89	87 93	88 96	89 100	
90			-22 1	-3 3	+7 4	14 6	20 8	25 10	29 11	33 13	36 15	39 17	42 19	45 21	47 23	50 25	52 27	54 30	56 32	58 34	60 36	62 39	63 41	65 44	67 46	68 49	70 52	71 54	73 57	74 60	76 63	77 66	78 69	80 72	81 75	82 79	84 82	85 85	86 89	88 93	89 96	90 100
91			-40	-9 2	+3 4	12 5	18 7	23 9	28 10	32 12	35 14	38 16	41 18	44 20	47 22	49 24	51 26	53 28	55 30	57 32	59 35	61 37	63 39	65 42	66 44	68 47	69 49	71 52	72 55	74 58	75 60	77 63	78 66	80 69	81 72	92 76	84 79	85 82	86 86	87 89	89 93	90 96
92				-17 1	-1 3	+9 4	16 6	22 8	26 9	30 11	34 13	37 15	40 17	43 19	46 20	48 22	51 24	53 27	55 29	57 31	59 33	61 35	62 38	64 40	66 42	67 45	69 47	71 50	72 52	74 55	75 58	76 61	78 64	79 67	81 70	82 73	83 76	85 79	86 82	87 86	88 89	90 93
93				-29 1	-6 2	+6 4	14 5	20 7	25 9	29 10	33 12	36 14	39 16	42 17	45 19	48 21	50 23	52 25	54 27	56 29	58 31	60 34	62 36	64 38	65 40	67 43	69 45	70 48	72 50	73 53	75 56	76 58	78 61	79 64	80 67	82 70	83 73	84 76	86 79	87 82	88 86	89 89
94					-12 2	+2 3	11 5	18 6	23 8	28 9	32 11	35 13	38 14	41 16	44 18	47 20	49 22	51 24	54 26	56 28	58 30	60 32	61 34	63 36	65 39	67 41	68 43	70 46	71 48	73 51	74 53	76 56	77 59	79 61	80 64	81 67	83 70	84 73	85 76	87 79	88 83	89 86
95					-22 1	-3 2	+8 4	15 5	21 7	26 9	30 10	34 12	37 13	40 15	43 17	46 19	48 21	51 22	53 24	55 26	57 28	59 30	61 33	63 35	65 37	66 39	68 41	69 44	71 46	73 49	74 51	76 54	77 56	78 59	80 62	81 65	82 67	84 70	85 73	86 76	88 80	89 83
96					-39	-8 2	+4 3	13 5	19 6	24 8	29 9	33 11	36 13	40 14	42 16	45 18	48 19	50 21	52 23	55 25	57 27	59 29	60 31	62 33	64 35	66 37	67 40	69 42	71 44	72 47	74 49	75 51	77 54	78 57	80 59	81 62	82 65	84 68	85 71	86 74	87 77	89 80
97						-16 1	0 3	+10 4	17 5	23 7	27 8	32 10	35 12	39 13	42 15	44 17	47 18	49 20	52 22	54 24	56 26	58 28	60 30	62 32	64 34	65 36	67 38	69 40	70 42	72 45	73 47	75 49	76 52	78 54	79 57	81 60	82 62	83 65	85 68	86 71	87 74	88 77
98						-27 1	-4 2	+7 3	15 5	21 6	26 8	30 9	34 11	37 12	41 14	44 16	46 17	49 19	51 21	53 23	55 24	58 26	59 28	61 30	63 32	65 34	67 36	68 38	70 41	72 43	73 45	75 47	76 50	78 52	79 55	80 57	82 60	83 63	84 65	86 68	87 71	88 74
99						-54	-10 1	+3 3	12 4	19 6	24 7	29 8	33 10	36 11	40 13	43 15	45 16	48 18	50 20	53 21	55 23	57 25	59 27	61 29	63 31	65 33	66 35	68 37	70 39	71 41	73 43	74 46	76 48	77 50	79 53	80 55	81 58	83 60	84 63	85 66	87 68	88 71
100							-19 1	-1 2	+9 4	17 5	22 6	27 8	32 9	35 11	39 12	42 14	45 15	47 17	50 19	52 20	54 22	56 24	58 26	60 27	62 29	64 31	66 33	68 35	69 37	71 39	72 41	74 44	75 46	77 48	78 51	80 53	81 55	83 58	84 61	85 63	87 66	88 69
101							-33	-6 2	+6 3	14 4	21 6	26 7	30 8	34 10	38 11	41 13	44 14	46 16	49 18	51 19	54 21	56 23	58 24	60 26	62 28	64 30	65 32	67 34	69 36	70 38	72 40	74 42	75 44	77 46	78 49	79 51	81 53	82 56	84 58	85 61	86 63	88 66
102								-13 1	+2 2	12 4	19 5	24 6	29 8	33 9	37 11	40 12	43 13	46 15	48 17	51 18	53 20	55 21	57 23	59 25	61 27	63 28	65 30	67 32	68 34	70 36	72 38	73 40	75 42	76 44	78 47	79 49	81 51	82 54	83 56	85 59	86 61	87 64
103								-22 1	-2 2	+9 3	16 4	22 6	27 7	32 8	35 10	39 11	42 13	45 14	48 16	50 17	52 19	55 20	57 22	59 24	61 25	63 27	65 29	66 31	68 33	70 35	71 37	73 39	74 41	76 43	77 45	79 47	80 49	92 52	83 54	84 56	86 59	87 61
104								-39	-7 1	+5 3	14 4	20 5	26 6	30 8	34 9	38 10	41 12	44 13	47 15	49 16	52 18	54 19	56 21	58 23	60 24	62 26	64 28	66 29	68 31	69 33	71 35	73 37	74 39	76 41	77 43	79 45	80 47	81 50	83 52	84 54	86 57	87 59
105									-14 1	+2 2	11 3	18 5	24 6	29 7	33 8	37 10	40 11	43 12	46 14	49 15	51 17	53 18	56 20	58 21	60 23	62 25	64 26	65 28	67 30	69 32	71 34	72 36	74 37	75 39	77 41	78 44	80 46	81 48	83 50	84 52	85 55	87 57
106									-25 1	-3 2	+8 3	16 4	22 5	27 6	32 8	36 9	39 10	42 12	45 13	48 14	50 16	53 17	55 19	57 20	59 22	61 24	63 25	65 27	67 29	69 30	70 32	72 34	73 36	75 38	77 40	78 42	80 44	81 46	82 48	84 50	85 53	86 55
107									-47	-8 1	+5 2	14 4	20 5	26 6	30 7	35 8	38 10	41 11	44 12	47 14	50 15	52 17	54 18	57 19	59 21	61 23	63 24	65 26	66 27	68 29	70 31	72 33	73 35	75 36	76 38	78 40	79 42	81 44	82 46	83 49	85 51	86 53
108										-16 1	+1 2	11 3	18 4	24 5	29 7	33 8	37 9	40 10	44 12	46 13	49 14	52 16	54 17	56 19	58 20	60 22	62 23	64 25	66 26	68 28	69 30	71 31	73 33	74 35	76 37	77 39	79 41	80 43	82 45	83 47	85 49	86 51
109										-27	-3 2	+8 3	16 4	23 5	28 6	32 7	36 8	39 10	43 11	46 12	48 13	51 15	53 16	56 18	58 19	60 21	62 22	64 24	66 25	67 27	69 28	71 30	72 32	74 34	76 35	77 37	79 39	80 41	82 43	83 45	84 47	86 49
110										-58	-9 1	+5 2	14 3	21 4	26 5	31 7	35 8	38 9	42 10	45 11	48 13	50 14	53 15	55 17	57 18	59 20	61 21	63 23	65 24	67 26	69 27	70 29	72 31	74 32	75 34	77 36	78 38	80 40	81 41	83 43	84 45	85 47
111											-17 1	+1 2	11 3	19 4	24 5	29 6	34 7	37 8	41 10	44 11	47 12	49 13	52 15	54 16	57 17	59 19	61 20	63 22	65 23	67 25	68 26	70 28	72 29	73 31	75 33	77 34	78 36	80 38	81 40	82 42	84 44	85 46
112											-29	-4 1	+8 2	16 3	23 4	28 6	32 7	36 8	40 9	43 10	46 11	49 13	51 14	54 15	56 16	58 18	60 19	62 21	64 22	66 24	68 25	70 27	71 28	73 30	75 31	76 33	78 35	79 37	81 38	82 39	84 42	85 44
113												-10 1	+5 2	14 3	21 4	26 5	31 6	35 7	39 8	42 10	45 11	48 12	51 13	53 14	55 16	58 17	60 18	62 20	64 21	66 23	68 24	69 26	71 27	73 29	74 30	76 32	77 34	79 35	80 37	82 39	83 41	85 43
114												-18 1	+1 2	11 3	19 4	25 5	30 6	34 7	38 8	41 9	44 10	47 11	50 12	53 14	55 15	57 16	59 17	61 19	63 20	65 22	67 23	69 24	71 26	72 27	74 29	76 31	77 32	79 34	80 36	82 37	83 39	85 41
115												-31	-4 1	+8 2	17 3	23 4	28 5	33 6	37 7	40 8	44 9	47 11	49 12	52 13	54 14	57 15	59 17	61 18	63 19	65 21	67 22	69 23	70 25	72 26	74 28	75 29	77 31	78 33	80 34	81 36	83 38	84 40
116													-10 1	+5 2	14 3	21 4	27 5	32 6	36 7	39 8	43 9	46 10	49 11	51 12	54 13	56 15	58 16	60 17	62 18	64 20	66 21	68 23	70 24	72 25	73 27	75 28	77 30	78 31	80 33	81 35	83 36	84 38
117													-18 1	+1 1	12 2	19 3	25 4	30 5	35 6	38 7	42 8	45 9	48 11	51 12	53 13	55 14	58 15	60 16	62 18	64 19	66 20	68 22	70 23	71 24	73 26	75 27	76 29	78 30	79 32	81 33	82 35	84 37
118													-31	-3 1	+9 2	17 3	24 4	29 5	33 6	37 7	41 8	44 9	47 10	50 11	52 12	55 13	57 14	59 16	62 17	64 18	65 19	67 21	69 22	71 23	73 25	74 26	76 28	78 29	79 31	81 32	82 34	84 35
119														-9 1	+6 2	15 3	22 4	27 4	32 5	36 6	40 7	43 8	46 9	49 10	52 12	54 13	57 14	59 15	61 16	63 17	65 19	67 20	69 21	71 22	72 24	74 25	76 27	77 28	79 30	80 31	82 [illegible]	83 34

DRY BULB
TEMPERATURES

TA No. 454-0-1A
10-63

U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU

RELATIVE HUMIDITY and DEW POINT TABLE

Pressure 23 Inches of Mercury

For use at elevations between 6101 and 8500 feet above sea level
(In Alaska use at elevations between 5701 and 7900 feet above sea level)

Values in the body of the table are relative humidities (in percent) and dew points (in deg. Fahr.), with respect to water, for indicated values of wet and dry bulb temperatures in degrees Fahrenheit.

HOW TO USE THE TABLE

Locate at the top of the column the reading corresponding to the wet bulb temperature. Locate at the left side of the table the reading corresponding to the dry bulb temperature. Follow down the column under the wet bulb temperature, and across from the dry bulb temperature; at the intersection of these two columns will be found the relative humidity (%) in black and the dew point (°F.) in red.

USCOMM-WB-DC

WET BULB TEMPERATURES

DRY BULB TEMPERATURES

	9	10	11	12	13	14	15	16	17	18	19	20
15	-30 11	-15 24	-7 37	0 50	+5 64	9 77	13 91					
16	2	-25 14	-13 26	-5 39	+1 52	6 65	10 78	14 92				
17		-44 5	-21 17	-10 29	-3 41	+3 54	8 66	12 79	15 92			
18			-34 8	-17 19	-8 31	-1 43	+5 55	9 67	13 80	16 93		
19				-28 10	-14 22	-5 33	+1 45	6 57	10 69	14 81	17 93	
20				-53 2	-23 13	-11 24	-3 35	+3 47	8 58	12 70	15 82	18 94

	13	14	15	16	17	18	19	20	21	22	23	24	25
21	-38 5	-18 16	-8 27	-1 37	+5 48	9 60	13 71	17 82	20 94				
22		-30 8	-15 18	-6 29	+1 39	6 50	11 61	14 72	18 83	21 95			
23		1	-24 11	-11 21	-3 31	+3 41	8 52	12 62	16 73	19 84	22 95		
24			-41 4	-19 14	-8 23	-1 33	+5 43	9 53	13 64	17 74	20 85	23 96	
25				-31 7	-15 16	-5 26	+1 35	7 45	11 55	15 65	18 75	21 86	24 96

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
26	1	-24 10	-11 19	-3 28	+3 37	8 47	13 56	16 66	20 76	23 86	25 97				
27		-42 3	-19 12	-8 21	0 30	+5 39	10 48	14 58	18 67	21 77	24 87	26 97			
28			-31 6	-14 15	-5 23	+2 32	7 41	12 50	16 59	19 69	22 78	25 88	27 98		
29			1	-23 9	-10 17	-2 25	+5 34	9 43	13 52	17 61	20 70	23 79	26 89	29 98	
30				-40 3	-18 11	-7 19	+1 28	6 36	11 44	15 53	19 62	22 71	25 80	27 89	30 99

	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
31	-29 6	-13 14	-4 22	+3 30	8 38	13 46	17 55	20 63	23 72	26 81	28 90	31 99				
32	-57 1	-21 9	-9 16	-1 24	+5 32	10 40	14 48	18 56	21 64	24 73	27 82	30 91	32 100			
33		-36 4	-16 11	-5 18	+2 26	7 34	12 41	16 49	20 57	23 66	26 74	28 83	31 92	33 100		
34			-26 6	-11 13	-2 21	+4 28	10 35	14 43	18 51	21 59	24 67	27 75	30 84	32 92	34 100	
35			-46 2	-19 9	-7 16	+1 23	7 30	12 37	16 45	19 52	23 60	26 68	28 76	31 84	33 92	35 100

	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
36	-31 4	-13 11	-4 18	+3 25	9 32	13 39	17 46	21 54	24 61	27 69	29 77	32 84	34 92	36 100				
37		-22 7	-9 13	0 20	+6 27	11 34	15 41	19 48	22 55	25 63	28 70	31 77	33 85	35 92	37 100			
38		-37 3	-16 9	-5 16	+3 22	8 29	13 35	17 42	21 49	24 57	27 64	29 71	32 78	34 85	36 92	38 100		
39			-25 5	-10 11	-1 18	+4 24	11 31	15 37	19 44	22 51	25 58	28 64	30 71	33 78	35 85	37 93	39 100	
40			-45 2	-18 8	-6 14	+2 20	8 26	13 32	17 39	21 46	24 52	27 58	29 65	32 72	34 79	36 86	38 93	40 100

	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
41	-29 4	-12 10	-2 16	+5 22	10 28	15 34	19 41	22 47	25 53	28 59	30 66	33 72	35 79	37 86	39 93	41 100				
42	-57 1	-20 6	-7 12	+1 18	8 24	13 30	17 36	20 42	24 48	27 54	29 60	32 66	34 73	36 80	38 86	40 93	42 100			
43		-33 3	-13 9	-3 14	+4 20	10 26	15 31	19 37	22 43	25 49	28 55	30 61	33 67	35 73	37 80	39 86	41 93	43 100		
44			-22 5	-8 11	+1 16	7 22	12 27	17 33	20 38	24 44	26 50	29 56	32 62	34 68	36 74	38 80	40 87	42 93	44 100	
45			-37 2	-14 7	-3 13	+4 18	10 24	15 29	18 34	22 40	25 45	28 51	31 57	33 62	35 68	37 74	39 81	41 87	43 93	45 100

	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
46	-24 4	-9 9	0 15	+7 20	12 25	16 30	20 35	23 41	26 46	29 52	32 57	34 63	36 69	39 75	41 81	42 87	44 94	46 100				
47	-41 2	-15 7	-4 12	+4 17	10 21	14 26	18 31	22 37	25 42	28 47	31 53	33 58	35 64	38 70	40 75	42 81	43 87	45 94	47 100			
48		-25 4	-9 9	0 13	+7 18	12 23	16 28	20 33	23 38	27 43	29 48	32 53	34 59	37 64	39 70	41 76	43 82	45 88	46 94	48 100		
49		-45 1	-16 6	-4 11	+3 15	9 20	14 24	18 29	22 34	25 39	28 44	31 49	33 54	36 60	38 65	40 71	42 76	44 82	46 88	47 94	49 100	
			-26 3	-9 8	0 12	+6 17	12 21	16 26	20 30	24 35	27 40	29 45	32 50	35 55	37 60	39 66	41 71	43 77	45 82	47 88	4	

WET BULB TEMPERATURES

DRY BULB TEMPERATURES

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
51	-48 1	-16 5	-5 10	+3 14	9 18	14 23	18 27	22 32	25 36	28 41	31 46	33 51	36 56	38 61	40 66	42 72	44 77	46 83	48 88	49 94	51 100				
52		-27 3	-10 7	-1 11	+6 15	12 20	16 2[illegible]	20 28	24 33	27 37	30 42	32 47	35 52	37 57	39 62	41 67	43 72	45 77	47 83	49 88	50 94	52 100			
53		-50 1	-18 5	-5 9	+3 13	9 17	14 21	18 25	22 30	25 34	28 38	31 43	34 48	36 52	38 57	40 62	42 67	44 73	46 78	48 83	50 89	51 94	53 100		
54			-29 2	-11 6	-1 10	+6 14	12 18	16 22	20 26	24 31	27 35	30 39	33 44	35 49	37 53	40 58	42 63	44 68	46 73	47 78	49 83	51 89	52 94	54 100	
55			-57	-19 4	-6 8	+3 12	9 16	14 20	18 24	22 28	26 32	29 36	31 40	34 45	36 49	39 54	41 59	43 64	45 68	47 73	48 79	50 84	52 89	53 94	55 100
56				-30 2	-11 6	-1 9	+6 13	12 17	16 21	21 25	24 29	27 33	30 37	33 41	35 46	38 50	40 55	42 59	44 64	46 69	48 74	50 79	51 84	53 89	54 95
57					-19 4	-6 7	+3 11	9 15	14 18	19 22	22 26	26 30	29 34	32 38	34 42	37 47	39 51	41 55	43 60	45 65	47 69	49 74	51 79	52 84	54 89
58					-32 2	-12 5	-1 9	+6 12	12 16	17 20	21 23	24 27	28 31	31 35	33 39	36 43	38 47	40 52	42 56	44 61	46 65	48 70	50 75	52 79	53 84
59						-20 3	-6 7	+3 10	9 14	15 17	19 21	23 25	26 28	29 32	32 36	35 40	37 44	39 48	42 52	44 57	46 61	48 66	49 70	51 75	53 80
60						-32 2	-12 5	-1 8	+6 12	12 15	17 18	21 22	25 26	28 29	31 33	34 37	36 41	39 45	41 49	43 53	45 57	47 62	49 66	50 71	52 75
61							-20 3	-6 6	+3 10	10 13	15 16	19 20	23 23	27 27	30 30	33 34	35 38	38 42	40 46	42 50	44 54	46 58	48 62	50 67	52 71
62							-32 2	-11 5	-1 8	+7 11	13 14	17 17	21 21	25 24	28 28	31 31	34 35	37 39	39 43	41 46	43 50	45 54	47 59	49 63	51 67
63								-19 3	-5 6	+4 9	10 12	15 15	20 19	24 22	27 25	30 29	33 32	36 36	38 40	40 43	43 47	45 51	47 55	49 59	50 63
64								-32 1	-11 4	0 7	+7 10	13 13	18 17	22 20	26 23	29 26	32 30	35 33	37 37	40 40	42 44	44 48	46 52	48 56	50 60
65									-19 3	-5 6	+4 9	11 12	16 15	20 18	24 21	28 24	31 27	34 31	36 34	39 38	41 41	43 45	45 49	47 52	49 56
66									-31 1	-10 4	0 7	+8 10	14 13	18 16	22 19	26 22	29 25	32 28	35 32	38 35	40 39	42 42	44 46	46 49	48 53
67										-18 3	-4 6	+5 8	11 11	16 14	21 17	25 20	28 23	31 26	34 29	37 33	39 36	41 39	44 43	46 46	48 50
68										-29 1	-9 4	+1 7	8 10	14 12	19 15	23 18	27 21	30 24	33 27	36 30	38 33	41 37	43 40	45 44	47 47
69										-58	-16 3	-3 5	+5 8	12 11	17 13	21 16	25 19	29 22	32 25	35 28	37 31	40 34	42 38	44 41	46 44
70											-27 2	-8 4	+2 7	9 9	15 12	20 15	24 17	27 20	31 23	34 26	36 29	39 32	41 35	43 38	46 42
71											-50	-15 3	-2 5	+6 8	13 10	18 13	22 16	26 18	29 21	32 24	35 27	38 30	40 33	43 36	45 39
72												-25 2	-7 4	+3 6	10 9	16 11	20 14	24 17	28 19	31 22	34 25	37 28	39 31	42 34	44 37
73												-43 1	-13 3	-1 5	+7 8	13 10	18 13	23 15	27 18	30 20	33 23	36 26	39 29	41 32	43 34
74													-22 2	-6 4	+4 6	11 9	16 11	21 14	25 16	29 19	32 21	35 24	38 27	40 29	43 32
75													-37 1	-12 3	0 5	+8 7	14 10	19 12	24 15	27 17	31 20	34 22	37 25	39 28	42 30
76														-19 2	-4 4	+5 6	12 9	17 11	22 13	26 16	30 18	33 21	36 23	38 26	41 28
77														-32 1	-10 3	+2 5	9 7	15 10	20 12	24 14	28 17	32 19	35 21	37 24	40 26
78															-17 2	-3 4	+6 6	13 8	18 11	23 13	27 15	30 17	33 20	36 22	39 25
79															-27 1	-8 3	+3 5	11 7	16 9	21 12	25 14	29 16	32 18	35 21	38 23
80															-52	-14 2	-1 4	+8 6	14 8	19 10	24 12	28 15	31 17	34 19	37 22

	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
56	56 100																								
57	55 95	57 100																							
58	55 90	56 95	58 100																						
59	54 85	56 90	58 95	59 100																					
60	54 80	55 85	57 90	59 95	60 100																				
61	53 76	55 80	56 85	58 90	60 95	61 100																			
62	53 72	54 76	56 81	58 85	59 90	61 95	62 100																		
63	52 68	54 72	55 76	57 81	59 85	60 90	62 95	63 100																	
64	52 64	53 68	55 72	57 77	58 81	60 86	61 90	63 95	64 100																
65	51 60	53 64	54 68	56 73	58 77	59 81	61 86	62 90	64 95	65 100															
66	50 57	52 61	54 65	55 69	57 73	59 77	60 82	62 86	63 91	65 95	66 100														
67	50 54	51 57	53 61	55 65	57 69	58 73	60 78	61 82	63 86	64 91	66 95	67 100													
68	49 51	51 54	53 58	54 62	56 66	58 70	59 74	61 78	62 82	64 86	65 91	67 95	68 100												
69	48 48	50 51	52 55	54 58	56 62	57 66	59 70	60 74	62 78	63 82	65 87	66 91	68 95	69 100											
70	48 45	50 48	51 52	53 55	55 59	57 63	58 66	60 70	61 74	63 78	64 82	66 87	67 91	69 95	70 100										
71	47 42	49 46	51 49	53 52	54 56	56 59	58 63	59 67	61 71	63 75	64 79	65 83	67 87	68 91	70 96	71 100									
72	46 40	48 43	50 46	52 50	54 53	56 56	57 60	59 64	61 67	62 71	64 75	65 79	67 83	68 87	69 91	71 96	72 100								
73	46 37	48 41	50 44	52 47	53 50	55 53	56 57	58 60	60 64	62 68	63 71	65 75	66 79	68 83	69 87	70 91	72 96	73 100							
74	45 35	47 38	49 41	51 44	53 47	55 51	56 54	58 57	60 61	61 64	63 68	64 72	66 75	67 79	69 83	70 87	71 91	73 96	74 100						
75	44 33	46 36	48 39	50 42	52 45	54 48	56 51	58 55	59 58	61 61	62 65	64 68	65 72	67 76	68 80	70 83	71 87	72 92	74 96	75 100					
76	43 31	45 34	48 37	50 40	52 43	53 46	55 49	57 52	59 55	60 58	62 62	63 65	65 69	66 72	68 76	69 80	71 84	72 88	73 92	75 96	76 100				
77	42 29	45 32	47 35	49 37	51 40	53 43	55 46	56 49	58 52	60 55	61 59	63 62	65 66	66 69	68 73	69 76	70 80	72 84	73 88	74 92	76 96	77 100			
78	42 27	44 30	46 33	48 35	50 38	52 41	54 44	56 47	58 50	59 53	61 56	63 59	64 63	66 66	67 69	69 73	70 76	71 80	73 84	74 88	75 92	77 96	78 100		
79	41 26	43 28	45 31	48 33	50 36	52 39	54 41	55 44	57 47	59 50	61 53	62 56	64 60	65 63	67 66	68 70	70 73	71 77	72 80	74 84	75 88	76 92	78 96	79 100	
80	40 24	42 26	45 29	47 31	49 34	51 37	53 39	55 42	57 45	58 48	60 51	62 54	63 57	65 60	66 63	68 67	69 70	71 73	72 77	73 81	75 84	76 88	77 92	79 96	80 100

WET BULB TEMPERATURES

DRY BULB TEMPERATURES

	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
81	-23 1	-5 3	+5 5	12 7	17 9	22 11	26 13	30 16	33 18	36 20	39 22	42 25	44 27	46 30	48 32	50 35	52 37	54 40	56 43	58 45	60 48	61 51	63 54	64 57	66 60	68 64	69 67	70 70	72 74	73 77	75 81	76 84	77 88	78 92	80 96	81 100				
82	-40 1	-11 2	+1 4	9 6	15 8	20 10	25 12	29 14	32 16	35 19	38 21	41 23	43 25	46 28	48 30	50 33	52 35	54 38	56 41	57 43	59 46	61 49	62 52	64 55	66 58	67 61	69 64	70 67	71 71	73 74	74 77	76 81	77 85	78 89	79 92	81 96	82 100			
83		-19 2	-3 3	+6 5	13 7	19 9	23 11	27 13	31 15	34 17	37 19	40 22	42 24	45 26	47 29	49 31	51 33	53 36	55 38	57 41	59 44	60 47	62 49	64 52	65 55	67 58	68 61	70 64	71 68	73 71	74 74	75 78	77 81	78 85	79 88	80 92	82 96	83 100		
84		-31 1	-8 3	+3 4	11 6	17 8	22 10	26 12	30 14	33 16	36 18	39 20	42 22	44 25	46 27	49 29	51 32	53 34	55 37	56 39	58 42	60 44	62 47	63 50	65 53	66 56	68 59	69 62	71 65	72 68	74 71	75 74	76 78	78 81	79 85	80 89	82 92	83 96	84 100	
85			-15 2	-1 4	+8 5	14 7	20 9	24 11	28 13	32 15	35 17	38 19	41 21	43 23	46 25	48 28	50 30	52 32	54 35	56 37	58 40	59 42	61 45	63 48	64 50	66 53	68 56	69 59	70 62	72 65	73 68	75 71	76 75	77 78	79 81	80 85	81 89	83 92	84 96	85 100
86			-25 1	-6 3	+5 4	12 6	18 8	23 10	27 12	31 14	34 16	37 18	40 20	42 22	45 24	47 26	49 28	51 31	53 33	55 35	57 38	59 40	61 43	62 45	64 48	66 51	67 54	69 56	70 59	72 62	73 65	74 68	76 72	77 75	78 78	80 82	81 85	82 89	84 92	85 96
87			-44	-12 2	+1 4	9 5	16 7	21 9	26 11	29 13	33 14	36 16	39 18	42 20	44 22	46 25	49 27	51 29	53 31	55 33	57 36	59 38	60 41	62 43	64 46	65 48	67 51	68 54	70 57	71 60	73 63	74 66	75 69	77 72	78 75	79 78	81 82	82 85	83 89	85 92
88				-20 1	-3 3	+7 5	14 6	19 8	24 10	28 12	32 13	35 15	38 17	41 19	43 21	46 23	48 25	50 27	52 30	54 32	56 34	58 36	60 39	62 41	63 44	65 46	66 49	68 52	69 54	71 57	72 60	74 63	75 66	77 69	78 72	79 75	81 79	82 82	83 85	84 89
89				-33 1	-8 2	+3 4	11 5	17 7	22 9	27 11	30 12	34 14	37 16	40 18	43 20	45 22	47 24	50 26	52 28	54 30	56 32	58 35	59 37	61 39	63 42	64 44	66 47	68 49	69 52	71 55	72 58	73 60	75 63	76 66	78 69	79 72	80 76	82 79	83 82	84 86
90					-15 2	-1 3	+8 5	15 6	21 8	25 10	29 11	33 13	36 15	39 17	42 19	44 21	47 22	49 25	51 27	53 29	55 31	57 33	59 35	61 38	62 40	64 42	66 45	67 47	69 50	70 52	72 55	73 58	75 61	76 64	77 67	79 70	80 73	81 76	83 79	84 82
91					-25 1	-5 2	+5 4	13 5	19 7	24 9	28 10	32 12	35 14	38 16	41 17	43 19	46 21	48 23	50 25	53 27	55 29	57 31	58 34	60 36	62 38	64 40	65 43	67 45	68 48	70 50	71 53	73 56	74 58	76 61	77 64	78 67	80 70	81 73	82 76	84 79
92					-44	-11 2	+2 3	10 5	17 6	22 8	27 10	30 11	34 13	37 15	40 16	43 18	45 20	48 22	50 24	52 26	54 28	56 30	58 32	60 34	61 36	63 39	65 41	66 43	68 46	70 48	71 51	73 53	74 56	75 59	77 61	78 64	79 67	81 70	82 73	83 76
93						-18 1	-2 3	+8 4	15 6	20 7	25 9	29 10	33 12	36 14	39 15	42 17	44 19	47 21	49 23	51 24	53 26	55 28	57 30	59 33	61 35	63 37	64 39	66 41	68 44	69 46	71 49	72 51	74 54	75 56	76 59	78 62	79 64	81 67	82 70	83 73
94						-31 1	-7 2	+4 3	12 5	18 6	23 8	28 9	32 11	35 13	38 14	41 16	44 18	46 20	49 21	51 23	53 25	55 27	57 29	59 31	61 33	62 35	64 37	66 40	67 42	69 44	70 47	72 49	73 51	75 54	76 57	78 59	79 62	80 65	82 68	83 71
95							-13 1	+1 3	10 4	16 6	22 7	26 9	30 10	34 12	37 13	40 15	43 17	45 18	48 20	50 22	52 24	54 26	56 28	58 30	60 32	62 34	64 36	65 38	67 40	69 42	70 45	72 47	73 49	75 52	76 54	77 57	79 60	80 62	81 65	83 68
96							-22 1	-3 2	+7 4	14 5	20 6	25 8	29 9	33 11	36 12	39 14	42 16	45 17	47 19	50 21	52 23	54 24	56 26	58 28	60 30	61 32	63 34	65 36	67 38	68 41	70 43	71 45	73 47	74 50	76 52	77 55	78 57	80 60	81 63	82 65
97							-38	-9 2	+4 3	12 4	18 6	23 7	28 9	32 10	35 12	38 13	41 15	44 16	46 18	49 20	51 21	53 23	55 25	57 27	59 29	61 31	63 33	64 35	66 37	68 39	69 41	71 43	72 45	74 48	75 50	77 53	78 55	80 58	81 60	82 63
98								-16 1	0 2	+9 4	16 5	22 6	26 8	30 9	34 11	37 12	40 14	43 15	46 17	48 19	50 20	53 22	55 24	57 26	59 27	61 29	62 31	64 33	66 35	67 37	69 39	71 41	72 44	74 46	75 48	76 51	78 53	79 55	81 58	82 60
99								-26 1	-5 2	+6 3	14 4	20 6	25 7	29 9	33 10	36 11	39 13	42 14	45 16	48 18	50 19	52 21	54 23	56 24	58 26	60 28	62 30	64 32	65 34	67 36	69 38	70 40	72 42	73 44	75 46	76 49	78 51	79 53	80 56	82 58
100								-47	-10 1	+3 3	11 4	18 5	23 7	28 8	32 9	35 11	39 12	42 14	44 15	47 17	49 18	51 20	54 21	56 23	58 25	60 27	61 28	63 30	65 32	67 34	68 36	70 38	71 40	73 42	74 44	76 47	77 49	79 51	80 54	81 56
101									-18 1	-1 2	+9 3	16 5	22 6	26 7	31 9	34 10	38 11	41 13	43 14	46 16	49 17	51 19	53 20	55 22	57 24	59 25	61 27	63 29	65 31	66 33	68 35	70 37	71 39	73 41	74 43	76 45	77 47	78 49	80 52	81 54
102									-29	-6 2	+6 3	14 4	20 5	25 7	29 8	33 9	37 11	40 12	43 13	45 15	48 16	50 18	53 19	55 21	57 23	59 24	61 26	62 28	64 29	66 31	68 33	69 35	71 37	72 39	74 41	75 43	77 45	78 47	80 50	81 52
103										-12 1	+2 2	11 4	18 5	23 6	28 7	32 9	36 10	39 11	42 13	45 14	47 15	50 17	52 18	54 20	56 22	58 23	60 25	62 26	64 28	66 30	67 32	69 34	70 35	72 37	74 39	75 41	76 43	78 46	79 48	81 50
104										-20 1	-2 2	+9 3	16 4	22 5	27 7	31 8	35 9	38 10	41 12	44 13	46 15	49 16	51 17	54 19	56 20	58 22	60 24	62 25	63 27	65 29	67 30	68 32	70 34	72 36	73 38	75 40	76 42	78 44	79 46	80 48
105										-33	-6 1	+6 3	14 4	20 5	25 6	30 7	33 9	37 10	40 11	43 12	46 14	48 15	51 17	53 18	55 20	57 21	59 23	61 24	63 26	65 27	66 29	68 31	70 33	71 34	73 36	74 38	76 40	77 42	79 44	80 46
106											-13 1	+2 2	11 3	18 4	24 6	28 7	32 8	36 9	39 10	42 12	45 13	48 14	50 16	52 17	55 19	57 20	59 22	61 23	63 25	64 26	66 28	68 30	69 31	71 33	73 35	74 37	76 39	77 41	79 43	80 45
107											-21 1	-2 2	+9 3	16 4	22 5	27 6	31 7	35 9	38 10	41 11	44 12	47 14	49 15	52 16	54 18	56 19	58 21	60 22	62 24	64 25	66 27	67 28	69 30	71 32	72 34	74 35	75 37	77 39	78 41	80 43
108											-35	-7 1	+5 2	14 3	20 5	25 6	30 7	34 8	37 9	41 10	43 12	46 13	49 14	51 15	53 17	56 18	58 20	60 21	62 23	63 24	65 26	67 27	69 29	70 31	72 32	74 34	75 36	77 38	78 39	79 41
109												-13 1	+2 2	11 3	18 4	24 5	29 6	33 7	36 9	40 10	43 11	45 12	48 13	51 15	53 16	55 17	57 19	59 20	61 22	63 23	65 25	67 26	68 28	70 29	72 31	73 33	75 34	76 36	78 38	79 40

APPENDIX 3. CLOUD CLASSIFICATION AND IDENTIFICATION

A3.1 Cloud Observations

Although detailed cloud observations are not a required part of routine fire-weather reporting, a sound knowledge of cloud types and forms can help fire management personnel in many ways, particularly during times of wildfire or prescribed burning. With this knowledge, a person will have a better chance of foreseeing such events as lightning, rainstorms, sudden gusts of wind, or possible sustained high winds (Hardy and others 1955).

CLOUD CLASSIFICATION

Clouds are classified into four families distinguished by their height above ground: High clouds (cirrus or cirroform clouds), middle clouds (given an "alto" prefix), low clouds, and clouds with vertical development (cumulus or cumuloform clouds). High clouds, usually composed entirely of ice crystals, generally occur at altitudes ranging from 20,000 to 40,000 ft. Middle clouds may have bases between about 8,000 ft and 20,000 ft.

Cumulus clouds, forming near the top of rising warm air columns (convection columns), can have base heights ranging from a few thousand feet to 15,000 ft or higher. In the Western United States, their formation is particularly favored over mountain terrain. The clouds may range from small, puffy but relatively flat, fair-weather cumulus to massive cumulonimbus associated with thunderstorms. These storm clouds ("thunderheads") commonly extend to altitudes of 30,000 ft and may reach 50,000 ft or higher.

CLOUD CHARACTERISTICS AND INDICATIONS

The basic cloud characteristics are summarized in figure A3.1. Illustrations of the various stages of cumulus cloud development appear in figures A3.2 through A3.5. In addition to the potential storm indication by towering cumulus, a middle type of cloud termed altocumulus castellanus (fig. A3.6) should also be noted. Forenoon occurrence of these clouds, with their characteristic turret form, often precedes thunderstorm activity in the afternoon.

Another type of cloud potentially significant in fireweather is the lens-shaped altocumulus, termed a lenticular cloud (fig. A3.7). These clouds (Schroeder and Buck 1970; Schaefer and Day 1981), appearing over and to the lee of mountain ranges, indicate strong winds aloft and possible turbulence near ridges. The clouds result from waves in the air flow that are generated when the strong winds blow across the mountains.

A form of altocumulus often associated with a large-scale weather system is shown in figure A3.8; clouds producing rain may or may not follow. Termed altocumulus undulatus, the clouds are arranged in parallel bands at right angles to the wind. The distinct roll pattern usually indicates relatively strong winds at cloud level.

Cirrus-type clouds, composed of ice crystals and typically feathery in appearance (fig. A3.9), are sometimes the forerunner of an approaching weather system. Besides indicating high-altitude moisture and wind direction, they may also indicate an upper-air "jetstream," particularly when the cloud elements are in the form of long plumes (fig. A3.9, part B). A dense type of cirrus (fig. A3.10) may be produced from the anvil tops of thunderstorms.

Further details about cloud types may be obtained from Schroeder and Buck (1970), Schaefer and Day (1981), and cloud identification charts available at National Weather Service offices.

Family	Genus	Species	Abbreviation	Description
HIGH CLOUDS 16,500 to 45,000 feet	Cirrus		Ci	Wispy, hair-like clouds. Formed of delicate filaments, patches, narrow bands, or feather-like plumes.
	Cirrocumulus		Cc	Thin, white, grainy, and rippled patches or sheets or layers. Show very slight vertical development in the form of turrets and shallow towers.
	Cirrostratus		Cs	Transparent, hair-like or smooth whitish veil. Covers all or part of the sky. Produces halo phenomenon.
MIDDLE CLOUDS 6,500 to 23,000 feet	Altocumulus		Ac	Extensive sheet of regularly arranged white and gray, somewhat rounded cloudlets.
		Altocumulus castellanus	Ac cas	Altocumulus with vertical development in the form of small towers or turrets. Elements have a common horizontal base and appear to be arranged in lines.
		Altocumulus lenticularis	Ac len	A patch of altocumulus in the shape of a lens or almond. Often stationary and very elongated with well-defined outlines.
	Altostratus		As	Grayish or bluish sheet or layer covering all or part of the sky. Sun may show vaguely but no halo.
	Nimbostratus		Ns	Dark, gray cloud layer thick enough to blot out the sun. Continuous rain or snow; without lightning.
LOW CLOUDS Surface to 6,500 feet	Stratocumulus		Sc	Gray and whitish layer with dark patches formed of nonfibrous rounded masses or rolls. Like altocumulus but lower. May have virga at base.
	Stratus		St	Gray layer with uniform base which may give drizzle. When sun is visible through cloud, its outline is clearly discernible.
THE VERTICAL CLOUDS	Cumulus		Cu	Detached clouds, generally dense and sharply outlined. Developing vertically in the form of rising mounds, domes, or towers. Brilliant white in sunlight. Base is dark and nearly horizontal.
		Cumulus humilis	Cu hum	*Fair weather cumulus* with little vertical extent; generally appear flattened.
		Cumulus congestus	Cu con	*Towering cumulus* with strong vertical extent in the form of domes or towers. May be accompanied by other cumulus or stratocumulus with bases at same level.
	Cumulonimbus		Cb	Heavy and dense cloud with considerable vertical extent, in the form of a mountain or huge towers. The upper part usually smooth, sometimes fibrous, with top flattened to anvil shape or vast cirrus plume. Produces lightning, hail, tornadoes, heavy rain, and high winds.
		Cumulonimbus calvus	Cb cal	*Cumulonimbus without anvil.* Any tower development lacks sharp outlines. May have rain or virga at base.
		Cumulonimbus capillatus	Cb cap	*Cumulonimbus with anvil-shaped top.* Top may also be in the form of a plume, or a vast more or less disorderly mass of hair. Top may extend to 40,000 feet or more. May have rain or virga at base. Produces lightning, hail, heavy rain, and high winds.

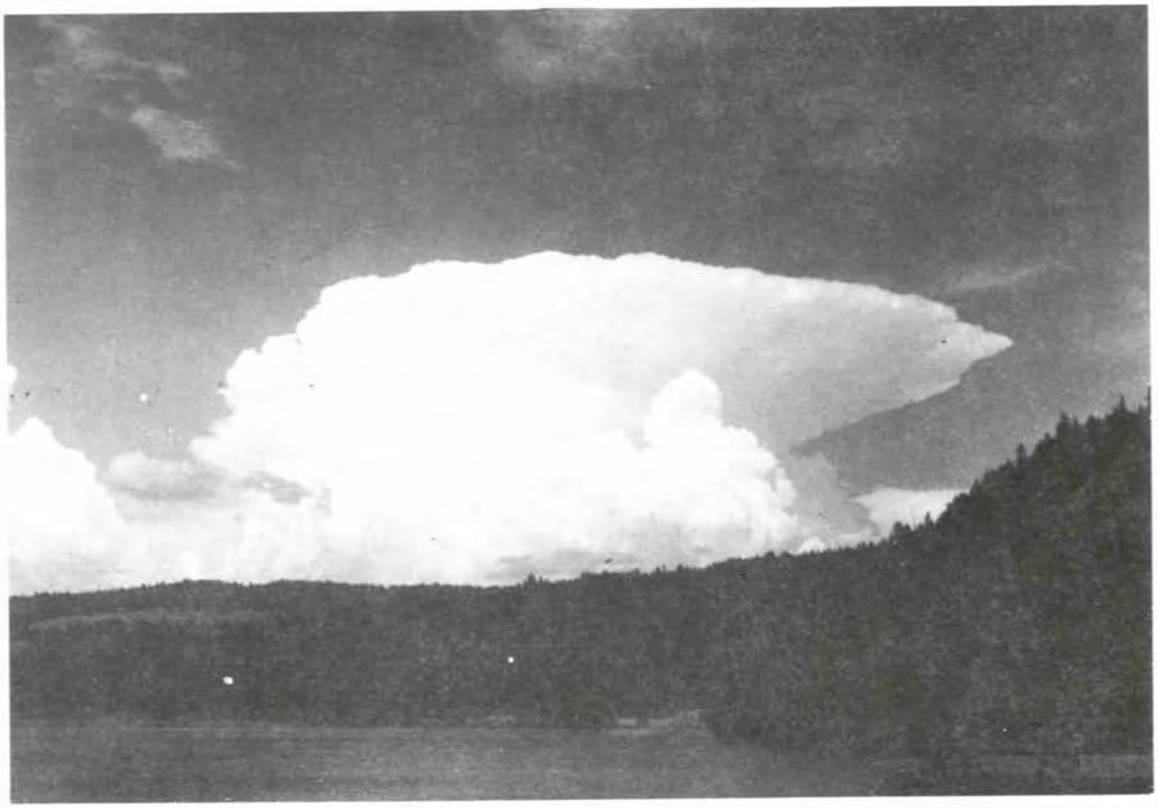
Figure A3.1—A simplified cloud classification (reproduced from Fischer and Hardy 1976).

Figure A3.2—Fair-weather cumulus.

Figure A3.3 (A and B)—Towering cumulus.

Figure A3.3 (Con.)

Figure A3.4—Cumulonimbus (ice-topped cumulus), without anvil.



A

Figure A3.5 (A and B)—Cumulonimbus with anvil top. A: distant.

Figure A3.5 (con.)—B: thunderstorm in progress.

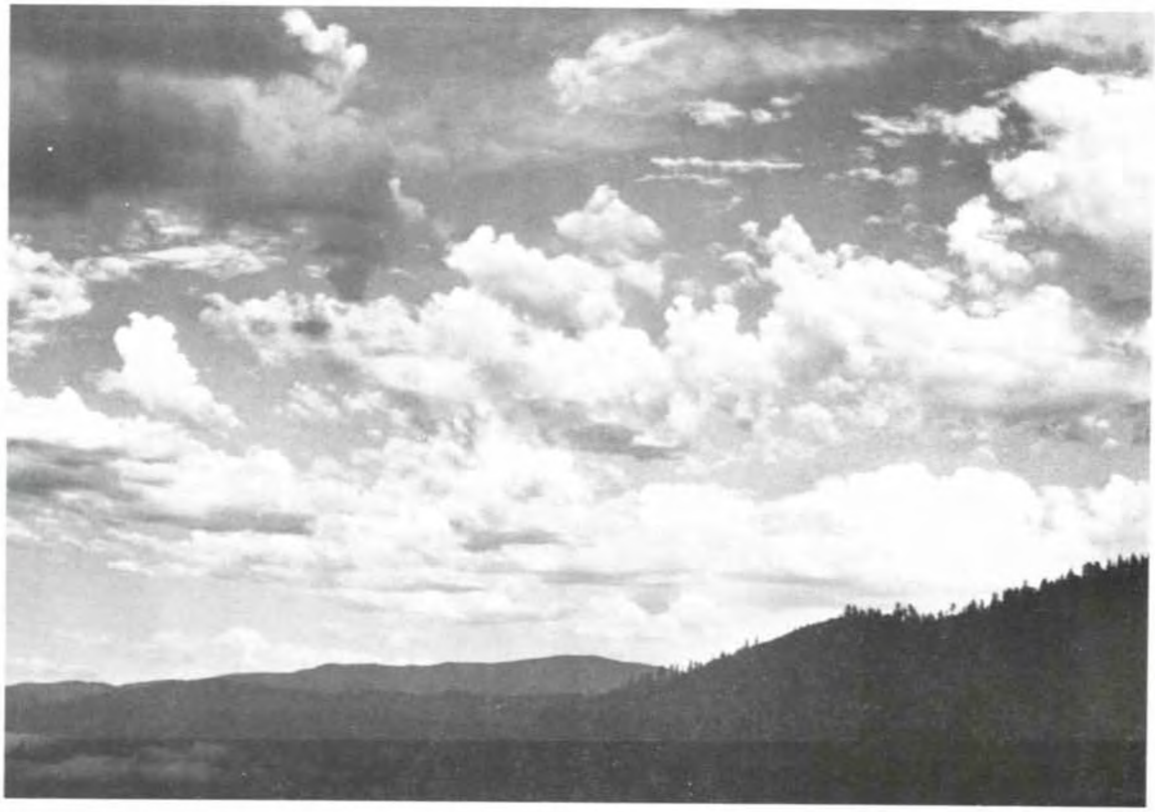


Figure A3.6—Altocumulus castellanus.

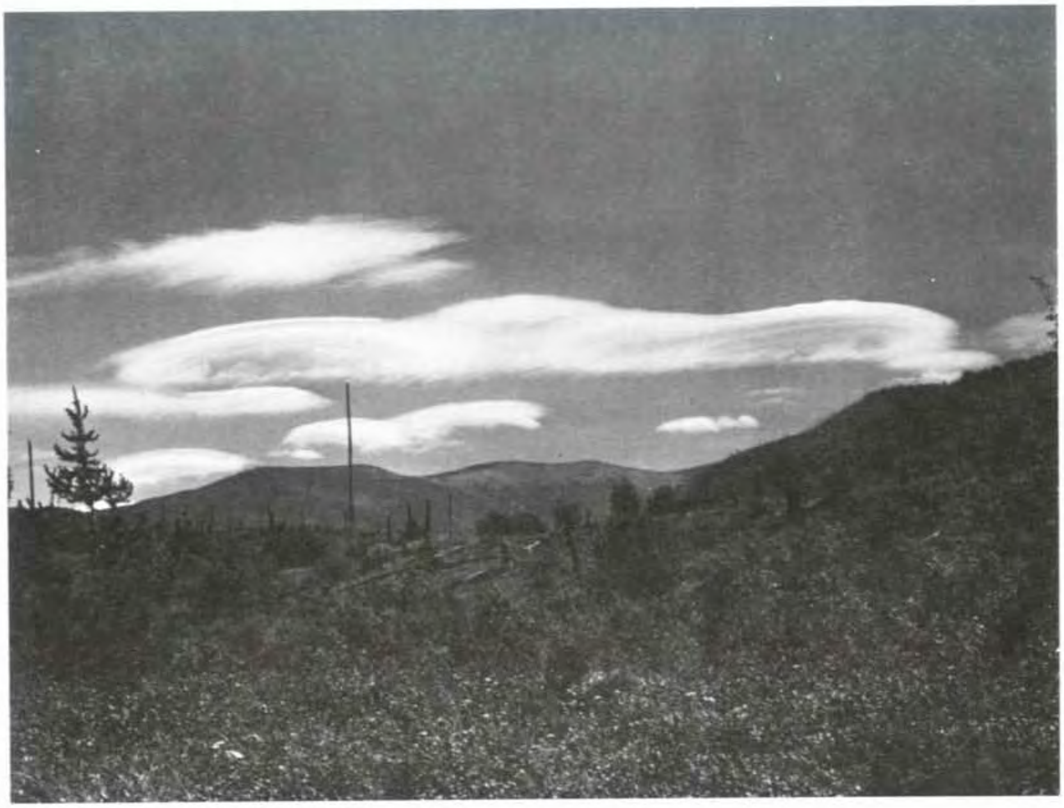


Figure A3.7—Altocumulus lenticularis (lenticular cloud).

Figure A3.8—Altocumulus undulatus.

A

B

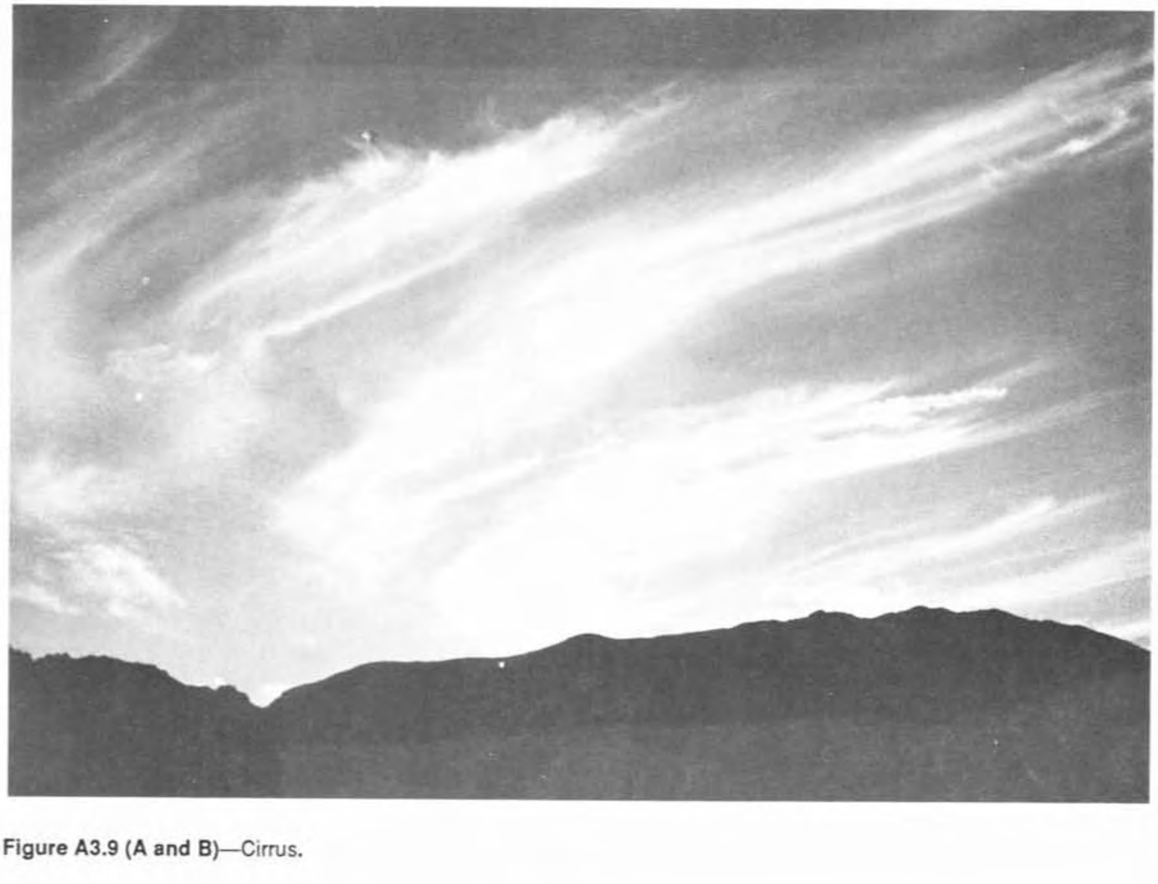
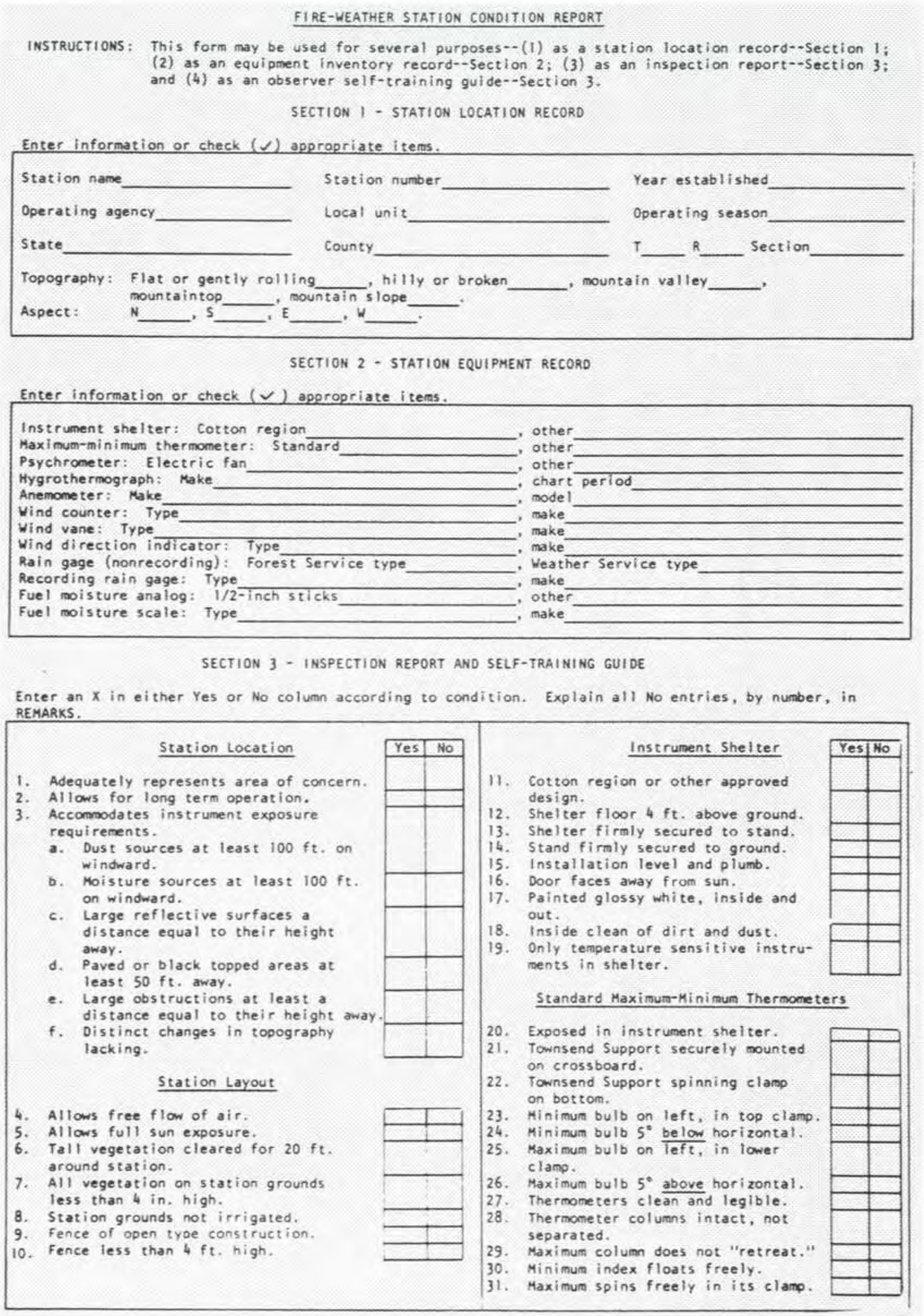


Figure A3.9 (A and B)—Cirrus.

Figure A3.10—Dense cirrus, derived from anvil top of cumulonimbus.

APPENDIX 4. EQUIPMENT INSTALLATION AND MAINTENANCE CHECKLISTS FOR MANUAL FIRE-WEATHER STATIONS



FIRE-WEATHER STATION CONDITION REPORT

INSTRUCTIONS: This form may be used for several purposes--(1) as a station location record--Section 1; (2) as an equipment inventory record--Section 2; (3) as an inspection report--Section 3; and (4) as an observer self-training guide--Section 3.

SECTION 1 - STATION LOCATION RECORD

Enter information or check (✓) appropriate items.

Station name ________ Station number ________ Year established ________

Operating agency ________ Local unit ________ Operating season ________

State ________ County ________ T____ R____ Section ________

Topography: Flat or gently rolling_____, hilly or broken_____, mountain valley_____, mountaintop_____, mountain slope_____.

Aspect: N_____, S_____, E_____, W_____.

SECTION 2 - STATION EQUIPMENT RECORD

Enter information or check (✓) appropriate items.

Instrument shelter: Cotton region ________, other ________

Maximum-minimum thermometer: Standard ________, other ________

Psychrometer: Electric fan ________, other ________

Hygrothermograph: Make ________, chart period ________

Anemometer: Make ________, model ________

Wind counter: Type ________, make ________

Wind vane: Type ________, make ________

Wind direction indicator: Type ________, make ________

Rain gage (nonrecording): Forest Service type ________, Weather Service type ________

Recording rain gage: Type ________, make ________

Fuel moisture analog: 1/2-inch sticks ________, other ________

Fuel moisture scale: Type ________, make ________

SECTION 3 - INSPECTION REPORT AND SELF-TRAINING GUIDE

Enter an X in either Yes or No column according to condition. Explain all No entries, by number, in REMARKS.

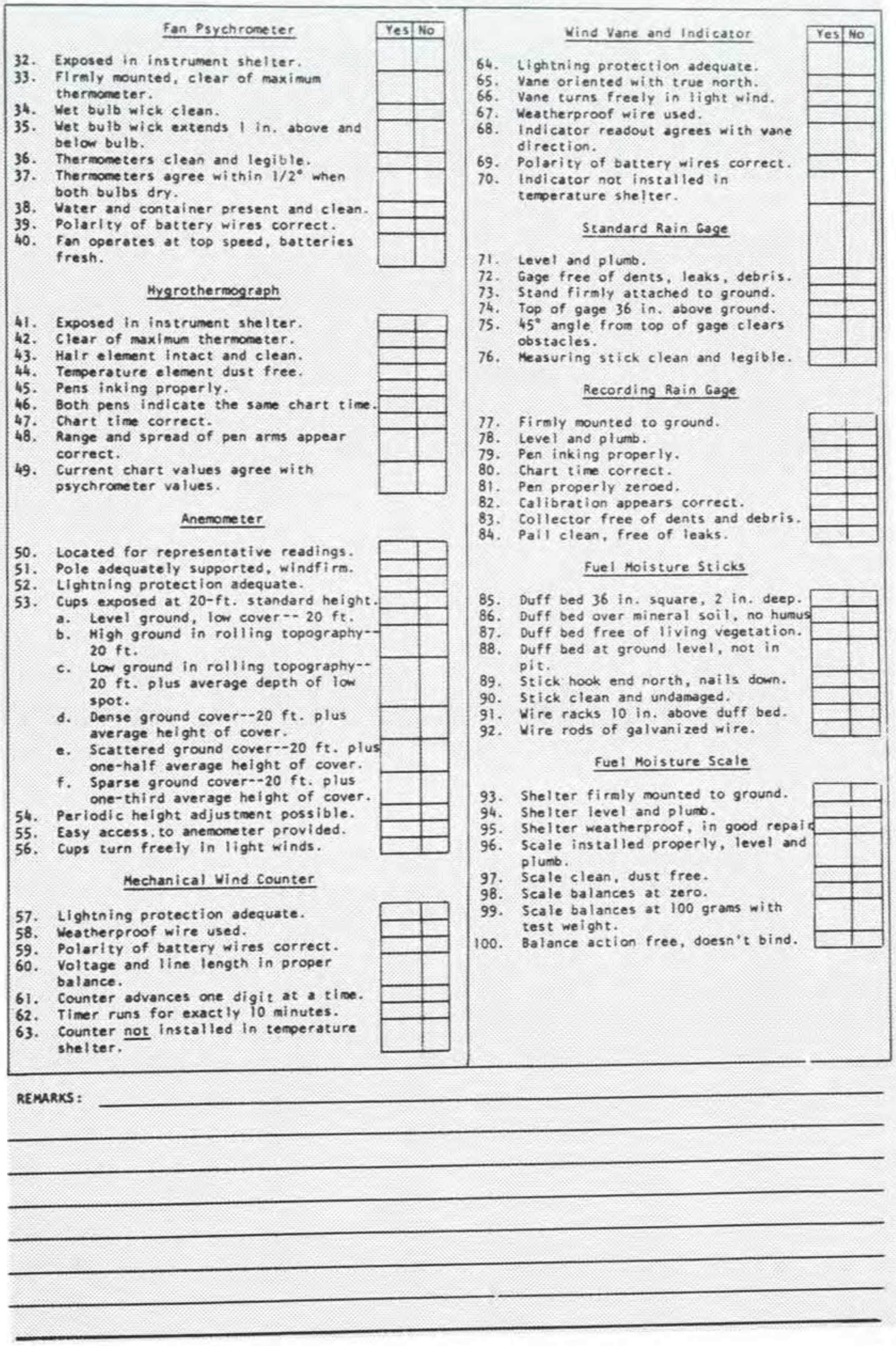
Station Location	Yes	No
1. Adequately represents area of concern.		
2. Allows for long term operation.		
3. Accommodates instrument exposure requirements.		
a. Dust sources at least 100 ft. on windward.		
b. Moisture sources at least 100 ft. on windward.		
c. Large reflective surfaces a distance equal to their height away.		
d. Paved or black topped areas at least 50 ft. away.		
e. Large obstructions at least a distance equal to their height away.		
f. Distinct changes in topography lacking.		

Station Layout		
4. Allows free flow of air.		
5. Allows full sun exposure.		
6. Tall vegetation cleared for 20 ft. around station.		
7. All vegetation on station grounds less than 4 in. high.		
8. Station grounds not irrigated.		
9. Fence of open type construction.		
10. Fence less than 4 ft. high.		

Instrument Shelter	Yes	No
11. Cotton region or other approved design.		
12. Shelter floor 4 ft. above ground.		
13. Shelter firmly secured to stand.		
14. Stand firmly secured to ground.		
15. Installation level and plumb.		
16. Door faces away from sun.		
17. Painted glossy white, inside and out.		
18. Inside clean of dirt and dust.		
19. Only temperature sensitive instruments in shelter.		

Standard Maximum-Minimum Thermometers		
20. Exposed in instrument shelter.		
21. Townsend Support securely mounted on crossboard.		
22. Townsend Support spinning clamp on bottom.		
23. Minimum bulb on left, in top clamp.		
24. Minimum bulb 5° below horizontal.		
25. Maximum bulb on left, in lower clamp.		
26. Maximum bulb 5° above horizontal.		
27. Thermometers clean and legible.		
28. Thermometer columns intact, not separated.		
29. Maximum column does not "retreat."		
30. Minimum index floats freely.		
31. Maximum spins freely in its clamp.		

Figure A4.1—Fire-weather station condition report (Fischer and Hardy 1976).



Fan Psychrometer	Yes	No
32. Exposed in instrument shelter.	☐	☐
33. Firmly mounted, clear of maximum thermometer.	☐	☐
34. Wet bulb wick clean.	☐	☐
35. Wet bulb wick extends 1 in. above and below bulb.	☐	☐
36. Thermometers clean and legible.	☐	☐
37. Thermometers agree within 1/2° when both bulbs dry.	☐	☐
38. Water and container present and clean.	☐	☐
39. Polarity of battery wires correct.	☐	☐
40. Fan operates at top speed, batteries fresh.	☐	☐

Hygrothermograph		
41. Exposed in instrument shelter.	☐	☐
42. Clear of maximum thermometer.	☐	☐
43. Hair element intact and clean.	☐	☐
44. Temperature element dust free.	☐	☐
45. Pens inking properly.	☐	☐
46. Both pens indicate the same chart time.	☐	☐
47. Chart time correct.	☐	☐
48. Range and spread of pen arms appear correct.	☐	☐
49. Current chart values agree with psychrometer values.	☐	☐

Anemometer		
50. Located for representative readings.	☐	☐
51. Pole adequately supported, windfirm.	☐	☐
52. Lightning protection adequate.	☐	☐
53. Cups exposed at 20-ft. standard height.	☐	☐
a. Level ground, low cover-- 20 ft.	☐	☐
b. High ground in rolling topography--20 ft.	☐	☐
c. Low ground in rolling topography--20 ft. plus average depth of low spot.	☐	☐
d. Dense ground cover--20 ft. plus average height of cover.	☐	☐
e. Scattered ground cover--20 ft. plus one-half average height of cover.	☐	☐
f. Sparse ground cover--20 ft. plus one-third average height of cover.	☐	☐
54. Periodic height adjustment possible.	☐	☐
55. Easy access to anemometer provided.	☐	☐
56. Cups turn freely in light winds.	☐	☐

Mechanical Wind Counter		
57. Lightning protection adequate.	☐	☐
58. Weatherproof wire used.	☐	☐
59. Polarity of battery wires correct.	☐	☐
60. Voltage and line length in proper balance.	☐	☐
61. Counter advances one digit at a time.	☐	☐
62. Timer runs for exactly 10 minutes.	☐	☐
63. Counter <u>not</u> installed in temperature shelter.	☐	☐

Wind Vane and Indicator	Yes	No
64. Lightning protection adequate.	☐	☐
65. Vane oriented with true north.	☐	☐
66. Vane turns freely in light wind.	☐	☐
67. Weatherproof wire used.	☐	☐
68. Indicator readout agrees with vane direction.	☐	☐
69. Polarity of battery wires correct.	☐	☐
70. Indicator not installed in temperature shelter.	☐	☐

Standard Rain Gage		
71. Level and plumb.	☐	☐
72. Gage free of dents, leaks, debris.	☐	☐
73. Stand firmly attached to ground.	☐	☐
74. Top of gage 36 in. above ground.	☐	☐
75. 45° angle from top of gage clears obstacles.	☐	☐
76. Measuring stick clean and legible.	☐	☐

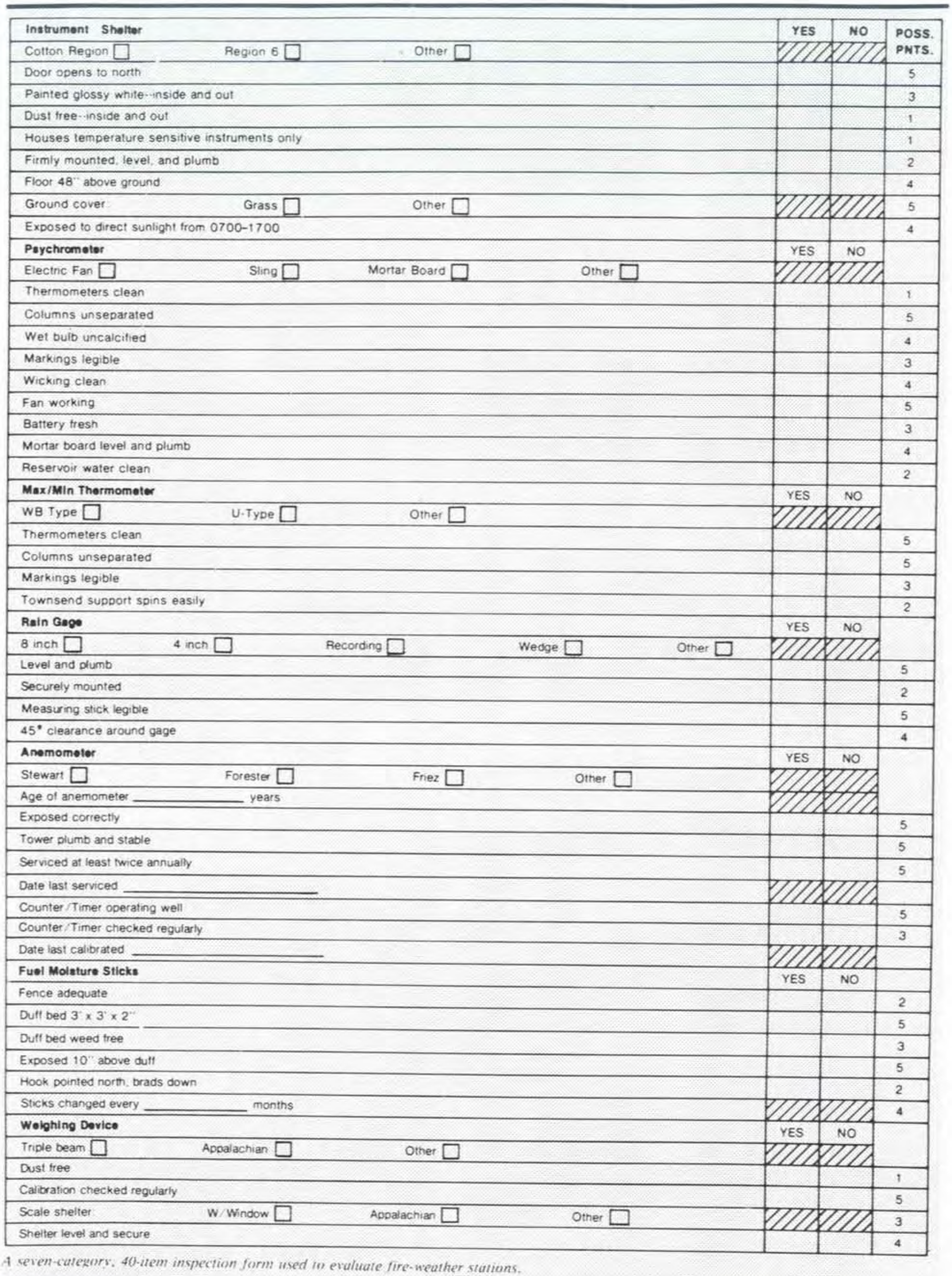
Recording Rain Gage		
77. Firmly mounted to ground.	☐	☐
78. Level and plumb.	☐	☐
79. Pen inking properly.	☐	☐
80. Chart time correct.	☐	☐
81. Pen properly zeroed.	☐	☐
82. Calibration appears correct.	☐	☐
83. Collector free of dents and debris.	☐	☐
84. Pail clean, free of leaks.	☐	☐

Fuel Moisture Sticks		
85. Duff bed 36 in. square, 2 in. deep.	☐	☐
86. Duff bed over mineral soil, no humus	☐	☐
87. Duff bed free of living vegetation.	☐	☐
88. Duff bed at ground level, not in pit.	☐	☐
89. Stick hook end north, nails down.	☐	☐
90. Stick clean and undamaged.	☐	☐
91. Wire racks 10 in. above duff bed.	☐	☐
92. Wire rods of galvanized wire.	☐	☐

Fuel Moisture Scale		
93. Shelter firmly mounted to ground.	☐	☐
94. Shelter level and plumb.	☐	☐
95. Shelter weatherproof, in good repai	☐	☐
96. Scale installed properly, level and plumb.	☐	☐
97. Scale clean, dust free.	☐	☐
98. Scale balances at zero.	☐	☐
99. Scale balances at 100 grams with test weight.	☐	☐
100. Balance action free, doesn't bind.	☐	☐

REMARKS: ____________________

Figure 4.1 (Con.)



Instrument Shelter	**YES**	**NO**	**POSS. PNTS.**
Cotton Region ☐ Region 6 ☐ Other ☐	▨	▨	
Door opens to north			5
Painted glossy white--inside and out			3
Dust free--inside and out			1
Houses temperature sensitive instruments only			1
Firmly mounted, level, and plumb			2
Floor 48" above ground			4
Ground cover: Grass ☐ Other ☐	▨	▨	5
Exposed to direct sunlight from 0700–1700			4
Psychrometer	YES	NO	
Electric Fan ☐ Sling ☐ Mortar Board ☐ Other ☐	▨	▨	
Thermometers clean			1
Columns unseparated			5
Wet bulb uncalcified			4
Markings legible			3
Wicking clean			4
Fan working			5
Battery fresh			3
Mortar board level and plumb			4
Reservoir water clean			2
Max/Min Thermometer	YES	NO	
WB Type ☐ U-Type ☐ Other ☐	▨	▨	
Thermometers clean			5
Columns unseparated			5
Markings legible			3
Townsend support spins easily			2
Rain Gage	YES	NO	
8 inch ☐ 4 inch ☐ Recording ☐ Wedge ☐ Other ☐	▨	▨	
Level and plumb			5
Securely mounted			2
Measuring stick legible			5
45° clearance around gage			4
Anemometer	YES	NO	
Stewart ☐ Forester ☐ Friez ☐ Other ☐	▨	▨	
Age of anemometer __________ years	▨	▨	
Exposed correctly			5
Tower plumb and stable			5
Serviced at least twice annually			5
Date last serviced ________________	▨	▨	
Counter/Timer operating well			5
Counter/Timer checked regularly			3
Date last calibrated ________________	▨	▨	
Fuel Moisture Sticks	YES	NO	
Fence adequate			2
Duff bed 3' x 3' x 2"			5
Duff bed weed free			3
Exposed 10" above duff			5
Hook pointed north, brads down			2
Sticks changed every __________ months	▨	▨	4
Weighing Device	YES	NO	
Triple beam ☐ Appalachian ☐ Other ☐	▨	▨	
Dust free			1
Calibration checked regularly			5
Scale shelter: W/Window ☐ Appalachian ☐ Other ☐	▨	▨	3
Shelter level and secure			4

A seven-category, 40-item inspection form used to evaluate fire-weather stations.

Figure A4.2—Inspection form for evaluating station maintenance (Frost and Haines 1982).

APPENDIX 5. DETAILED SPECIFICATION DRAWINGS FOR MISCELLANEOUS ITEMS AT MANUAL FIRE-WEATHER STATIONS

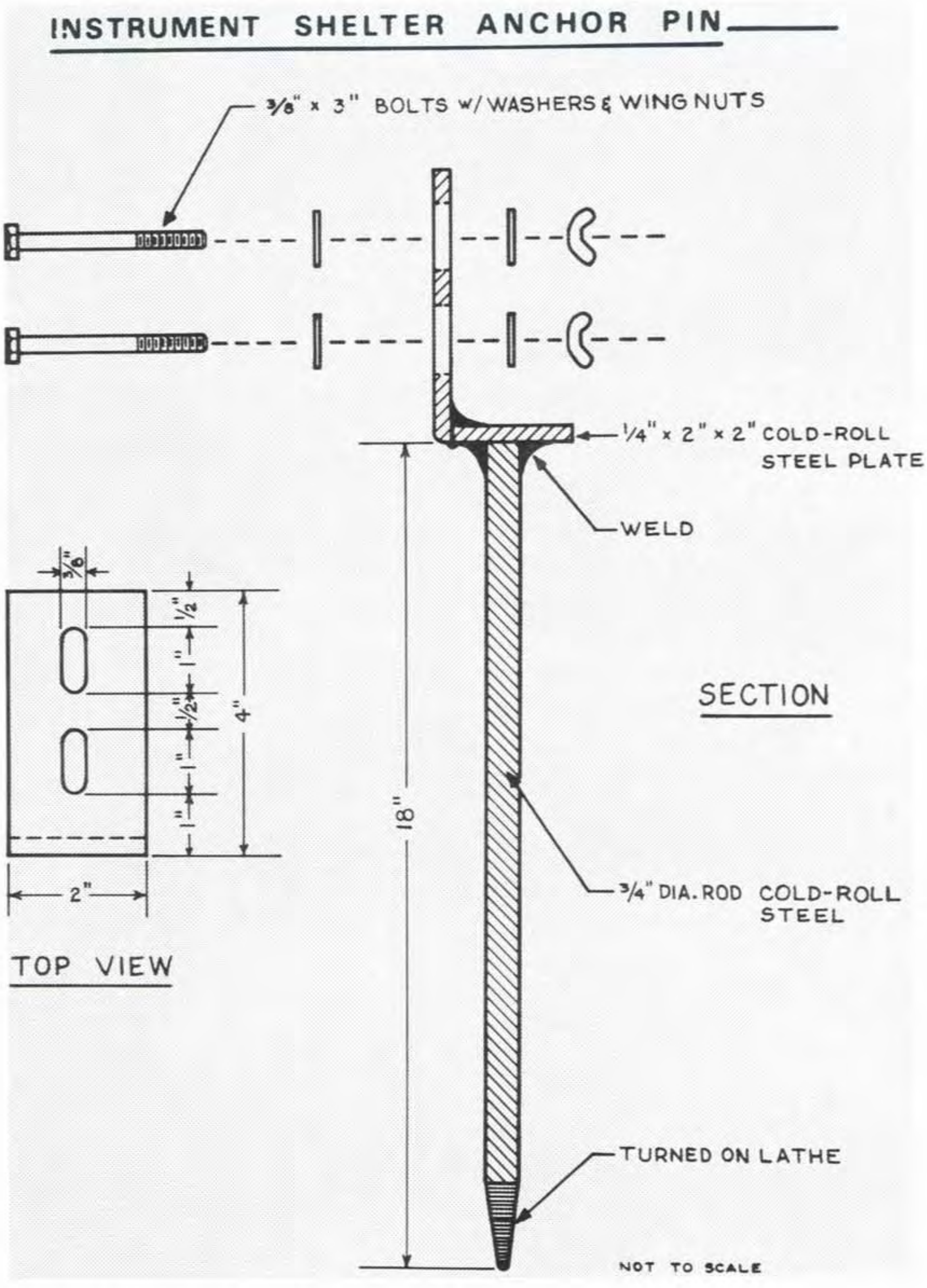


Figure A5.1—Instrument shelter anchor pin (section 16.1).

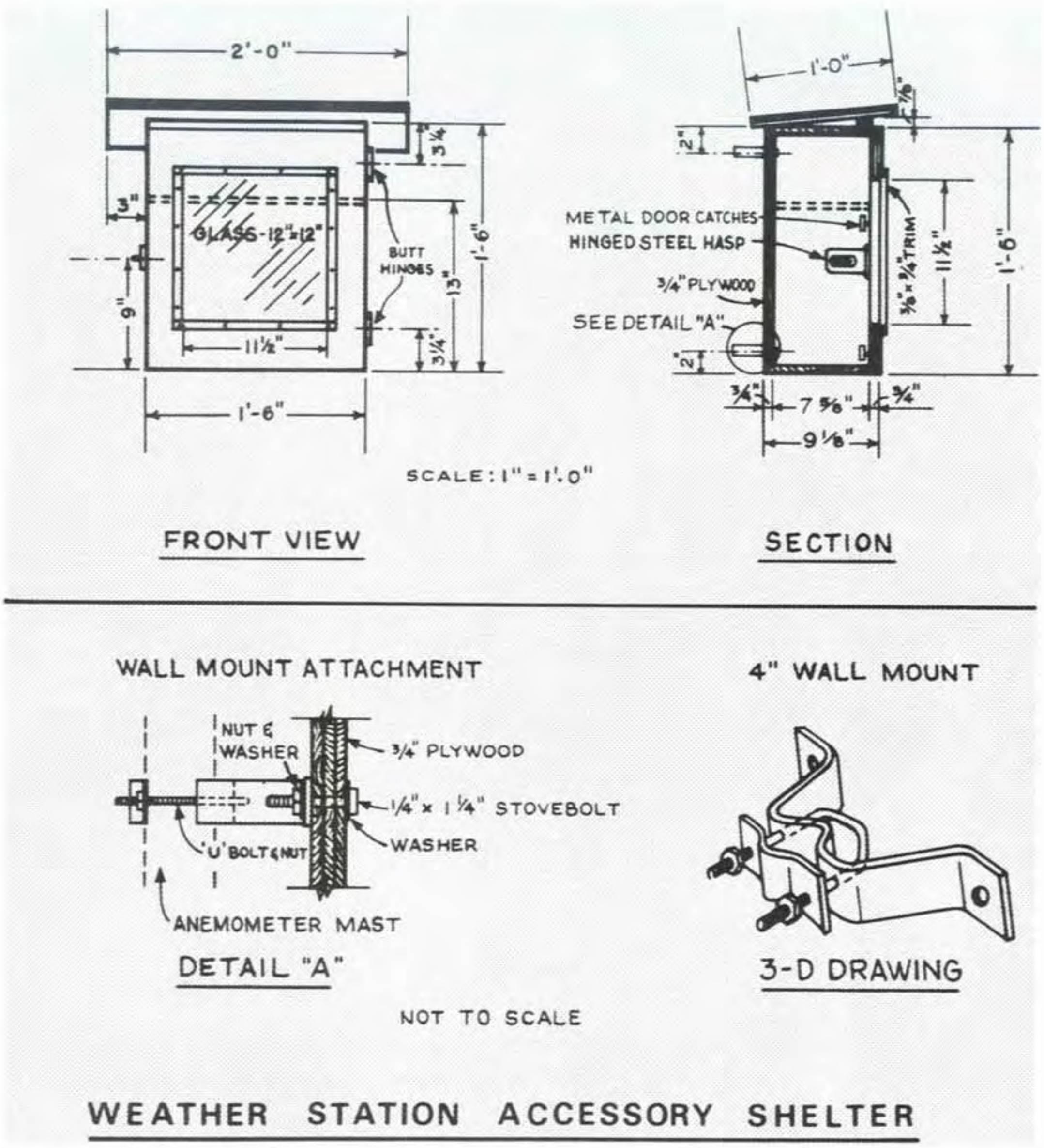


Figure A5.2—Weather station accessory shelter (section 17.2).

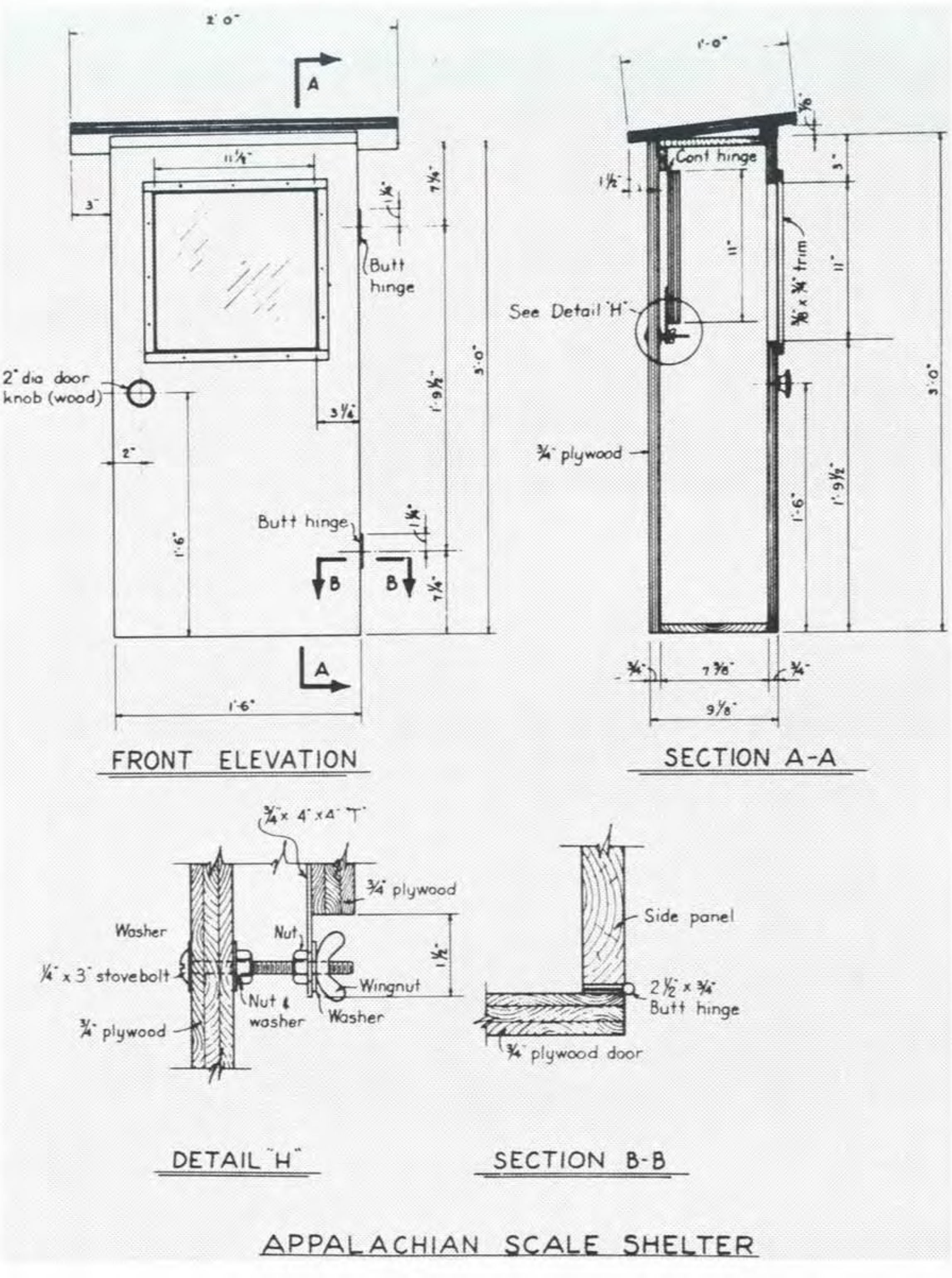
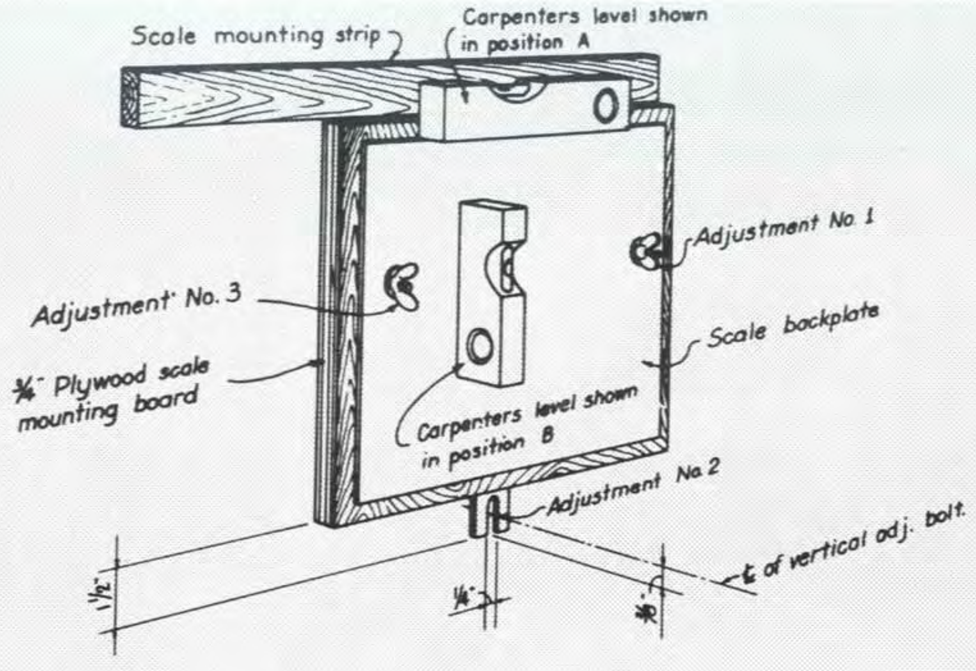
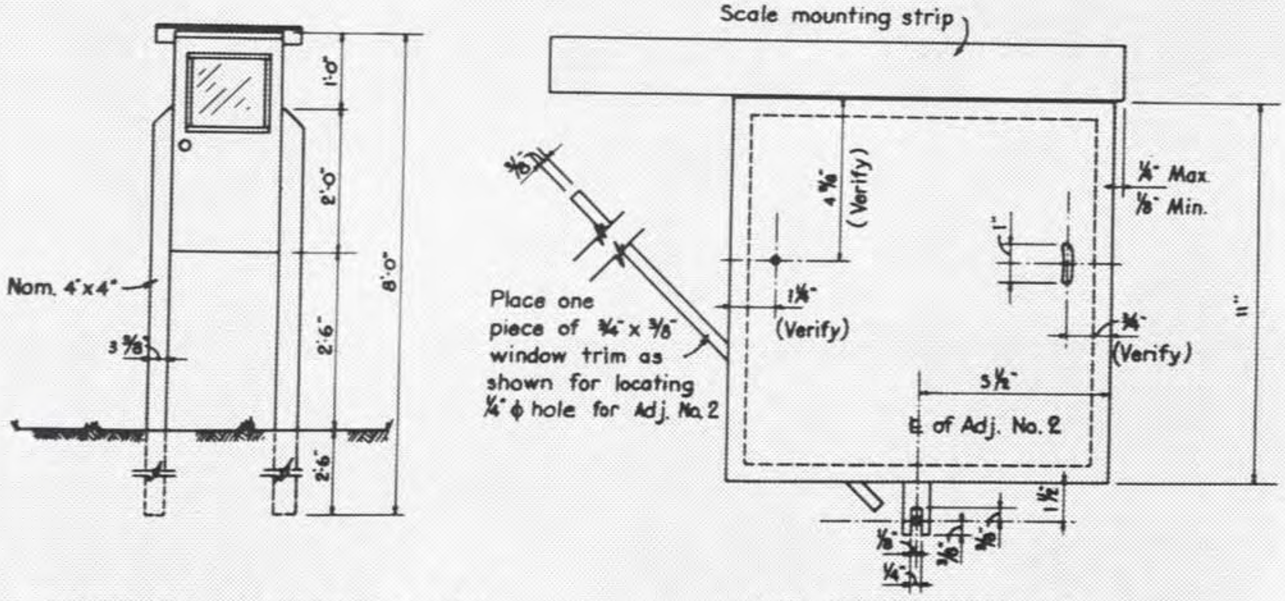


Figure A5.3—Appalachian scale shelter (sections 10.2, 19.2).



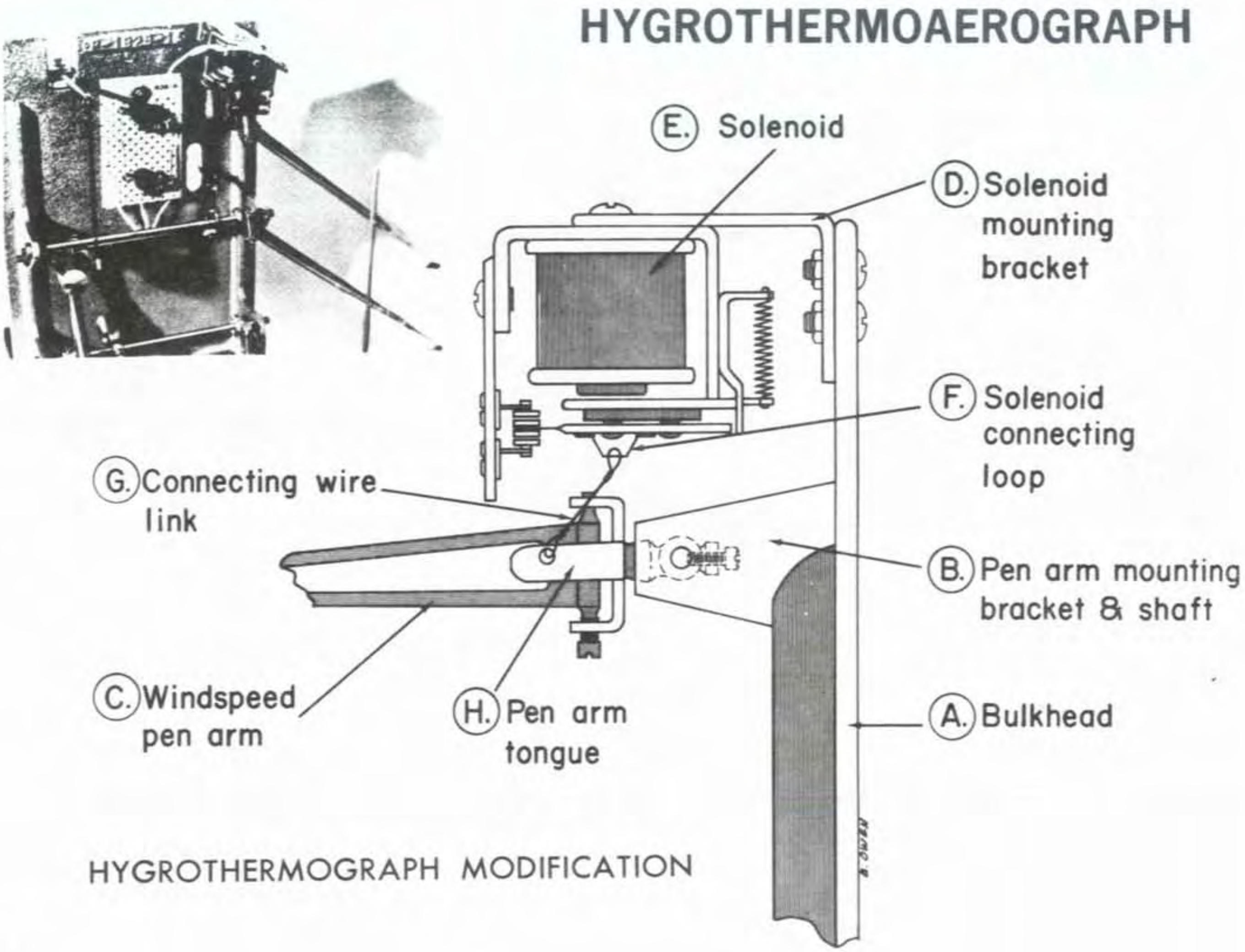
PERSPECTIVE VIEW
SCALE LEVELING DETAIL



SHELTER MOUNTING DETAIL

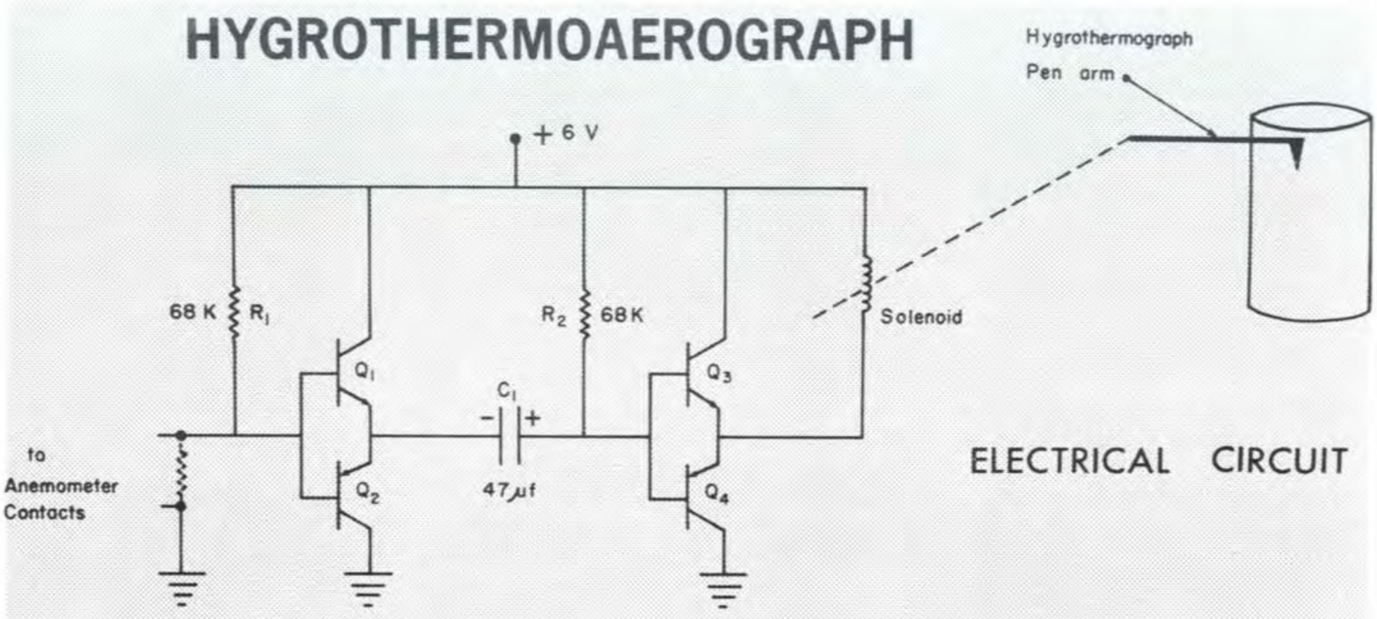
MOUNTING BOARD DETAIL

Figure A5.3 (Con.)



A

Figure A5.4—Hygrothermoaerograph (section 8.1): A, mechanical details; B, electrical circuit.



Parts List

1 – Solenoid	– D.C. Relay; 200 ohm w/silver contacts.(SIGMA-200 or equivalent.)
2 – Resistors	– R_1 and R_2 = 68k, ± 10%; 1/2 watt.
1 – Capacitor	– C_1 = 47µf, 10 volt D.C.; ± 10%.
1 – Battery	– 6 volt, lantern type.
4 – Transistors	– Q_1, and Q_3; NPN FAIRCHILD S 7581 or equivalent. Q_2, and Q_4; PNP G.E. 2N1303 or equivalent.

B

Figure A5.4 (Con.)

APPENDIX 6. USER INSTRUCTIONS FOR RETRIEVING RAWS DATA

A6.1 Retrieval of Data from AFFIRMS Computer

The following instructions enable a user to retrieve RAWS data via the Data General (Forest Service) computer system or other computer terminal and printer that can access the AFFIRMS computer (via telephone dial-up and modem if necessary). After proper identification (ID) has been entered, a series of command prompts are received and answered by the user, as shown here in uppercase letters.

COMMAND: RAWS

The RAWS command activates the RAWS processing module.

R-COMMAND:

To obtain RAWS data, the user responds to this prompt with any one or all of three basic commands, DSPW, DSPR, and DSPC, explained below. To exit from RAWS, the user enters RET. Any other response will cause the message "GARBLED INPUT, RETRY" to appear, followed by a repeat of the R-COMMAND prompt.

THE DSPW COMMAND

R-COMMAND: DSPW XXXXXXXX, where the X's denote a specified station's eight-digit transmission identification number (ID).

When the DSPW command is entered, the RAWS module will display the hourly data for the preceding 24 hours for the specified station. The data are formatted in columns with abbreviated headings. For example, the command DSPW 3248E192 will display the 24 hours of data for the station with the transmission ID of 3248E192. Repeat the command, with appropriate ID, for data from additional, selected stations. *It is important to include the assigned transmission ID*; otherwise, if DSPW alone is entered, the data for *all* RAWS sites will be displayed in sequence.

The DSPW command can also be used with a two-digit hour command to obtain data only for a single hourly observation time; the time is rounded to the nearest whole hour. An example would be DSPW 3248E192 15. (Note: there must be a blank space before the two-digit hour.)

Error Messages—There are two error messages associated with the DSPW two-digit hour command:

(1) If the time requested is after the latest update time (transmission time), the following message will be displayed on the computer terminal (with the actual hours given instead of the X symbols): TIME XX NOT AVAILABLE FOR TODAY; LAST UPDATE WAS XXXX

In such a case, request the time rounded to the nearest previous whole hour.

(2) Another error message is: NO DATA FOR CURRENT DAY

This occurs when there are no data in the file from 0000 hours to the requested time. In such a case, check the file by using the DSPW command for a 24-hour display of station data. If no data are found, notify your RAWS coordinator or call the BIFC RAWS Sensing System Branch at (FTS) 554-1576 to see if the data intercept link is broken.

THE DSPR COMMAND

R-COMMAND: DSPR XXXXXXXX (specify the station transmission ID)

The DSPR command displays the latest three days of data in the 1300 l.s.t. observational format (data for 1300, plus 24-hour maximum and minimum temperature and relative humidity values and 24-hour precipitation). The formatted columns have no headings but follow the AFFIRMS sequence. As with the DSPW command, *be sure to include the eight-digit station transmission ID.*

THE DSPC COMMAND

R-COMMAND: DSPC XXXXXXXX (specify the station transmission ID)

The DSPC command displays, in a format with column headings A through J, the hourly values of additional weather parameters (not included in the DSPW display). For example, columns A and B are commonly used for wind gust information. Column B shows the maximum 1-second windspeed value during the preceding 1-hour period; column A, the wind direction at that time.

THE RET COMMAND

R-COMMAND: RET

The RET command is used after all of the desired RAWS data have been obtained. This command will terminate communication with the RAWS module and activate a further prompt command. A reply of BYE will terminate connection with the AFFIRMS computer. Example, COMMAND: BYE

A6.2 Access of RAWS Data from NESDIS

The following instructions apply to retrieval of RAWS data directly from the National Environmental Satellite Data Information Service (NESDIS) computer at Silver Spring, MD. This option is available should AFFIRMS or the BLM/BIFC satellite downlink be out of service.

ACCESSING COMPUTER

To access the computer, with 300 baud rate; half duplex, 30 characters per second, even parity:

Dial (202) 899-2521

To access the computer, with 1200 baud rate:

Dial (202) 899-6595 or (202) 899-6596

When the computer prints DCS - ENTER ID, type DAFS06 (carriage return).

The computer will print several lines of information and then print ENTER: MSG, RLT, DIS or STOP

At this point, enter RLT/ followed by the first six digits of the station number, the Julian date on which the data are to begin, and the transmission time (hours, minutes, and seconds GMT) of the starting data group. An example follows:

```
ENTER: MSG, RLT, DIS, or STOP RLT/
324534,231234700
```

Here, the Julian date number is 231 (August 19) and the transmission time is 23 hours, 47 minutes, and 00 seconds G.m.t. The G.m.t. times are 5 hours faster than eastern standard time; 8 hours faster than Pacific standard time.

EXITING COMPUTER

After all of the desired data output has been received, hit the "BREAK" key.

The computer will print ENTER: MSG, RLT, DIS or STOP

Type in STOP, on the same line; then hit carriage return key.

EVALUATION OF DATA OUTPUT

In the above example, the following data output is received:

```
3245349C 231234733
00.01 00.55 18.70 224 161 176 163 001
00.01 00.69 18.10 226 165 185 148 001
00.01 00.47 19.40 225 168 192 134 001
 //////  30W
```

The first line contains the station ID, followed by the date (231) and transmission time of the data group (the time is 23 hours, 47 minutes, and 33 seconds G.m.t.).

For instructions in evaluating the data, the above columns will be numbered (example given for last line):

```
    1     2     3    4   5   6   7   8
00.01 00.47 19.40 225 168 192 134 001
```

(1) Accumulated precipitation; subtract the current value from that on previous line to obtain the hourly amount. Amount is zero.

(2) Windspeed; move decimal one place to right and round off. Speed is 5 miles per hour.

(3) Wind direction, in degrees azimuth; move decimal one place to the right. Direction is 194 degrees, or south.

(4) Battery voltage; requires conversion table. Value is 13.24.

(5) Air temperature; requires conversion table. Value is 61 °F.

(6) Fuel temperature; requires conversion table. Value is 78 °F.

(7) Relative humidity; requires conversion table. Value is 53 percent.

(8) Barometric pressure; requires conversion table. Disregard, no sensor installed.

APPENDIX 7. EQUIPMENT SOURCES; MANUFACTURERS AND SUPPLIERS

Table A7.1—Sources of equipment described in this handbook: name of company; classification of company (F, manufacturer; D, distributor); general category of equipment (M, manual, including manually read electronic instruments or their output devices; A, automated data acquisition systems); and types of instruments or sensors made or sold (T, air temperature; H, relative humidity or dewpoint; WS, windspeed; WD, wind direction; P, precipitation; B, barometric pressure; FT/M, fuel temperature and fuel moisture;[1] R, solar radiation; V, evaporation; ST/M, soil temperature and soil moisture; L, water level). Designations are based on literature from companies. Letter a denotes sensors can be used in automated systems; d, all of sensors for automated systems are from other manufacturers; e, primarily manually read electronic equipment with built-in data processing and storage; i, interface for computer/printer available; s, sensors only

		Equipment	Instruments or sensors												
Company	Class	category	AT	H	WS	WD	P	B	FT/M		R	V	ST/M		L
Belfort Instrument Co.	F	M,A	X	X	X	X	X	X			X	X			X
Ben Meadows Co.	D	M	X	X	X	X	X	X		X		X		X	X
Campbell Scientific, Inc.	F	Ad	X	X	X	X	X				X		X	X	
Climatronics Corp.	F	A	X	X	X	X	X	X			X		X		
Climet Instruments	F	A	X	X	X	X	X	X			X		X		
Controlex, Inc.	F	Me,A	X		X						X				
Davis Instruments	F	M			X										
The Eppley Laboratory, Inc.	F	Ma									X				
Forestry Suppliers, Inc.	D	M	X	X	X	X	X	X		X	X	X	X	X	X
Handar	F	A	X	X	X	X	X	X	X	X	X	X	X	X	X
Hinds International, Inc.	F	Me,i	X		X	X		X							
Kahl Scientific Instr. Co.	F	M,A	X	X	X	X	X	X	X		X	X	X		
John W. Kennedy Consultants	D	A	X	X	X	X	X				X		X		X
Leupold & Stevens, Inc.	F	M,A					X								X
Li-Cor, Inc.	F	A	X				X				X		X		
Maximum, Inc.	F	M	X		X	X		X							
Meteophysics Corp.	F	Ad	X	X	X	X	X	X			X		X		
Met One, Inc.	F	A	X	X	X	X	X	X			X		X		
NRG Systems	F	Me,A			X	X									
Omnidata International, Inc.	F	Ad	X	X	X	X	X	X			X			X	X
Palmer Instruments, Inc.	F	M	X										X		
Qualimetrics, Inc., Science Associates	D	M,A	X	X	X	X	X	X			X	X	X		X
Qualimetrics, Inc. Weathertronics Division	F	M,A	X	X	X	X	X	X			X	X	X	X	X
RainWise, Inc.	F	Me,i	X	X	X	X	X	X							
Rodco Products, Inc.	F	Me	X												
Rotronic Instrument Corp.	F	As	X	X											
Sensor Instruments, Inc.	F	Me,i	X	X	X		X	X			X				
Sierra-Misco, Inc.	F	M,A	X	X	X	X	X	X	X	X	X	X	X	X	X
Simerl Instruments	F	M			X										
Sofrel, Inc.	F	Ad	X	X	X	X	X	X			X				
Taylor Scientific/Sybron	F	M	X	X	X	X	X	X							
Teledyne Geotech	F	A	X	X	X	X	X	X			X		X		
Texas Electronics, Inc.	F	Me,A	X	X	X	X	X	X			X				
Vaisala	F	M,A	X	X	X	X	X	X			X	X	X		X
Western Fire Equipment Co.	D	M	X	X	X	X				X					
R.M. Young Company	F	Me,i,As	X	X	X	X									

---

[1] Primary source of standard ½-inch fuel moisture sticks is: USDA Forest Service, Northern Region, Administration Division, Federal Building, P.O. Box 7669, Missoula, MT 59807.

Table A7.2—Name, address, and telephone number[1] of companies (table A7.1) manufacturing or distributing type of equipment described in this handbook

Company	Address	Phone
Belfort Instrument Company	727 S. Wolfe St. Baltimore, MD 21231	(301) 342-2626
Ben Meadows Co.	P.O. Box 80549 Atlanta (Chamblee), GA 30366	(404) 455-0907 TF (800) 241-6401 In GA (800) 241-3136
Campbell Scientific, Inc.	P.O. Box 551 Logan, UT 84321	(801) 753-2342
Climatronics Corp.	140 Wilbur Place Airport International Plaza Bohemia, NY 11716	(516) 567-7300
Climet Instruments	P.O. Box 1760 Redlands, CA 92373	(714) 793-2788
Controlex, Inc. (Natural Power, Inc.)	Francestown Turnpike New Boston, NH 03070	(603) 487-5512
Davis Instruments	3465 Diablo Ave. Hayward, CA 94545	(415) 732-9229
The Eppley Laboratory, Inc.	14 Sheffield Ave. Newport, RI 02840	(401) 847-1020
Forestry Suppliers, Inc.	P.O. Box 8397 Jackson, MS 39204	(601) 354-3565 TF (800) 647-5368
Handar	1180 Bordeaux Drive Sunnyvale, CA 94089-1281	(408) 734-9640
Hinds International, Inc.	P.O. Box 929 Hillsboro, OR 97123	(503) 648-1355
Kahl Scientific Instrument Corp.	P.O. Box 1166 El Cajon, CA 92022	(619) 444-2158
John W. Kennedy Consultants, Inc.	9101 Cherry Lane, #113 Laurel, MD 20708	(301) 490-1600
Leupold & Stevens, Inc.	P.O. Box 688 Beaverton, OR 97075	(503) 646-9171
Li-Cor, Inc.	P.O. Box 4425 Lincoln, NE 68504	(402) 467-3576
Maximum, Inc.	42 South Ave. Natick, MA 01760	(617) 785-0113
Meteophysics Corp.	3030 Bridgeway Bldg., #215 Sausalito, CA 94965	(415) 331-5181
Met One, Inc.	481 California Ave. Grants Pass, OR 97526	(503) 479-1248
NRG Systems	1955 Church Hill Road Charlotte, VT 05445	(802) 425-3468
Omnidata International, Inc.	P.O. Box 3489 Logan, UT 84321	(801) 753-7760 TF (800) 321-7218

(con.)

Table A7.2 (Con.)

Company	Address		Phone
Qualimetrics, Inc., Science Associates	P.O. Box 230 Princeton, NJ 08542	 TF	(609) 924-4470 (800) 247-7234
Qualimetrics, Inc., Weathertronics Division	P.O. Box 41039 Sacramento, CA 95841	 TF	(916) 923-0055 (800) 824-5873
Palmer Instruments, Inc.	3131 Wasson Rd. Cincinnati, OH 45209		(513) 871-7800
RainWise, Inc.	P.O. Box 443 Bar Harbor, ME 04609		(207) 288-5169
Rodco Products Co., Inc.	P.O. Box 944 Columbus, NE 68601		(402) 563-3596
Rotronic Instrument Corp.	160 E. Main Huntington, NY 11743		(516) 427-3994
Sensor Instruments Co., Inc.	41 Terrill Park Drive Concord, NH 03301	 TF	(603) 224-0167 (800) 633-1033
Sierra-Misco, Inc.	1825 Eastshore Highway Berkeley, CA 94710		(415) 843-1282
Simerl Instruments	238 West St. Annapolis, MD 21401		(301) 849-8667
Sofrel, Inc.	7685 Commerce Way, Suite 105 Eden Prairie, MN 55344		(612) 937-8835
Taylor Scientific/Sybron	95 Glenn Bridge Road Arden, NC 28704		(704) 684-8111
Teledyne Geotech	P.O. Box 469007 Garland, TX 75046-9007		(214) 271-2561
Texas Electronics, Inc.	P.O. Box 7225 Dallas, TX 75209		(214) 631-2490
Vaisala (USA)	2 Tower Office Park Woburn, MA 01801		(617) 933-4500
Western Fire Equipment Co.	440 Valley Drive Brisbane, CA 94005		(415) 467-5650
R.M. Young Company	2801 Aero-Park Drive Traverse City, MI 49684		(616) 946-3980

[1] TF denotes toll-free (800) number.

APPENDIX 8. CONVERSION OF MEASUREMENT UNITS—FORMULAS, EXAMPLES, AND CONDENSED TABLES

A8.1 Temperature

Degrees Fahrenheit (F) to degrees Celsius (C)—

C = 5/9 (F – 32)

Example, if F = 54, C = 5/9 (22) = 110/9 = 12

Example, if F = 17, C = 5/9 (–15) = –75/9 = –8

Example, if F = –24, C = 5/9 (–56) = –280/9 = –31

Degrees Celsius (C) to degrees Fahrenheit (F)—

F = 9/5 (C) + 32

Example, if C = 31, F = 1.8 (31) + 32 = 56 + 32 = 88

Example, if C = –7, F = 1.8 (–7) + 32 = –13 + 32 = 19

Table A8.1—Temperature conversion table (condensed)

Fahrenheit (F) to Celsius (C)		Celsius (C) to Fahrenheit (F)	
F	C	C	F
–40	–40	–40	–40
–30	–34	–30	–22
–20	–29	–20	–4
–10	–23	–10	14
0	–18	0	32
10	–12	10	50
20	–7	20	68
30	–1	30	86
40	4	40	104
50	10	50	122
60	16		
70	21		
80	27		
90	32		
100	38		
110	43		
120	49		

A8.2 Precipitation and Evaporation

Inches (in) to millimeters (mm)—

1.00 in = 25.4 mm

Example: 0.08 in = 0.08 (25.4) mm = 2 mm

Example: 1.30 in = 1.30 (25.4) mm = 33 mm

Millimeters (mm) to inches (in)—

1.00 mm = 0.0394 in

Example: 6 mm = 6 (0.0394) in = 0.24 in

Example: 65 mm = 65 (0.0394) in = 2.56 in

SNOWFALL OR SNOW DEPTH

Inches (in) to centimeters (cm)—

1.00 in = 2.54 cm

Example: 7.8 in = 7.8 (2.54) cm = 19.8 cm

Centimeters (cm) to inches (in)—

1.00 cm = 0.394 in

Example: 53 cm = 53 (0.394) in = 21 in

Table A8.2—Precipitation or evaporation conversion table (condensed)

Inches to millimeters		Millimeters to inches		Inches to centimeters	
In	mm	mm	In	In	cm
0.01	0.25	1	0.04	0.10	0.3
.05	1.3	5	.20	.50	1.3
.10	2.5	10	.39	1.00	2.5
.20	5.1	20	.79	2.00	5.1
.30	7.6	30	1.18	3.00	7.6
.40	10.2	40	1.58	4.00	10.2
.50	12.7	50	1.97	5.00	12.7
.60	15.2	60	2.36	6.00	15.2
.80	20.3	70	2.76	8.00	20.3
1.00	25.4	80	3.15	10.00	25.4
1.50	38.1	90	3.55	15.00	38.1
2.00	50.8	100	3.94	20.00	50.8
3.00	76.2	120	4.72	30.00	76.2
4.00	101.6	140	5.52	40.00	101.6
5.00	127.0	160	6.30	50.00	127.0

A8.3 Windspeed

Miles per hour (mi/h) to kilometers per hour (km/h)—

1 mi/h = 1.609 km/h

Example: 6 mi/h = 6 (1.609) km/h = 10 km/h

Example: 27 mi/h = 27 (1.609) km/h = 43 km/h

Kilometers per hour (km/h) to miles per hour (mi/h)—

1 km/h = 0.621 mi/h

Example: 7 km/h = 7 (0.621) mi/h = 4 mi/h

Miles per hour (mi/h) to knots (kt)—

1 mi/h = 0.868 kt

Example: 22 mi/h = 22 (0.868) kt = 19 kt

Knots (kt) to miles per hour (mi/h)—

1 kt = 1.152 mi/h

Example: 12 kt = 12 (1.152) mi/h = 14 mi/h

Table A8.3—Windspeed conversion table (condensed)

Miles/hour to kilometers/hour		Kilometers/hour to miles/hour	
Mi/h	km/h	km/h	Mi/h
1	1.6	1	0.6
2	3.2	2	1.2
4	6.4	4	2.5
6	9.7	6	3.7
8	12.9	8	5.0
10	16.1	10	6.2
12	19.3	12	7.5
14	22.5	14	8.7
16	25.7	16	9.9
18	29.0	18	11.2
20	32.2	20	12.4
25	40.2	25	15.5
30	48.3	30	18.6
35	56.3	35	21.7
40	64.4	40	24.8
45	72.4	45	27.9
50	80.5	50	31.1

A8.4 Barometric Pressure

Inches of mercury (in Hg) to millibars (mb)—

1 in Hg = 33.864 mb Example: 30.12 in Hg = 1,020 mb

Millibars (mb) to inches of mercury (in Hg)—

1 mb = 0.02953 in Hg Example: 988 mb = 29.18 in

Table A8.4—Barometric pressure conversion table (condensed)

Inches of mercury to millibars		Millibars to inches of mercury	
In Hg	**mb**	**mb**	**In Hg**
23.00	779	750	22.15
24.00	813	800	23.62
25.00	847	850	25.10
26.00	880	900	26.58
27.00	914	950	28.05
28.00	948	960	28.35
28.50	965	970	28.64
29.00	982	980	28.94
29.20	989	990	29.23
29.40	996	1,000	29.53
29.60	1,002	1,010	29.83
29.80	1,009	1,020	30.12
30.00	1,016	1,030	30.42
30.20	1,023	1,040	30.71
30.40	1,029	1,050	31.01
30.60	1,036	1,060	31.30
30.80	1,043		
31.00	1,050		

A8.5 Solar Radiation

RADIANT FLUX PER UNIT AREA, AS IN INSTANTANEOUS MEASUREMENT

Langleys per minute (ly/min) to watts per square meter (W/m^2)—
(Note: 1 langley = 1 gram calorie per square centimeter)

1 ly/min = 698 W/m^2 Example: 1.25 ly/min = 873 W/m^2

Langleys per minute (ly/min) to Btu per square foot per minute ($Btu/ft^2/min$)—

1 ly/min = 3.69 $Btu/ft^2/min$ Example: 1.25 ly/min = 4.61 $Btu/ft^2/min$

QUANTITY OF RADIATION PER UNIT AREA, AS IN DAILY TOTAL

Langleys (ly) to watt-hours per square meter (Wh/m^2)—

1 ly = 11.61 Wh/m^2 Example: 540 ly = 6,269 Wh/m^2

Langleys (ly) to Btu per square foot (Btu/ft^2)—

1 ly = 3.69 Btu/ft^2 Example: 540 ly = 1,993 Btu/ft^2

A8.6 Other Measures

WEIGHTS

Ounces (oz) to grams (g)—

1 oz = 28.353 g

Grams (g) to ounces (oz)—

1 g = 0.03527 oz Example: 100 g = 3.53 oz

Pounds (lb) to kilograms (kg)—

1 lb (16 oz) = 0.454 kg

Kilograms (kg) to pounds (lb)—

1 kg = 2.2046 lb

LIQUID VOLUME

Gallons (gal) to liters (L)—

1 gal (4 quarts) = 3.788 L

Liters (L) to gallons (gal)—

1 L = 0.264 gal

DISTANCES

(See section A8.2 for inches, millimeters, and centimeters.)

Feet (ft) to meters (m)—

1 ft = 0.305 m Example: 20 ft = 6.1 m

Meters (m) to feet (ft)—

1 m = 3.28 ft

Miles (mi) to kilometers (km)—

1 mi = 1.609 km

Kilometers (km) to miles (mi)—

1 km = 0.621 mi

AREAS

Acres to hectares (ha)—

1 acre (43,560 ft^2) = 0.405 ha

Hectares (ha) to acres—

1 ha = 2.471 acres

APPENDIX 9. ABBREVIATIONS AND ACRONYMS

AC	Alternating current
AFFIRMS	Administrative Forest Fire Information Retrieval and Management System
AWS	Automatic weather station(s)
BIFC	Boise Interagency Fire Center
BLM	Bureau of Land Management
DC	Direct current; VDC, volts direct current
DCP	Data collection platform
DG	Data General
DRGS	Direct readout ground station
FS	Forest Service
GOES	Geostationary operational environmental satellite
LCD	Liquid crystal display
LED	Light-emitting diode
NCC-FC	National Computer Center at Fort Collins, CO
NCDC	National Climatic Data Center
NESDIS	National Environmental Satellite Data Information Service
NFDRS	National Fire Danger Rating System
NFWDL	National Fire-Weather Data Library
NOAA	National Oceanic and Atmospheric Adminstration
NPS	National Park Service
NWS	National Weather Service
RAWS	Remote automatic weather station(s); P-RAWS, portable RAWS
SCS	Soil Conservation Service
USDA	U.S. Department of Agriculture
USDI	U.S. Department of the Interior

INDEX

Finklin, Arnold I.; Fischer, William C. 1990. Weather station handbook—an interagency guide for wildland managers. NFES No.1140. Boise, ID: National Wildfire Coordinating Group. 237 p.

A comprehensive guide for the operation of weather stations providing data for wildland resource management. Both manually operated and automatic-type weather stations are included. Especially intended for use by USDI Bureau of Land Management and National Park Service, USDA Forest Service, and similar agencies. Describes instrumental equipment, siting, installation, data collection, and maintenance.

KEYWORDS: weather stations, weather instruments, weather observations, fire-weather, fire management

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