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.

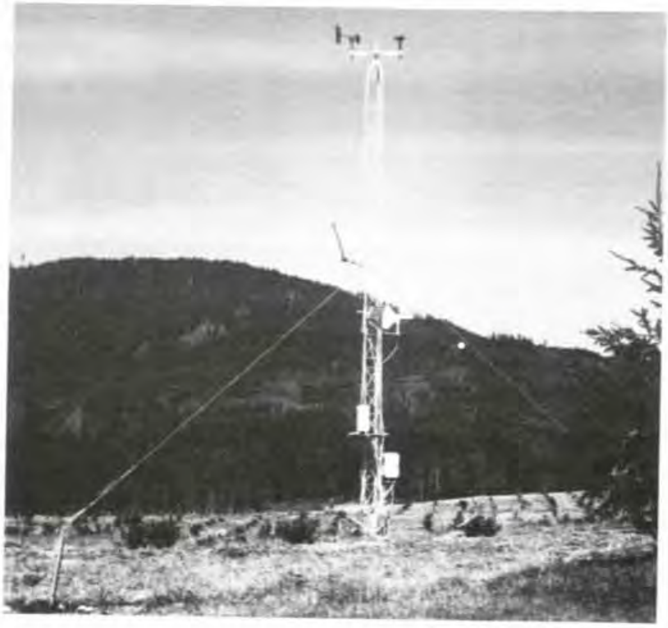

Figure 40.1—A RAWS installation on 30-ft Rohn-type tower. (Photo courtesy of Handar.)

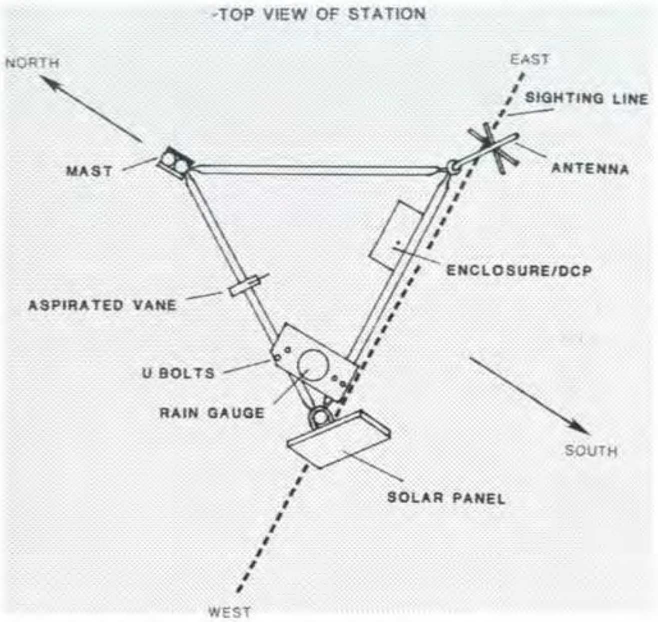

Figure 40.2—Diagram showing correct positioning of standard RAWS tripod tower and components. Radiation shield (with air temperature/relative humidity probe) may, alternatively, be located on south side of tower (on east-west crossarm). (Adapted from USDI BLM, RAWS Support Facility 1987.)

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.

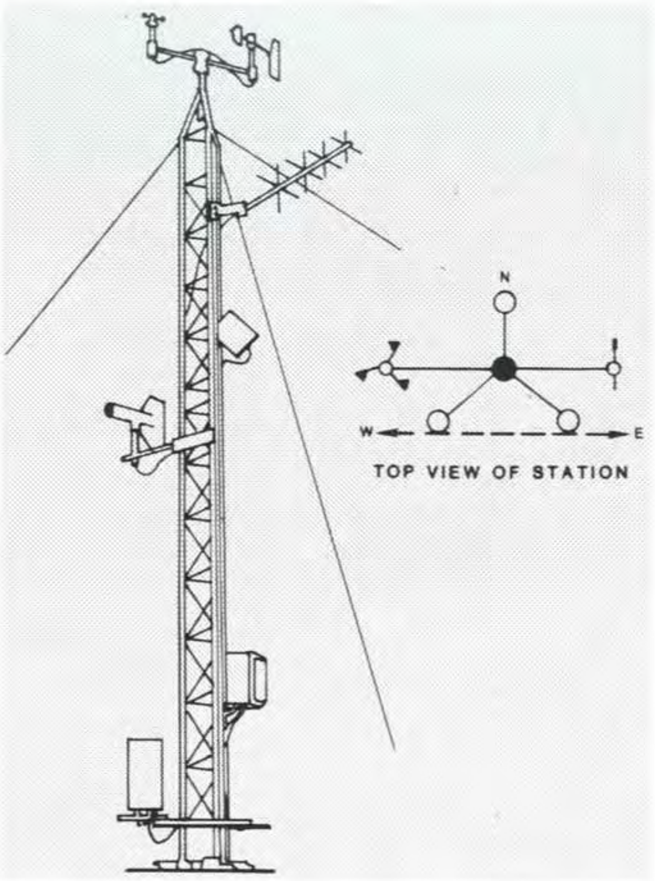

Figure 40.3—Diagram showing correct alignment of Rohn-type tower base. (From USDI BLM, RAWS Support Facility 1987.)

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 $1^{3}/_{4}$ 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.)

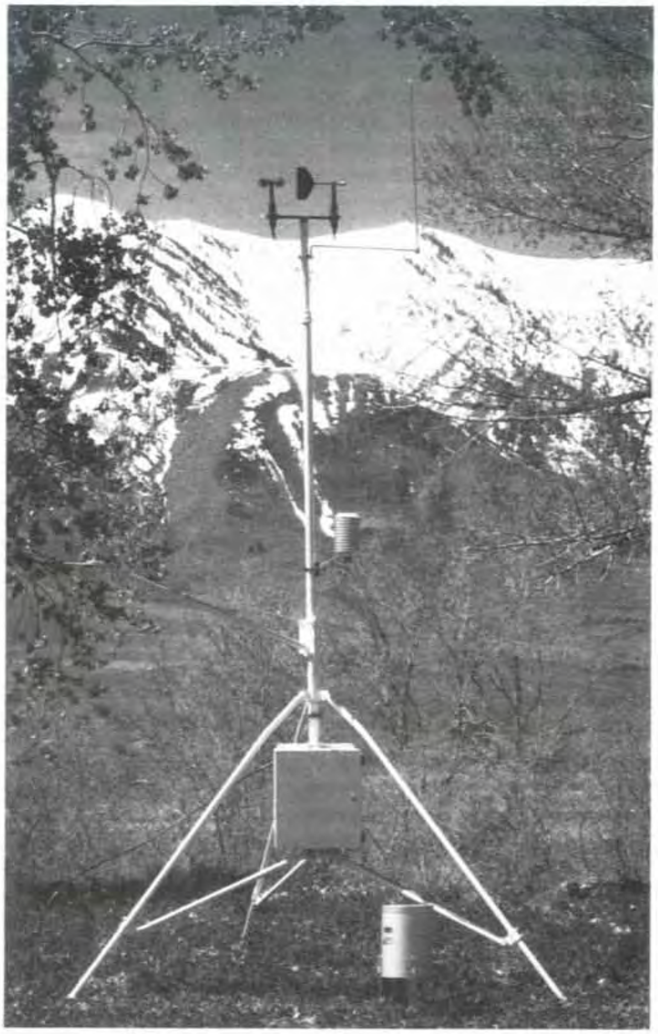

Figure 44.3—Easy Logger recording system (Omnidata International, Inc.), with Wind Sentry (R.M. Young Co.) anemometer and wind vane, tipping bucket rain gauge (Sierra-Misco, Inc., model 2501), Gill multiplate radiation shield (R.M. Young Co.) housing temperature and relative humidity probe (Phys-Chemical Research Corp.), and pyranometer (Li-Cor). (Photo courtesy of Omnidata International, Inc.)

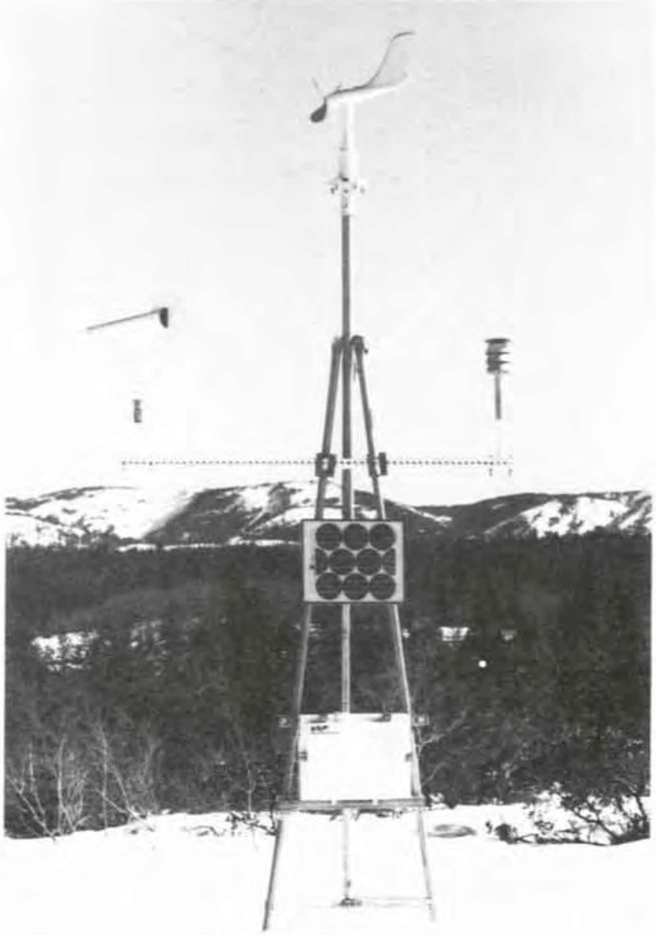

Figure 44.4—Weathertronics automatic weather station, with Skyvane wind sensor, and vane-type and pagoda-type radiation shields for temperature and/or humidity probes. (Photo courtesy of Qualimetrics, Inc.)

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.