Chapter 5  Maintenance and Calibration
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Acknowledgments

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Chapter 5  Maintenance and Calibration

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Chapter 5 Maintenance and Calibration

622.0500 Introduction

Quality snow survey water supply forecasts depend on accurate data. Accurate data collection can be ensured by implementing a strong maintenance and calibration program. This chapter contains maintenance procedures for manual data collection sites, and calibration and maintenance procedures for SNOw TELemetry (SNOTEL) automated data collection sites.

The information in this chapter supersedes information in the U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (formerly, Soil Conservation Service) (NRCS), National Engineering Handbook (NEH), Section 22, Snow Survey and Water Supply Forecasting, April 1972.

Trade names are used in the publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee of a product by the USDA nor does it imply an endorsement by the Department over other products not mentioned.

622.0501 Manual data collection site maintenance

Manual snow measurements are collected at established snow courses and aerial marker locations. The following section describes maintenance protocols for these manual snow sampling sites, as well as the access routes (trails) into the sites. Maintenance of the sampling equipment is also included.

(a) Snow course maintenance

Snow courses are manual data collection sites consisting of a selected line of marked length, and are used by the NRCS to collect data from remote, high elevation, mountainous regions.

Snow courses are located in unique locations to correlate snow-water equivalent (SWE) to the seasonal streamflow runoff from a basin or watershed. Factors impacting snow data collection include site physical changes, canopy changes, and vegetation changes. Changes due to natural causes such as fire, flood, or wind may also impact data collection.

Table 5–1 outlines the maintenance schedule for manual data collection sites.

Maintenance of a snow course often requires the use of hand tools such as shovels, saws, and hammers. Nails, bolts, or some cement may be needed, depending on how end points and sample points are marked.

<table>
<thead>
<tr>
<th>Component</th>
<th>Field maintenance and calibration verification</th>
<th>Shop maintenance</th>
<th>Replace</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snow course and marker</td>
<td>Annual</td>
<td>N/A</td>
<td>As needed</td>
</tr>
<tr>
<td>Aerial marker</td>
<td>As needed</td>
<td>N/A</td>
<td>As needed</td>
</tr>
<tr>
<td>Federal snow sampler spring balance</td>
<td>Twice a year</td>
<td>6 years</td>
<td>As needed</td>
</tr>
</tbody>
</table>

(210–VI–NEH, Amend. 73, March 2015)
Good documentation on the data and/or maintenance forms during the sampling season, as well as during maintenance visits, helps field personnel determine what tools and equipment will be needed during a site maintenance visit (fig. 5–1).

Woody vegetation (bushes, heavy bunched grasses, and downed trees and branches) causes the greatest interference to good sampling on the ground. If possible, remove woody vegetation growing on the course as completely as possible to prevent it from growing back. This may require digging up the roots.

Overhead interference is usually the result of the vegetation canopy growing directly over or nearly over the sample points. To clear the canopy may require removal of entire trees. Ensure that the removal of trees is acceptable to the land owner or manager of the property. This is typically addressed in the special use permit or agreement arranged during the site selection and installation procedures. See National Engineering Handbook, Part 622, Chapter 3, Site Selection (NEH622.03), and NEH622.04, Site Installation.

Take photos to document the changes that occur at the site. It is important to take one photo from the same location each time, and capture the ground and canopy in the photo. Try to capture items that may need attention at the next maintenance visit.

Sometimes a snow course is dramatically changed due to an environmental or land use calamity. Carefully document such events so that data can be analyzed to determine the effects of the changes on the snowpack and its correlation to stream runoff. For more information, refer to NEH622.08, Standards and Specifications.

(b) Aerial marker maintenance

Aerial markers are used in remote, mountainous locations that are difficult to reach by over-snow travel. Site selection is the same as snow courses, with one additional requirement. The marker must be in a position which is easily observable from the air without undue hazard to the aircraft (fig. 5–2).

Aerial markers are subject to damage from snow loads, snow creep, animals, and vandalism. It is usually the lower bars that are damaged. Although snow creep often breaks the pipe, it is more likely to bend the marker off vertical.

Factors impacting snow data collection include site physical changes, canopy changes, and vegetation changes. Changes due to natural causes such as fire, flood, or wind may also impact data collection.

Figure 5–1 Snow course with well-marked sample points and well-maintained vegetation

Figure 5–2 Well-maintained aerial marker with all cross arms and bright paint
Maintenance of aerial markers generally focuses on the marker itself, and ensuring that it is clearly visible to passing aircraft. This will often require the use of hand tools such as wrenches, shovels, saws, and hammers. The technician may also need nails, bolts, paint, or some cement. Good documentation during the sampling season helps field personnel determine the required tools and equipment for the site maintenance visit.

Tall trees are rarely found near aerial markers, because markers are sited in open locations for clear visibility from above. Sometimes small seedlings, bushes, and even tall, heavy grass can affect the way the snow rests around the marker. Clear these obstacles according to NEH622.08.

Snowpack or soft soil may allow the marker to be pushed into the soil. Erosion or livestock may remove soil from around the marker. Soil may even accumulate around a marker which changes the height of the marker aboveground. Check the actual height of the marker’s cross members annually and adjust to the original height when required.

Take photos of aerial markers at least every 3 years to document the changes that may occur at the site. It is important to take one of the photos from the same location each time, and to capture the ground and canopy in the photo. Try to capture items that may need attention at the next maintenance visit.

Sometimes an aerial marker site is dramatically changed due to an environmental or land use calamity. Carefully document such situations, so that data can be analyzed to determine the effects of the changes on the snowpack. For more information, refer to NEH622.08.

(c) Access trail maintenance

Maintenance of trails to snow courses and aerial markers is necessary to ensure an obstacle-free passage to the site. Roads and trails that are well-defined in the summer often are completely obscured by snow during the winter snow season. Install trail blazes or markers at a sufficient height aboveground to be visible even under the heaviest snowpacks. Even the most experienced surveyor, familiar with the terrain and area, can become confused or disoriented while traveling in heavy snow or fog.

Ensure markings are made of high-visibility materials that resist fading and weathering. Replace markings if they fade or become lost or dislodged.

In some instances, it may be desirable to leave some portions of a trail or road unmaintained to reduce interest from passersby and reduce the chance for vandalism. For more information, refer to NEH622.08.

(d) Equipment maintenance

This section details how to maintain the equipment used to collect manual measurements of snowpack water content and snow depth.

(i) Snow sampler (snow tube) maintenance

The proper maintenance of snow survey sampling equipment and instruments is essential for reliable and accurate sampling results. Clean, waxed, or silicone-coated snow tubes and a sharp cutter bit will minimize difficulties in obtaining accurate samples.

Apply coatings—Prior to applying any type of coating, clean the snow tubes of any varnish, shellac, or other coating. If solvents or paint and varnish removers are used, this remover must be rinsed off with a naphtha solvent (or equivalent) and wiped dry with a clean cloth. A circular wire brush attached to a 3-foot rod helps in cleaning the inside of the tubes. An electric drill clamped in a vise, with a brush attachment, will simplify this task. Once tubes are cleaned of all grease, varnish, or shellac, application of the inside coating can be started.

Self-polishing liquid wax is probably the simplest to apply. Automobile liquid wax, liquid floor wax, or liquid furniture wax is also acceptable. Two to three coats should be sufficient in most cases. Avoid anti-skid waxes since they would cause sticking in the tubes. Silicone and Teflon® waxes, such as used in ovens and on cooking utensils, are effective. However, they must be baked onto the inside of the tube at the proper temperature. Paste waxes have been found to work well and are easily applied to a clean tube with a swab and rags. Final polishing with a clean, dry cloth is the key to ensuring a good, nonstick surface.
**Cutter bit maintenance or replacement**—The cutter bit is made of steel and is usually casehardened. Sharpen the bit occasionally with a fine-cut file to get maximum cutting efficiency in ice layers within the snowpack. When filing the cutter, follow the pattern of the old cutter. There are two styles to sharpen the cutter: "standard" and "sharpened." Ensure the cutter type used is recorded in the metadata for the snow courses measured.

Inspect the cutter bit for any teeth that may be broken off or bent inward by striking rocks. If any teeth are broken, remove the cutter and replace it with a new one. Straighten or file smooth any bent teeth to the same diameter as the shoulder on the inside of the cutter.

When replacing a cutter bit, have a new cutter handy and ready to install immediately after removing the old cutter. To remove the old cutter, lightly clamp the tube in a vise, using several wraps of heavy cloth or inner tube around the tube where it is secured in the vise. Heat the tube around the cutter with a gas torch flame, while gripping the old cutter with a pair of pliers and pull outward away from the tube. A small wet, cold rag wadded up inside the cutter (but not touching the tube) helps to keep the cutter from heating and expanding with the outer metal. The outside metal of the tube will eventually expand enough for the cutter to slide out.

Quickly grasp the new cutter by the teeth end and push it into place; ensure the cutter is up against the end of the tube. Remove heat and let the tube cool. After the tube has cooled, try turning and pulling the cutter bit to see if it will come out. There is enough difference in the machining of various cutters and tubes that sometimes a cutter pulls out easily. If this is the case, install another bit until the cutter bit is connected to the tube without slipping or working free.

**Sampling tube compatibility**—Several instrument companies and machine shops design and manufacture snow sampling tubes. Unfortunately, the threads of the couplings from each shop are slightly different, such that the threads of one type will bind if used with a different manufacturer's threading. For this reason, it is important to keep sections of the same manufacturer's tubes together in one set.

Often, the threads of a particular set of tubes fit too tightly for easy uncoupling. If this occurs, grind or lap out the threads with a small amount of valve-grinding compound. Do not hurry the lapping process. Use plenty of oil with the compound and turn the tubes back and forth many times. Clean out the compound with an old toothbrush and naphtha solvent (or equivalent). Wipe the threads dry and attempt to resecure the tube sections. A small amount of petroleum jelly (or similar compound) is a good lubricant to use on the threading.

Occasionally a coupling becomes twisted or pushed down, so that the graduation between tube and coupling is less than standard. If this occurs, a machine shop or the manufacturer should slip the coupling back into place.

Correct dents and cave-ins caused by carrying and using the driving wrench with a mandrel or a metal plug the same size as the inside diameter of the tube. Strike the tube with a soft (rubber) hammer to draw the dent up. Do not use a steel hammer for this task.

If the tube is prone to collecting sticking snow while sampling, do not clean the tube by hitting the side against trees, marker posts, or other objects, as that will dent the tube. Clean the tube by loosening the snow through the slots with a case knife or other tool. When the plugs of snow have been broken up and removed, clean the loose snow out by drawing a cloth through the tube from the top end and out through the cutter end. A strong cord such as nylon is tied to the cloth with a small weight, such as a spanner wrench, to the other end. Drop the weight through the tube and then draw the cloth through to clean the tube. A wooden dowel may also be helpful in cleaning stuck snow from the snow tube. For more information, refer to NEH622.08.

(ii) **Spring balance maintenance**

The spring balance is the most delicate component of the manual snow sampling equipment, and requires care in handling, transportation, and storage. Periodic cleaning and calibration verifications are necessary to ensure proper long-term operation. The balance should operate smoothly and move freely. Never apply grease or oil to the balance. If dirt or grit collects between the two sliding sleeves, wipe them clean with solvent and dry the sleeves with a clean cloth.
The mechanism of the spring balance is simple. Remove the outer shell by taking out the screw or screws around the top of the cylinder. Gently snap the spring once or twice, and the top ring post will slip off the outer cylinder. Stretch the spring down about 3 inches, and insert a screwdriver or a nail in the spring coil. Relax the spring tension and punch out the round pin to free the ring post.

After removing the round pin supporting the spring, the spring will drop inside. To remove the bottom pigtail post, use a quarter-inch round rod as a punch. Hold the inner cylinder in hand and tap on the long quarter-inch punch, driving off the pigtail post. Unscrew the spring from the round pin and disassemble the inside scale for cleaning or repair.

When reassembling the balance, it is possible to modify the zero point of the springs by adding a short link of stout steel wire or an eighth-inch steel welding rod between the loop in the top end of the spring and the small pin through the top ring post. The ends of this link must be tight together. It is often necessary to grind the sides of the upper half of this link so that it swings freely. This small adjusting process makes it impossible to read zero on the scales even with one tube, provided the link is a little long. This adjustment does not hamper the calibration of the balance although there is a little loss of capacity at the upper end with heavy weights.

If the balance is used to measure 2 or 3 feet of low density snow, adjust it so that there is always a fairly large plus value-to-tare weight and never close to zero. This adjustment process is not necessary on all balances, only on those on which the surveyors are prone to use zero as a tare weight.

After the scale has been assembled, check the calibration. The spring scale may not measure the exact total weight, but the incremental weight is what counts and must be exact. Use a calibrated weight set to ensure the scale measures the correct incremental weight. Ideally, the scale should be checked at both upper and lower ranges.

622.0502 SNOTEL automated data collection site maintenance

Annual maintenance for SNOTEL stations provides an opportunity to ensure general station integrity, perform necessary preventive maintenance, and replace components on a schedule that meets specified sensor calibration or replacement intervals.

To ensure accurate data collection, annual maintenance/calibration of SNOTEL sites is required. Each SNOTEL station must receive one annual onsite maintenance visit by data collection office (DCO) personnel, or personnel assigned by the DCO. Maintenance personal should be trained, experienced, and technically proficient to verify that sensors are within calibration standards, and to document site and station conditions. If the minimal maintenance and calibration requirements cannot be met, thoroughly document this information in the station metadata, noting specific reasons for not meeting the standard (e.g., insufficient staff, funding, capital resources).

The annual site visit/inspection also serves for removing vegetative growth, repairing site facilities, and ensuring proper site drainage. If there are environmental or other regulations prohibiting appropriate site maintenance, develop a plan to bring the station into compliance. If sites are considerably compromised, it is critical to document this in the station metadata (including photographs) so that users of the data have the opportunity to assess it.

Data collection offices are responsible for monitoring the quality of the data produced by the SNOTEL stations in their DCO area. DCOs base considerations for maintenance needs on system performance as defined in the National Resources Conservation Service (NRCS) Remote Hydrometeorological Monitoring and Data Collection Station Performance Standards for response to the midnight nominal poll, down time, and data stability. In the event of system failures, bad data, or questionable data, it is the responsibility of the DCO to initiate corrective action to the station.

Response time to unscheduled maintenance and repair will depend on the value of the data to the water supply forecasting staff, cooperators, or other criteria, and available personnel to conduct the site visit/repair.
Safety will always be the first and most important consideration when determining when to access a SNOTEL site for any reason, especially in the winter months, when weather and avalanche conditions can prevent maintenance from occurring for many weeks.

(a) Annual maintenance/calibration or sensor replacement

SNOTEL sensors and other key components must be calibrated or replaced on a regular basis to ensure the measurement and collection of accurate, repeatable, and reliable data (table 5–2). Annual service of SNOTEL stations provides an opportunity to ensure general station integrity, perform necessary preventive maintenance, and replace or calibrate sensors and components.

Some replacement sensors must be certified and calibrated by the NRCS National Water and Climate Center (NWCC) Electronics Maintenance Facility (EMF).

Many times swapping sensors rather than calibrating a sensor in the field will reduce the time required to perform calibration checks. Check new sensors for proper operation, by documenting the output of the sensor through the data logger after installation.

The following sections describe annual maintenance procedures and the minimum replacement and calibration interval for specific sensors. For more information, refer to NEH622.08.

(b) Air temperature sensor

Note: Inspect air temperature sensors annually. Sensor calibration or replacement must not exceed 6 years (table 5–2).

Air temperature is the temperature of the air at a standard height above ground. Personnel should perform annual maintenance and calibration verification of the air temperature sensor in the field.

(i) Thermometer/thermistor shop calibration

Every 6 years sensors or thermometers being calibrated must be within ± 0.5 degrees Celsius (of the primary/transfer standard) to a minimum of three temperatures at approximately 0, 15, and 30 degrees Celsius. Thermistors must be calibrated at three points within this range a maximum of every 6 years. In the years where a three-point calibration is not performed, an annual single-point verification in ambient air is required. In lieu of calibration verification, sensors may be replaced.

To check the calibration of thermistors in the shop, verify instrument output readings versus those of a certified transfer standard thermometer. The certified primary standard thermometer against which all other thermometers are calibrated must be either National Institute of Standards and Technology (NIST)-certified or NIST-traceable, and carry a NIST certification or traceability from the manufacturer (or equivalent). The calibration is only applicable during the period for which it is certified as NIST-traceable; once certification has expired, the calibration thermometer either must be replaced or sent to an accredited facility for recertification. These protocols apply to electronic thermometers as well as to liquid-in-glass thermometers. The calibration instrument must be accurate to at least 0.1 degrees Celsius.

Check the certificate of calibration for the NIST thermometer before calibrating field thermometers. NIST-certified primary standard thermometers are not for field use; however, transfer standards certified versus the primary standard are acceptable for field verification of thermistors.

(ii) Field calibration and maintenance

Six-year multipoint verification—This procedure may be performed in lieu of sensor replacement. This procedure, conducted every 6 years, requires two technicians at the SNOTEL site. One technician climbs the meteorological tower to access the temperature sensor, while the second technician reads and records the system output values from the data logger in real time.

Equipment required for 6-year field calibrations:

- container to hold the water bath
- cold water and ice for creating ice baths and other baths
- transfer standard thermometer or electronic thermistor/thermocouple (calibrated in shop)
- calibration form
### Table 5–2  SNOTEL station maintenance, calibration, and replacement schedule

<table>
<thead>
<tr>
<th>Component</th>
<th>Field maintenance and calibration verification</th>
<th>Shop maintenance and calibration</th>
<th>Replace (new or recalibrated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature sensor</td>
<td>Annual (single point); 6 years (3 point)</td>
<td>Every 6 years</td>
<td>As needed</td>
</tr>
<tr>
<td>Antenna</td>
<td>Annual</td>
<td>N/A</td>
<td>As needed</td>
</tr>
<tr>
<td>Barometric pressure sensor</td>
<td>Annual</td>
<td>Every 3 years</td>
<td>3 years max</td>
</tr>
<tr>
<td>Battery</td>
<td>Annual</td>
<td>N/A</td>
<td>As needed</td>
</tr>
<tr>
<td>Data logger</td>
<td>Annual</td>
<td>As needed</td>
<td>6 years max</td>
</tr>
<tr>
<td>Electrical cables and wiring</td>
<td>Annual</td>
<td>N/A</td>
<td>As needed</td>
</tr>
<tr>
<td>Meteor burst radio</td>
<td>Annual</td>
<td>As needed</td>
<td>6 years max(^1)</td>
</tr>
<tr>
<td>Pressure transducer (snow pillow SWE sensor)</td>
<td>Annual</td>
<td>Every 6 years</td>
<td>6 years max</td>
</tr>
<tr>
<td>Pressure transducer (storage precipitation gage)</td>
<td>Annual</td>
<td>Every 6 years</td>
<td>6 years max</td>
</tr>
<tr>
<td>Relative humidity sensor</td>
<td>Annual</td>
<td>Annual</td>
<td>Annual</td>
</tr>
<tr>
<td>Shelter</td>
<td>Annual</td>
<td>N/A</td>
<td>As needed</td>
</tr>
<tr>
<td>Snow depth sensor</td>
<td>Annual (single point); 6 years (3 point)</td>
<td>Every 6 years</td>
<td>6 years max</td>
</tr>
<tr>
<td>Snow pillow</td>
<td>Annual</td>
<td>N/A</td>
<td>As needed</td>
</tr>
<tr>
<td>Soil moisture/temperature sensors</td>
<td>As needed</td>
<td>As needed</td>
<td>As needed</td>
</tr>
<tr>
<td>Solar panel</td>
<td>Annual</td>
<td>N/A</td>
<td>As needed</td>
</tr>
<tr>
<td>Solar radiation (pyranometer) sensor</td>
<td>Annual</td>
<td>Every 3 years</td>
<td>3 years max</td>
</tr>
<tr>
<td>Storage precipitation</td>
<td>Annual</td>
<td>N/A</td>
<td>As needed</td>
</tr>
<tr>
<td>Tipping bucket precipitation gage</td>
<td>Annual</td>
<td>Annual</td>
<td>3 years max</td>
</tr>
<tr>
<td>Tower</td>
<td>Annual</td>
<td>N/A</td>
<td>As needed</td>
</tr>
<tr>
<td>Wind speed and wind direction sensors</td>
<td>Annual</td>
<td>Annual</td>
<td>6 years max</td>
</tr>
</tbody>
</table>

\(^1\) Replace battery in meteor burst radio every 3 years.
**Step 1** Remove the thermistor from the radiation shield, if applicable.

**Step 2** Fill the water container with water or ice water (for 0 °C), and place the thermistor and transfer standard thermometer (or equivalent) in the ice bath to the same depth with the entire thermistor and transfer standard sensor being submerged (no metal casing extending from the water into the air).

**Step 3** Once the temperature has stabilized, adjust the temperature of the bath by adding warmer or colder water until the desired reference temperature is reached (0 °C for ice bath, ~15 °C, and ~30 °C). If using the ice bath, no temperature adjustment is necessary.

**Step 4** When the desired temperature is achieved in the bath, simultaneously read the transfer standard thermometer/thermistor, and the output of the SNOTEL thermistor on the data logger. Record both readings on the calibration form.

**Step 5** Repeat the series of measurements in steps 3 and 4, at least two more times for a minimum of three comparison points for each water bath.

**Step 6** Repeat steps 2 through 5 two more times using 15 ±2.0 degrees Celsius, and 30 ±2.0 degrees Celsius in place of the 0 degree Celsius ice bath in step 2.

**Step 7** Use the average of the three individual measurements made at each bath temperature for comparison between the transfer standard thermometer/thermistor and the site thermistor.

**Step 8** If the sensor values are within ±0.5 degree Celsius of the transfer standard the sensor can be considered operating correctly and should be returned to the radiation shield for continued measurement. If not, replace the sensor and repeat the calibration verification process for all three ice baths prior to installing in the site.

**Annual single-point verification**—This recommended procedure, conducted annually (each year during summer maintenance) requires one technician at the site.

Equipment required for annual field verification:
- transfer standard thermometer or electronic thermistor/thermocouple (calibrated in shop)
- calibration form

**Step 1** Upon arrival at the site, select a shaded location as close to the station's sensor as possible to place the reference sensor. Ideally, place an identical thermistor in the same shielding near the station's sensor. Once the temperature reading stabilizes (minimum of 15 minutes), simultaneously read the transfer sensor output and the site thermistor output. Record all readings on the calibration form.

**Step 2** If the readings agree to within ±3.0 degrees Celsius, take 2 more readings after waiting at least 5 minutes between readings. Once three consecutive readings have been recorded that agree to within ±3.0 degrees Celsius, the verification is complete.

**Step 3** If the sensor and the transfer standard do not agree to within ±3.0 degrees Celsius, then replace the sensor.

For more information, refer to NEH622.08.

(c) **Antenna**

**Note:** Inspect antennae annually. Antennae calibration, repair, or replacement should occur as needed (table 5–2).

Most of the antennae at SNOTEL stations are designed to transmit and receive from a meteor burst type of radio. Maintenance is generally a visual inspection of the antenna, connectors, and wires.

**Step 1** Check for broken, loose, or bent elements, proper alignment, loose connections at balen, or corroded connectors.

**Step 2** Check coaxial cable for kinks or cracking.

**Step 3** Test TXF or TXR with the “Test” command. “TXF” (Transmit Forward) value should be ~100W at 12.5V; “TXR” (Transmit Reverse) value should be less than 10W or less than 10 percent of TXF.
(d) Barometric pressure sensor

Note: Inspect barometric pressure sensors annually. Sensor calibration or replacement must not exceed 3 years (table 5–2).

Barometric pressure is defined as atmospheric pressure at sea level. It is measured in inches of mercury. During the course of a year, the highest pressure is around 30.40 inches, and the lowest around 29.50 inches. Low pressure (below 29.92) is associated with less stable weather patterns, and high pressure (above 29.92) is associated with more stable weather patterns.

The SNOTEL site barometric pressure sensor requires annual calibration checks. Calibration checks can be done by comparing the station reading to a certified National Oceanic and Atmospheric Administration (NOAA) weather station or using a currently-calibrated sensor while at the station location.

(i) Field calibration and maintenance

Perform field procedures during routine annual, site maintenance visits to SNOTEL stations. Calibration can be checked remotely or onsite.

The remote calibration check is the easiest and most efficient method. The calibration can be checked remotely by comparing the sensor reported value to the local reference barometric pressure reading (from an official National Weather Service (NWS) observation station) used to adjust the sensors offset to sea level (NEH622.04).

**Determining the offset**—During installation of barometric pressure sensors, the offset voltage has to be determined. The offset voltage is the amount a resulting voltage measurement has to be adjusted either plus or minus for the sensor's measurement to correspond with the actual pressure when compared to an official NWS station or in a calibrated environmental chamber. This offset should not change more than 3 percent of the entire span of output. The NRCS standard is to apply an offset to the calculated inches of mercury (Hg) rather than to the voltage. Over time, the change in offset should not be more than 3 percent of the sensor's range or about 0.12 inch.

(ii) Remote and onsite field calibration

Field (remote) calibration. The calibration of the sensor can be easily checked by using the data reported for the remote station and comparing it with the measurements (corrected for sea-level) from the local NWS observation station. To ensure calibration throughout the measurement range, do this for a variety of pressure readings that represent most of the span to ensure calibration throughout the measurement range.

**Step 1** Record the barometric pressure reported by the NWS official observation station as near as possible to the remote station. Often times this is a local airport.

**Step 2** Record the corresponding reading from the remote station that has been adjusted with the offset that was determined during installation.

**Step 3** Compare the measurements. The difference should be no more than 3 percent of the total range of the sensor or about 0.12 inch Hg.
Step 4  Repeat this for several measurements that will represent a range of the sensor's output.

Field (on site) calibration—Field calibration checks can also be performed using a hand-held barometric pressure sensor calibrated to the NTIS standard. This is probably the least desirable method, as it is more difficult to get comparative measurements for multiple points in the measurement range. This procedure is simply reading the barometric pressure measurement (corrected for sea level) for the hand held unit and comparing this with the measurement being reported from the sensor. Read the sensor measurement directly from the sensor using a voltmeter, or read it by connecting to the data logger. Apply the offset determined during installation to the sensor output and compare the readings of the two sensors. The difference in measurements should not be more than 3 percent of the sensor's range (about 0.12 inches Hg.).

(iii) Shop calibration
Perform shop calibration every 3 years in an environmental chamber to ensure sensor reliability throughout the span of the sensor. Check the sensor for consistent linearity throughout the span of the sensor by taking comparative measurements for at least five incremental points throughout the span range.

Step 1  Measure the voltage output for the sensor at ambient (barometric) pressure.

Step 2  Applying the appropriate calibration equation to convert voltage to inches Hg for the particular sensor, calculate the measured barometric pressure, and determine the required offset to use as a correction to report pressure equal to the known ambient measurement.

Step 3  Once the offset is determined, use the environmental chamber to apply at least five different pressures that span the range of the sensor. The offset should not need adjustment of more than ±3 percent of the entire range (about ± 0.12 inches Hg.). For more information, refer to NEH622.08.

(f) Data logger

Note: Inspect data loggers annually. Data logger calibration or replacement should occur as needed (table 5–2).

(i) Field maintenance

Step 1  Carefully inspect the logger for any physical damage such as burns, corrosion, scrapes, or dents.

Step 2  Ensure that all the wires are solidly connected by going through the wiring panel with a screwdriver to check that all the connectors are tight (fig. 5–7).

Step 3  Connect to the data logger and observe the time, date, and data values.

Step 4  Replace the logger (and its wiring panel) every 6 years for calibration and refurbishing by the NRCS EMF shop.

(ii) Shop calibration and maintenance
To ensure proper operation, send data loggers to the NRCS EMF shop for calibration every 6 years. Time and the elements can cause the logger to become unreliable in its consumption and output voltages. Often a data logger that is performing out of specification is not detectable by data observations alone. Therefore, the wiring and electrical components need a thorough check in a shop environment using specialized equipment.

Equipment needed to calibrate and maintain a data logger:
• computer with appropriate communications software
• power supply
• cables
• multimeter
• manufacturer-supplied test fixture

(e) Battery
Separate batteries typically power the data logger and meteor burst radio. The data logger is usually powered by one battery and the radio is powered by two batteries connected in a parallel configuration. Replace the battery any time it fails to maintain a minimum charge of 11.5 volts (loaded) or 11.0 volts (unloaded). Perform a voltage test on each battery at each site visit using a voltmeter or handheld device. If the voltage is below 11.0 volts, replace the battery. For more information, refer to NEH622.08.
manufacturer’s calibration software and procedures

Shop calibration procedures for the data logger are:

Step 1 Test all inputs and outputs according to the manufacturer’s recommendations:
- current drain
- single-ended input channels
- differential input channels
- pulse high frequency
- pulse low level AC
- pulse switch closure

Step 2 Test all logging and control capabilities and ranges according to manufacturer’s recommendations:
- referencing and keyboard communications
- running programs
- excitation channels
- control I/O port

Return out-of-spec event loggers to the manufacturer for repair and calibration. For more information, refer to NEH622.08.

(g) Electrical cables and wiring

Note: Inspect electrical cables and wiring annually. Parts should be replaced as needed (table 5–2).

Electrical wires and cables include those from the antenna, solar panels, and most of the sensors. Maintenance consists of a visual inspection for damage. Check for cracking, deterioration, corrosion, proper routing, and security. Replace as required for corrosion, aging, rodent damage, etc. Treat all connectors with moisture inhibitor, or use watertight connectors where possible.

(h) Meteor burst radio

Note: Inspect the meteor burst radio annually. Radio calibration or replacement must not exceed 6 years (table 5–2).

(i) Field maintenance
Meteor burst radio field maintenance activities are:

Step 1 Replace the internal battery every 3 years.

Step 2 Replace radios every 6 years for calibration, testing, and refurbishing by the NRCS EMF shop.

(ii) Shop maintenance
Send meteor burst radios to the NRCS EMF shop every 6 years to ensure proper operation. Time and the elements can cause a radio to become unreliable in its current consumption, transmit power, reflected power, RF, and operation over varying voltages. Often a radio that is performing out of specification will not be detectable by data observations alone. Therefore, the wiring and electrical components need a thorough check in a shop environment using specialized equipment.

The detailed alignment and calibration procedures for the meteor burst radio are beyond the scope of this document. However, the basic equipment and procedures used for full alignment of meteor burst radios are:
- adjustable 20 amp, 0–15 volt power supply
- computer with communications software
- various cables
- 100 watt, 50 ohm dummy load

Figure 5–4 Data logger wiring panel
- frequency generator
- oscilloscope
- multimeter
- various test fixtures

Calibration of the radio requires the following adjustments:

- Receiver—Proper alignment for frequency, sensitivity, and phaselock operations.
- Transmitter—Proper alignment for frequency, phase, power operations, and minimal spurious emissions.

For more information, refer to NEH622.08.

(i) Relative humidity sensor

Note: Inspect relative humidity sensors annually. Sensor calibration or replacement should occur annually (table 5–2).

Relative humidity is the ratio of the amount of water in the air at a given temperature to the maximum amount of water it could hold at that temperature; expressed as a percentage. At SNOTEL sites, this sensor is often combined with an air temperature sensor, and is mounted and maintained in much the same way.

Replace this sensor with a currently-calibrated sensor during each annual station visit.

Inspect the radiation shield and mounting for damage, as well.

(i) Shop calibration and maintenance

Step 1 Carefully inspect the sensor and clean the body of the transducer with isopropyl alcohol. Gently remove any sealing stickers on and around the access ports and clean the area with isopropyl alcohol. Unscrew the black filter cap from each transducer. Place these caps in the ultrasonic bath for an hour with no heat. After the bath, blow-dry each filter assembly with low volume compressed air. If not clean, rebathe until clean. If the filter cannot be cleaned, discard it. Let these filter caps dry thoroughly at room temperature before reinstalling them on the finished transducer.

Step 2 With water and a cotton swab, carefully clean around the area where the filter cap screws onto the head of the transducer.

Step 3 Inspect the relative humidity sensor module and the platinum temperature module under a microscope. Any corroded or damaged parts must be replaced.

Step 4 Inspect the rubber gasket on the bottom of the transducer unit. Replace the gasket if deteriorated or cracked.

Step 5 For calibrating the relative humidity/air temperature sensors, the humidity source should be either primary salt solutions or an acceptable humidity generator chamber traceable to NIST. Verify the temperature reading against a calibrated mercury thermometer traceable to NIST. Connect the output of the sensors to a calibrated data logger to collect the readings for evaluation.

Step 6 Inspect the sensor modules under a microscope for corrosion or damage. Replace any corroded or damaged parts. Replace the rubber gasket or cable if damaged or worn.

Step 7 Suspend the sensor head in the lithium chloride (LiCl) bath test fixture or humidity generator chamber along with the mercury thermometer. Allow the sensor and thermometer to stabilize prior to making any adjustments. Record the initial relative humidity and temperature readings on the calibration sheet prior to making any adjustments. Adjust the sensor outputs to within 1 degree of the thermometer and to 11.3 percent humidity, ±0.2 percent.

Step 8 Suspend the sensor in the sodium chloride (NaCl) bath fixture or humidity generator chamber and allowed to stabilize prior to adjustment. After stabilization, the sensor’s upper end adjustment should be set for an output of 75.5 percent, ±0.2 percent.

Step 9 Repeat this process until both readings are within 0.2 percent of the salt solutions.

Step 10 After the upper and lower ends have been set, suspend the sensors in solutions of magnesium chloride (MgCl₂) and potassium sulfate (K₂SO₄) or a humidity chamber to verify their
readings at 33.1 percent and 95 percent humidity to check for linearity. For more information, refer to the manufacturer’s specifications.

Step 11  Replace the access plugs and the filter cap and apply a calibration sticker to the sensor indicating the date of calibration and the technician’s name.

Shop maintenance should include confirmation that all components are updated to a minimum version that will meet specifications. For more information, refer to NEH622.08.

(j)  Shelter

Note: Inspect the shelter annually. Parts should be replaced or repaired as needed (table 5–2).

(i)  Field maintenance
Inspect the shelter for structural integrity at each visit. Pay special attention to any indications of leaking inside the shelter. Ensure ladders and any other attached devices are secure. Ensure all hinges and latches function smoothly. The foundation and floor should be in good condition. Repair any signs of deterioration or damage. Perform cosmetic maintenance regularly so that the appearance of the shelter is clean and well kept. For more information, refer to NEH622.08.

(k)  Snow depth sensor

Note: Inspect snow depth sensors annually. Sensor calibration verification or replacement must not exceed 6 years (table 5–2).

Snow depth is the distance in inches from the snow surface to the ground surface. Ultrasonic sensors are used to measure snow depth at SNOTEL stations. These sensors require annual calibration checks in the field. Replace sensors at least every 6 years for refurbishing and calibration by the NRCS EMF shop.

(i)  Field calibration and maintenance
The field calibration procedure for snow depth sensors is:

Step 1  Inspect the sensor housing and components for visible damage.

Step 2  Ensure all cable connections are tight.

Step 3  Confirm the correct orientation and height of the sensor.

Step 4  Place a flat object (at least 1 foot square) as a target directly beneath the sensor at approximately 1/3 the distance from the ground surface to the sensor. Carefully measure the distance from the target to the sensor and record on the maintenance form.

Step 5  Verify the target is level. Make a measurement with the sensor and record the reading on the maintenance form.

Step 6  Compare the sensor measurement with the manual measurement. If the sensor reading is within ±2 inches, continue to the next step. If the measurements are different by more than ±2 inches, retake manual and sensor measurements. If the measurement remains off by more than ±2 inches, replace or repair the sensor.

Step 7  Repeat measurements, documentation, and comparison for distances of about 50 percent and 70 percent of the distance from the sensor to ground surface. If any comparisons are off by more than 3 inches, repeat the procedure. If measurements are not within 3 inches or less, replace the sensor.

Step 8  Return all removed sensors to NRCS EMF or the manufacturer for maintenance and calibration.

Mounting/alignment—Conduct an inspection of the snow depth sensor and associated mounting hardware during the annual maintenance visit. Use a bubble level to verify and adjust the sensor alignment to the vertical position by resting the level on the casing. Check the level of the sensor in two perpendicular directions. Note any adjustments made to the alignment on the SNOTEL maintenance form, so that corrections can be made to the database offset and associated metadata files.

(ii)  Shop calibration and maintenance
The shop calibration procedure for snow depth sensors is:

Step 1  Inspect the housing and all external components for visible damage. Some sensors include
an air temperature probe for automatic temperature correction. Inspect the temperature probe for damage.

**Step 2** Open the housing and inspect inside housing and components for visible damage, moisture, or corrosion. Ensure any seals or fasteners are in good shape. Remove small amounts of moisture using an oven. Use small tools to remove minor amounts of corrosion. Obvious moisture and corrosion should trigger replacement of the sensor. Check Mylar® film for rips, tears, or delamination.

**Step 3** Perform electronic diagnostic tests to ensure that the operation of the sensor is within manufacturer’s specifications. Some diagnostic tests include:

- current draw during power up
- current draw during measurement initialization
- audio from transducer
- voltage output from crystal
- output voltage frequency

If tests fall outside of specifications, replace or repair the sensor.

**Step 4** Reassemble the housing loosely.

**Step 5** Dry the sensor in the oven.

**Step 6** Perform electrical diagnostic tests again.

**Step 7** Replace desiccant in housing and fully assemble.

**Step 8** If the sensor has an onboard temperature sensor, verify that the temperature sensor is within manufacturer’s specification.

**Step 9** Test distance measurement using a flat target. Test every 3 feet, up to 30 feet distance. Log each measurement. Measurements should be within 1 inch of actual distance for every measurement. If the sensor cannot be adjusted to measure within 1 inch for every measurement, then repair or replace the sensor.

**Step 10** Label sensors that pass tests as calibrated, dated, and initialed by the technician.

For more information, refer to NEH622.02, Data Parameters, and NEH622.08.

(l) **Snow pillow SWE sensor with pressure transducer**

**Note:** Inspect pressure transducers annually. Transducer calibration or replacement must not exceed 6 years (table 5–2).

(i) **Field maintenance**

Many factors can affect performance of the snow pillow measurement system. Environmental changes and mechanical failures can induce numerous anomalies in the recorded data. Performance problems are characterized by data editors as:

- hard fail
- gross over weigh/gross under weigh
- instability
- consistent decrease
- consistent increase

A **hard fail** usually indicates a flat pillow or failed transducer. **Gross over weigh** can mean an ice problem, drifting, snow creep, tree fall, etc. **Gross under weigh** can mean a leaking pillow, failing transducer, ice bridging, etc. The most common cause of **instability** is air bubbles in the pillow plumbing. A **consistent decrease** can be an indication of a leak in the system. A **consistent increase** over and above the precipitation gage increase may indicate wind redeposition, snow creep, or ice layers on the pillow which leverage more weight than is directly on the pillow itself. In all these cases (and others), sensor performance is affected and data quality is impaired.

Transducers should theoretically be able to maintain a ±0.1 percent full scale tolerance. In field applications there are many more uncontrolled factors that could affect the ultimate accuracy of the system. Differential ground surface movement between the transducer and the pillow due to frost heave, soil expansion, or contraction due to excess moisture or extremely dry conditions can cause the tolerance to be exceeded without any fault on the part of the sensor. Air bubbles in the plumbing line can compress and expand with variances in temperature and barometric pressure. Diurnal fluctuations caused by the daily expansion and contraction of metal components and fluids in the system are subsequently measured by the transducer. These measured fluctuations will induce data anom-
lies. Additionally, the pressure transducers are susceptible to fluctuations in voltage output as the temperatures change (both long-term and diurnally), or in some cases temperature will affect excitation voltages for the logger.

Field-checking the pillow system includes testing and verifying both the mechanical aspects of the pillow system response and the electrical performance of the transducer. Verify mechanical functions of the pillow system by conducting ground truth snow sampling (e.g., ground truth measurements) in the vicinity immediately adjacent to the pillow. Ground truth measurements include reading the level of fluid in the pillow manometer, conducting manual snow measurements at specified ground truth points around the pillow, and comparing the two measurements. The increase of the level of fluid in the manometer (from previous onsite manometer readings) multiplied by the specific gravity of the pillow fluid solution should be approximately equal to the amount of snow water equivalent measured around the pillow.

If the manual SWE measurement does not fall within ±10 percent of the manometer measurement, check the system for failure causes.

Another ground truth performed after melt-out (and generally during annual/summer maintenance) is to verify that the fluid in the manometer returns to the initial level or zero level. This level is usually established when the SNOTEL site is installed. The zero level should remain nearly the same over the years, but there are environmental factors that can cause it to fluctuate or need to be reset. Manometer levels that do not return to within ±0.5 inches of the initial setting likely indicates a need for the pillow and plumbing system to be inspected.

Confirm pillow performance by comparing the telemetered SWE accumulation with the telemetered accumulation of precipitation in the SNOTEL precipitation gage. Although SWE and precipitation are certainly different, and do not necessarily trend in a one-to-one relationship, they are related parameters. The data traces from the sensors should show symmetry in pattern and amount up to the ablation period. Refer to NEH622.06, Data Management, for more information.

(ii) **Pressure transducer calibration**

The electronic component of the snow pillow is the pressure transducer. Perform calibration verifications on pressure transducers annually. Compare the transducer output to the digital value calculated and value recorded by the data logger (app. 5A). Transducers should field test within the following limits:

- 0-50 inches head—within 1 inch of actual measurement
- Greater than 50 inches—within 2 percent of actual measurement

Replace transducers every 6 years with a calibrated/tested transducer from NRCS EMF. EMF will test and recalibrate each transducer using a DPI515 or dead weight tester. EMF will then test and recalibrate each transducer using a calibrated temperature chamber that excites the transducer electronics in order to verify and validate long-term performance, reliability, and repeatability over a wide range of temperatures. For more information, refer to NEH622.08.

(iii) **Other inspection points**

**Leaks**—Closely inspect snow pillows for leaks or signs of abrasion that could result in a failure in the pillow material (fabric). Repair leaks and abrasions with proper materials. If pillows are over 20 years old or in very poor condition, prioritize them for replacement.

**Purge air**—Check pillows annually for air pockets. If air is trapped inside a pillow, purge it from the pillow. This is typically done by removing the center valve, adding a standpipe, and compressing the pillow to force the air pocket out of the valve stem or center bung hole. Use a large rolling pin, or equivalent, to force the air to the center of the pillow for expulsion. Ensure proper care is taken not to damage the pillow during this process. Watch for sharp ends in the hardware cloth.

Steel pillows may also need to have air purged. Using a similar technique, purge each steel pillow until no air remains inside.

**Vegetation management**—Minimize vegetation around a snow pillow to eliminate potential impacts on snow deposition on the pillow. Generally, keep an area clear of vegetation around the pillow perimeter, extending outward approximately 4 feet. For metal
pillow arrays, remove vegetation growing between the pillows during maintenance visits. Clear sample points for manual ground truth measurements and install the sample point signs to be visible above the deepest anticipated snow depth. When fencing is required, place wire fences no closer than 6 feet from pillows, and wood fences no closer than 15 feet from the pillows. As a general rule, and when practicable, a 30 degree window (open to the sky) above the pillow will be maintained in all directions ensuring that snow will fall directly on the pillow under nominal nonwindy conditions. Refer to NEH622.08 for more information.

Fluid level—Install and operate snow pillows in a full condition (generally 3 to 4 barrels of solution water 50-50 mix) in order to respond correctly and collect high-quality, representative data. A visual inspection of the pillow will assess if adequate fluid levels are present. When the fluid levels drop to less than acceptable levels, additional fluid is added. When a pillow system requires additional fluid, inspect the system physically for visible leaks. If maintenance records indicate a frequent need for fluid additions, then replace the pillow. For more information, refer to NEH622.08.

Specific gravity—Measure the specific gravity of the snow pillow fluid (at 32 degrees, and various other temperatures to develop a reliable curve) when the pillow is installed or when additional fluid is added. Additionally, collect a verification of specific gravity every 6 years, following installation.

Plumbing—Inspect snow pillow plumbing for leaks, including the presence of air bubbles, annually. If air is found, bleed it from the lines. If air is suspected in the buried plumbing between the pillow and the transducer (shelter building), bleed it by running 1 to 2 gallons of fluid through the system to force the air out of either the pillow valve/bung or the manometer tube. Replacement of plumbing components should be consistent with existing configurations, unless a new plumbing installation is required due to insufficient plumbing size or leaks in the system. A hand-powered vacuum pump may help remove air from plumbing lines.

Manometer—Inspect the pillow manometer tube for leaks on an annual basis or during any subsequent site visit. It should be kept free of debris that might affect data quality. A layer of light oil is maintained at the top of the solution-water mixture to prevent evaporation through the manometer tube. If a manometer tube becomes stained from the dyes in the fluid (impacting the ability to read the meniscus), replace the manometer tubing. The manometer tubing is made of material that remains flexible at cold temperatures (such as Tygon®, or equivalent) (fig. 5–5).

Protective covering—Inspect any materials used as a protective covering for the pillow annually to determine if they may compromise pillow integrity by damaging the pillow exterior. If a top dressing is required, use pea gravel of a uniform size, and a depth of approximately 1 inch over the pillow. Pillows must be installed evenly and level on a surface that extends at least 3 feet beyond the perimeter of the pillow. Maintain proper bedding around the pillow edges and level them annually. Metal pillows are particularly susceptible to loss of backfill bedding under the pillow edges. However, fabric pillows are also susceptible to this condition. Inspect both types of pillows annually.

If a bear-proof protective covering is used (such as sheet metal or chain link fencing), the pillow response should be carefully examined and documented to ensure the operational dynamics of the pillow are not affected and the collected data is not biased. The sheet metal edges should be smooth as to not damage the pillow. Remove any burrs and spikes on chain-link fencing.

Fetch—Evaluate fetch (both upwind and downwind, based on the site’s predominant wind patterns) during site selection and site installation. When possible, the pillow site location should avoid obvious exposure to potential wind loading (or windblown) scenarios. As the vegetative structure changes through time at the site, periodic evaluation of wind loading and erosion of snowpack on the pillow should occur to determine impacts on measurement data. If necessary, modify or trim the trees and vegetation or move the instrument shelter to minimize potential wind influences on the pillow. This is a case-by-case evaluation and is site-specific. Decisions may be influenced by the ultimate use of the data.

(iv) Shop calibration and maintenance

Shop procedures for the snow pillow pertain mostly to calibration and maintenance of the pressure transducer associated with the system. Periodic calibration and maintenance is necessary to provide a means of verifying the accuracy and sensitivity of the transduc-
ers over an operating range of pressures and temperatures. To accomplish this, return all pressure transducers to EMF for testing and recalibration every 6 years.

Calibration of the transducer has two parts. Part one is to test whether transducers meet stated specification outputs at various pressures and temperatures. Part two is to adjust the outputs to meet those specifications, if necessary.

Evaluate and calibrate pressure transducers using manufacturer-designed techniques and primary standards for pressure, as well as a calibrated temperature chamber and calibrated power supplies, multimeters, and data acquisition systems. The pressure standard should be traceable to NIST. The temperature reading should be verified against a calibrated mercury thermometer traceable to NIST. The output of the sensors should be connected to a calibrated data logger or data acquisition system to collect the readings for evaluation. The pressure source should be extra dry nitrogen. All transducers should be exercised prior to calibration, tested for linearity throughout their designed temperature and pressure ranges, and calibrated at their designed temperature compensated range and pressure range from zero to full scale (app. 5A).

(m) Soil moisture/temperature sensor

Note: Inspect soil moisture and temperature sensors as needed. Sensor calibration or replacement should occur as needed (table 5–2).

Because soil moisture and temperature sensors are installed in the ground, it is nearly impossible to inspect their condition and check the calibration without great effort and disturbance of the surrounding soil. This makes it all the more important to carefully monitor and evaluate the data being retrieved from a soil sensor. Scrutinize the data carefully as to the reasonableness of the data. Pay careful attention to the changing climatic conditions and the responses that you might expect from the soil moisture sensor. Compare data often from collocated sensors (especially comparisons between the precipitation gages).

There are no field calibration procedures or any repair procedures for the sensor units. Remove and replace malfunctioning sensors.

Inspect these sensors carefully before installation. It is recommended that the sensor be hooked up to a power source and the outputs be checked prior to installation at a SNOTEL site. For more information, refer to NEH022.08.

(n) Solar panel

Solar panels are generally mounted on the meteorological tower. Maintenance involves a visual inspection for damage and replacement if the panel is damaged beyond repair.

Inspect solar panels for damaged cables or broken surfaces at all site visits. Clean the surface if needed. Check panel orientation visually to ensure they are pointed toward the best solar window and the angle is correct.

(i) Solar panel power output

Check the power output using these procedures:

\begin{align*}
\text{Step 1} & \quad \text{Using a multimeter, measure the output voltage by simply measuring across the leads from the panel.} \\
\text{Step 2} & \quad \text{Using a multimeter in series between the solar panel and regulator/battery, measure the output current from the solar panel.}
\end{align*}

Figure 5–5 Manometer fluid level—measure fluid level from bottom of meniscus
— Disconnect the positive lead from the solar panel to the regulator.
— Make sure the multimeter is set up to measure current. Connect the positive lead of the multimeter to the positive lead on the solar panel lead and the negative lead from the multimeter on the positive input of the regulator.

Step 3 If multiple panels are used, ensure blocking diodes are used where appropriate.

(ii) Solar panel regulator
Solar panel regulators control the amount of voltage and current being delivered to a battery from the solar panels. Check the output voltage to ensure it does not exceed the battery manufacturer’s recommended set point. It is best if the regulator is checked during the times when there is adequate supply from the solar panel.

Step 1 Disconnect the battery from the regulator.
Step 2 Using a multimeter, measure the voltage and current from the output of the regulator ensuring that it meets the manufacturer's specifications.
Step 3 If the voltage and current are adequate, hook the batteries to the regulator.

For more information, refer to NEH622.08.

(o) Solar radiation sensor
Note: Inspect solar radiation sensors annually. Sensor calibration or replacement must not exceed 3 years (table 5–2).

A standard solar radiation sensor (pyranometer) measures the total incoming solar radiation. To operate correctly radiation sensors must be exposed to as much sky as possible with no obstructions above or to the side, and no debris (dust, mold, branch shadows, etc.) on the sensor itself. Ensure open exposure, and that the sensor is both clean and level.

In the field, perform annual calibration checks and replace the sensor if it fails the check. If calibration checks are not done annually, then replace the sensor with a currently-calibrated sensor. Send replaced sensors to the NRCS EMF shop for full calibration checks or recalibration.

(i) Field calibration and maintenance
Pyranometer field calibration procedures are:

Step 1 Calibrate pyranometers against a like-type reference and having a current calibration listing.
Step 2 Place a reference pyranometer as close to the field pyranometer in a manner such that it is:
— not shadowed from the sun's light at any time
— not influenced by outside light sources or reflections
— level and at the same height as the reference pyranometer
— connected to the same data logger as the reference pyranometer
Step 3 Enter the most recent response calibration correction factors into the logger for each sensor under test including the reference pyranometer.
Step 4 Record the outputs of the pyranometers including the reference for three readings 10 minutes apart. Ideally the test period should be during normal daylight hours. Reject any pyranometers whose corrected output differs from the reference by more than 10 percent.
Step 5 Evaluate the pyranometers against the reference, record the new correction values in the calibration sheet, and mark the values on the body of the pyranometer.

In addition to calibration, perform the following solar radiation sensor maintenance procedures in the field:

Step 1 Verify proper alignment to ensure the sensor is in the vertical position.
Step 2 Gently clean the lens of the sensor with distilled water and a soft brush.
Step 3 Inspect the cable for damage and repair as necessary.
(ii) Shop calibration and maintenance
Pyranometer shop calibration procedures are:

Step 1  Calibrate pyranometers against a like-type reference and having a current calibration listing.

Step 2  Mount pyranometers to be calibrated next to the reference pyranometer in a manner such that they are:
— not shadowed from the sun’s light at any time
— not influenced by outside light sources or reflections
— level and at the same height as the reference pyranometer
— connected to the same data logger as the reference pyranometer

Step 3  Enter the most recent response calibration correction factors into the logger for each transducer under test including the reference pyranometer.

Step 4  Record the outputs of the pyranometers including the reference simultaneously every 10 minutes. The test period should be during a period of normal sun, not inclement or cloudy weather and run for a minimum of 3 days. Then the data should be plotted and evaluated and their new calibration factors determined. Reject any pyranometers whose output differs from the linearity of the reference by more than 2 percent. Reject any pyranometer whose calibration correction factor deviates from the previous factor by more than 2 percent per year since the last calibration. Likewise, reject any pyranometers whose corrected output differs from the reference by more than 10 percent.

Step 5  Evaluate the pyranometers against the reference and record the new correction values in the calibration sheet, as well as clearly marked on the body of the pyranometer.

In addition to calibration, perform the following maintenance procedures on the sensor at the EMF shop:

Step 1  Gently clean the plastic lens of the sensor with distilled water and a soft brush.

Step 2  Clean the weep hole to ensure drainage of accumulated water.

Step 3  Inspect the cable for damage and repair as necessary.

For more information, refer to NEH622.08.

(p) Storage precipitation gage with pressure transducer

Note: Inspect pressure transducers annually. Transducer calibration and/or replacement must not exceed 6 years (table 5–2).

(i) Field maintenance
Many factors can influence the performance of the storage precipitation gage and its associated pressure transducer. Environmental changes and mechanical failures induce numerous anomalies in the recorded data. Performance problems categorized by data editors include:

• hard fail
• gross over/under weigh
• instability
• consistent decrease
• consistent increase

A hard fail generally (though, not always) indicates a drained gage or failed transducer. Gross over weigh can indicate an ice problem, either in the gage, or (if comparing to pillow data) an icing/bridging problem on the pillow, or even a non-precipitation event (e.g., birds, rocks, branches). Gross under weigh can indicate a leaking gage, failing transducer, snow-capped gage, evaporation, or other cause. The most common cause of instability is air bubbles in the precipitation gage plumbing lines. Debris, insects, tree debris (pine needles, small branches or twigs), and birds falling into the gage also can cause plugs in the plumbing, resulting in inaccurate data. A consistent decrease can be an indication of a leak in the system.

Conduct field verification of the precipitation gage and transducer measurement system (including associated plumbing and valves, etc.) during the annual site maintenance visit. Field verification of the precipitation system includes measurement of the manometer fluid level. The manometer fluid level (elevation) should be
equal to the fluid level (elevation) in the precipitation gage. The gage fluid level will most likely need to be estimated. If the levels do not proximate each other, then there is likely blockage in the plumbing.

During each site visit (winter or summer), take a manometer reading and document it on a SNOTEL data sheet. A record of the visit is always left with the book onsite so that the previous manometer reading is available for reference. The increase of the level of fluid in the manometer (from the previous onsite manometer readings) should be equal to the amount of precipitation collected by the gage between the two site visits. The value calculated from the manometer readings should approximate the digital readings measured by the transducer and converted by the data logger for inclusion in the SNOTEL database. This serves as a ground truth verification of the precipitation gage system.

Confirm the precipitation gage general performance by comparing the telemetered precipitation gage accumulated value with the SWE accumulation from the snow pillow. Although precipitation and SWE are certainly different, and do not necessarily trend in a one-to-one relationship, they are related parameters.

The data traces from the sensors should show symmetry in pattern and amount up to the ablation period. Frequently, during the winter the precipitation gage will be plugged (inlet orifice blocked) with a snow or ice cap (fig. 5–4). This will result in anomalous precipitation data, as the precipitation accumulation will “flat-line,” thus rendering the data invalid until the snow plug drops into the gage. In the meantime, the snow on the plug will be displaced (such that not all the snow that should be collected and measured by the gage ever reaches the gage) by wind, melting on the gage exterior, and in all cases, sublimation.

These decreases (in the amount of snow to drop into the gage) significantly affect the amount of total precipitation measured by the gage. Therefore, oftentimes the precipitation gage in the current SNOTEL configuration is not capable of measuring and collecting accurate, reliable, and near real-time winter (i.e., frozen) precipitation.

To overcome these flat-line situations, it is highly recommended that the SWE data collected from the pillow be used to estimate the missing accumulated precipitation. This is intuitive, because the snow pillow is designed specifically to collect and measure winter, frozen precipitation and is not susceptible to plugging. Additionally, the greater size of the pillow (e.g., 10-ft diameter of polypropylene pillow versus 12-inch inlet diameter of precipitation gage) leads to more accurate readings when measuring widespread precipitation such as light, low-density snowfall. Refer to NEH622.06, Data Management.

(ii) **Pressure transducer calibration**

The electronic component of the storage precipitation gage is the pressure transducer. Perform calibration verifications of the pressure transducer in the field on an annual basis. Compare transducer output to the digital value calculated and value recorded by the data logger (app. 5A).

Transducers should field test within the following limits:

- 0–50 inches head—within 1 inch of actual measurement
- Greater than 50 inches—within 2 percent of actual measurement

Replace transducers every 6 years with a calibrated and tested transducer from EMF. EMF will test and recalibrate each transducer using a DPI515 or dead weight tester. For more information, refer to NEH622.08.

(iii) **Other inspection points**

**Recharge**—Precipitation gages are generally serviced and maintained with an antifreeze solution (propylene glycol and a stabilizer mix) topped with a layer of light, environmentally safe, industrial oil to prevent evaporation of the solution. The amount of antifreeze solution (recharge) added to the gage (following flushing) is determined by the average annual precipitation (snow and rain) at the site. In other words, sites that receive greater rainfall or snowfall amounts will require more solution, and sites that receive lesser precipitation amounts will require a lesser amount (volume) of recharge.
Also, ensure the recharge amount provides the necessary freeze protection, especially in early season.

**Recharge procedure**—An annual maintenance inspection and recharging of the gage is recommended except in areas of extreme remoteness or if the gage is sized to handle multiple years accumulation of precipitation. Recharge precipitation gages before the solution becomes dilute enough to freeze at the coldest anticipated temperature (app. 5B).

**Vertical orientation**—Inspect the precipitation gage annually to ensure that the orifice is maintained at a level position (fig. 5–7). If necessary, make adjustments and document modifications for metadata archival.

**Plumbing leaks**—Inspect the precipitation gage for plumbing leaks annually during the site maintenance visit. Repair any leaks and document modifications for metadata archival.

**Clean**—Clean precipitation gages whenever the solution is replaced.

**Paint**—If necessary, maintain precipitation gages in good condition with a coating of paint. When the coating begins to break down (over time and with weather), repaint the gage. Prior to painting, prepare the aluminum gage surface by cleaning with solvent to remove grease and oils. The standard gage color is dark brown. However, color variations may be made depending on site location and conditions and site lease-holder requirements.

**Alter shield**—Install and maintain the alter shield so that the vanes swing freely and remain in a level position at the specified height above the orifice (1/2 to 1 in). The alter shield will be installed at the great majority of sites. However, certain site considerations preclude installation of the shield (extreme winter icing or capping, for example) (fig. 5–6).

**Vegetation management**—Clear the area around the precipitation gage of trees that might fall and damage the gage. As a general rule (and when practical) maintain a 30-degree window (open to the sky) above the pillow in all directions. This ensures that snow will fall directly on the pillow under “nominal” nonwindy conditions.

**Gages**—Inspect gages for problems, leaks etc. during the annual maintenance visit to the site and replace as necessary. Some problems might include bullet holes or a bent orifice due to falling tree branches. The orifice should be checked to verify it remains level and round.

(iv) **Shop calibration and maintenance**
Shop procedures for the storage precipitation gage pertain mostly to calibration and maintenance of the pressure transducer associated with the system. Periodic calibration and maintenance is necessary to provide a means of verifying the accuracy and sensitivity of the transducers over an operating range of pressures and temperatures. To accomplish this, return all pressure transducers to EMF for testing and recalibration every 6 years.

Calibration of the transducer has two parts. Part one is to test whether transducers meet stated specification outputs at various pressures and temperatures. Part two is to adjust the outputs to meet those specifications, if necessary.

Evaluate and calibrate pressure transducers using manufacturer-designed techniques and primary standards for pressure, as well as a calibrated temperature chamber and calibrated power supplies, multimeters, and data acquisition systems. The pressure standard should be traceable to NIST. The temperature reading should be verified against a calibrated mercury thermometer traceable to NIST. The output of the sensors should be connected to a calibrated data logger or data acquisition system to collect the readings for evaluation. The pressure source should be extra dry nitrogen. All transducers should be exercised prior to calibration, tested for linearity throughout their designed temperature and pressure ranges, and calibrated at their designed temperature compensated range and pressure range from zero to full scale (app. 5A).

For more information, refer to NEH622.08.

(q) **Tipping bucket precipitation gage**

**Note:** Inspect tipping bucket precipitation gages annually. Gage calibration or replacement must not exceed 3 years (table 5–2).

When precipitation measurements more precise than 0.1 inch are required, measurements are made with tip-
ping bucket precipitation gages. The measurement device is a balanced, tipping bulkhead mechanism that is designed to tip with each 0.01 inch of precipitation collected. The bucket tipping causes a momentary switch closure that is counted by the data logger, resulting in a totaling of precipitation. The tipping bucket gages have the limitation of measuring only liquid precipitation and will only function when the temperature is above freezing.

(i) Field inspection and calibration
Clean, inspect, and verify for level tipping bucket precipitation gages annually. Insects, dirt, and dissolved solids precipitate out onto the tipping buckets and can imbalance the system, so care must be taken when cleaning the gage. Additionally, any displacement of the gage out of level can cause the gage to report inaccurate values.

Perform calibration verification in the field using manufacturer-specified procedures, fixtures, and quantities of water for the various makes and models of tipping bucket precipitation gages.

- Use a field calibration device to apply the specified amount of water at the specified rate. Record the number of tips of the gage rocking unit.
- Replace the gage if the number of tips is not within 3 percent of the specified number for the quantity of water used.

(ii) Shop calibration and maintenance
Following is the shop maintenance procedure for tipping bucket precipitation gages:

1. Carefully inspect the gage for corrosion, loose or broken mounting brackets, or any other physical sign of damage.
2. Remove the connecting wires from the gage bucket body.
3. Inspect the wiring using an ohmmeter to see if it is intact. On some models, there is a 10-ohm resistor. Make sure to check that resistor’s integrity. If open, replace the resistor and cover with heat shrink.
4. Remove the tipping bucket assembly.
5. Clean the tipping bucket parts with detergent and a soft brush.
6. Buff off any corrosion from the assembly with a Dremel® brush.
7. Blow dry with compressed air.
8. Lightly oil the bearings of the tipping bucket assembly with a cotton swab lightly soaked in machine oil.
9. Use an ohmmeter to check the reed switch in the tipping bucket assembly to ensure switch closure as the magnet on the tipping bucket passes the reed switch assembly. Adjust as necessary.
10. Confirm that all components are updated to a minimum version that will meet specifications.
11. Reinstall tipping bucket assembly into tipping bucket housing.
Step 12  Reattach wires to the tipping bucket assembly.

Step 13  Double-check the operation of the tipping bucket by attaching an ohmmeter to the cable on the gage and verifying switch closure as you rock the tipping bucket back and forth.

Following is the shop calibration procedure to validate tipping bucket gages. Perform calibrations using the manufacturer-specified procedures, fixtures, and quantities of water for the various makes and models of tipping bucket rain gages.

The equipment and supplies needed for calibrating and maintaining the tipping-bucket precipitation gage are:

- low-drip-rate burette, 1000 ml or equivalent, or a manufacturer-specified calibration device
- pipette, 10 ml
- deionized (DI) water
- duster and a small stiff-bristled cleaning brush
- alcohol
- cleaning rags
- calibration and maintenance form (app. 5C)

Step 1  Using the pipette, slowly drip the proper milliliters of water (manufacturer-specified) into the collecting funnel. The amount should correspond to 0.01 inch of precipitation, or one bucket tip.
Step 2  Repeat step 1 for at least 10 total bucket tips and record the response of the gage and the volume of water dispensed in order to activate each bucket tip. Record the results on the calibration form.

Step 3  Open the mechanism to clean and examine. Clean and wipe out as required.

Step 4  Clean the buckets with alcohol and a brush to remove the dissolved solids.

Step 5  Check the leveling indicator on the bottom to verify that the gage is level; adjust if necessary.

Step 6  Repeat steps 1 and 2 to verify proper operation, following cleaning. If not within specifications, follow the calibration procedure given in the gage manual.

Step 7  Using the 1,000 milliliter burette, determine a drip rate that is near the maximum recorded for the site (historical data from a proximate site, or extrapolated from area precipitation maps).

Step 8  Attach the burette (vertically) to the gage and allow the burette to drip into the gage at the rate determined in step 7. Allow the water to drip continuously until 10 bucket tips have occurred. Repeat the process for a total of three times (30 tips).

Step 9  Divide the volume added by the number of tips for each run, and then correct the volume to inches. Compare the inches per tip measured versus 0.01 inches to determine gage accuracy. The average volume per tip should be ±10 percent of 0.01 inches, or the gage should be adjusted per manufacturer's specifications, or removed and replaced. For more information, refer to NEH622.08.

(r) Tower

Important: Be aware of the potential safety risk when dealing with a damaged tower. Perform a complete hazard assessment before working on and around site towers.

Most towers used at SNOTEL installations are Rohn® 25G or 45G towers. Maintenance consists of:

- visual inspection for damage such as cracks, bends, leaning, or instability
- check for structural damage, proper alignment, and leveling
- ensure all bolts are tight

Replace towers in poor condition. Use enhanced fall protection to protect the technician when working on or around defective towers. For more information, refer to NEH622.08.

(s) Wind direction sensor

Note: Inspect wind direction sensors annually. Sensor calibration or replacement must not exceed 6 years (table 5–2).

Wind direction is measured in degrees azimuth. It is the direction from which the wind is coming relative to true north, which can be either 0 degrees or 360 degrees. Sensors to measure wind direction at SNOTEL stations consist of a wind vane interfaced to a potentiometer interface to a data logger. As the vane rotates to point into the wind direction, the potentiometer provides an output voltage that is proportional to the circular wind direction.

These sensors rely on moving parts that can remain in motion almost continuously at some locations. These sensors require annual maintenance and calibration checks, which can be performed in the field or in the shop. Replace the sensor every 6 years for refurbishing and recalibration in the NRCS EMF shop.

(i) Field or shop calibration and maintenance

Perform field calibration during routine site maintenance visits to SNOTEL stations. The wind direction sensor potentiometer only needs to be changed every 6 years. However, validate and verify the potentiometer annually, as failure can occur and accuracy and drift of the output must be documented.

Calibrating and maintaining the propeller-anemometer requires certain equipment:

- A vane angle fixture capable of securing the sensor in fixed directions throughout the compass
- Calibration and maintenance form (app. 5C)
Perform annual calibration checks using a compass, then positioning the vane in four directions (e.g., 90, 180, 270, 350 degrees from true north) and comparing the measurement to the data logger reading. (Avoid taking readings from 355 to 5 degrees azimuth.) The data logger reading should be within ±5 degrees azimuth of the compass reading.

The procedure to calibrate and validate wind direction sensors in the field or in the shop is:

**Step 1** Attach the sensor vane angle fixture for calibration. Set the vane angle to 30 degrees, 90 degrees, 180 degrees, 270 degrees, 330 degrees, and back to 30 degrees. Document the expected results vs. the observed output.

**Step 2** Verify that all readings are within ±5 degrees. Next check the sensor at 353 degrees, 354 degrees, 355 degrees, 356 degrees, 357 degrees, 358 degrees, 359 degrees, 360 degrees, 1 degree, 2 degrees, and 3 degrees. Note where the null (zero output) readings occur and document each reading on the calibration form. This will determine if there is drift with the sensor potentiometer.

**Step 3** If the sensor exhibits an output greater than ±5 degrees for any point verified in step 2, or indicates a zero reading or greater than ±5 degrees for any point in step 3, replace the potentiometer or the sensor with an EMF-calibrated sensor.

(ii) **Shop maintenance**

Perform shop maintenance procedures on wind direction sensors every 6 years. Send wind direction sensors removed from the field to the NRCS EMF shop or the manufacturer for repair.

The shop maintenance procedure for wind direction sensors is:

**Step 1** Inspect sensor casing and components for physical damage or wear.

**Step 2** Clean the sensor; repair any damaged parts.

**Step 3** Replace the potentiometer and bearing.

**Step 4** Bench test all sensors electrical properties for performance that is within specifications.

**Step 5** Evaluate sensor operation performance for its entire range of measurement (e.g., 0 to 360 degrees azimuth).

**Step 6** Check sensor calibration using calibrated oscilloscope, vane angle fixture, and data logger.

**Step 7** Monitor resulting voltage with an oscilloscope and specified voltage for particular angle. Confirm the comparison to be within manufacturer’s specification.

**Step 8** The resulting calculated wind direction must be within 0.25 degrees of the manufacturer’s corresponding wind direction for specific orientation. Replace any rotors outside of this specification.

**Step 9** Label sensors that pass the performance test as calibrated with the date of calibration and technician’s initials.

**Step 10** Document all maintenance and calibration procedures with the serial number of each sensor.

For more information, refer to NEH622.08.

(t) **Wind speed sensor**

**Note:** Inspect wind speed sensors (anemometers) annually. Sensor calibration or replacement must not exceed 6 years (table 5–2).

Wind speed is measured in miles per hour. It is the speed of the movement of air relative to the Earth’s surface. Sensors to measure wind speed at SNOTEL stations are propeller-driven shafts attached to a potentiometer. These sensors rely on moving parts that can remain in motion nearly continuously at some locations.

These sensors require annual maintenance and calibration checks, which can be performed in the field or in the shop. Replace the sensor a maximum of every 6 years for refurbishing and calibration in the NRCS EMF shop or return to the manufacturer.
Field or shop calibration and maintenance

Calibrating and maintaining wind speed anemometers requires:

- constant RPM tachometer with suitable attachments to connect to anemometer shaft
- voltmeter
- two new bearing assemblies, kept clean and protected prior to installation
- spacer for seating bearings properly
- calibration and maintenance form

Perform a complete visual inspection of the sensor housing and components. Ensure there is no physical damage and it is relatively clean. Replace bearings during each maintenance visit.

Check calibration of the wind speed rotor using a tachometer and voltmeter or data logger to compare output voltage to revolutions per minute (RPM). Compare output voltage with calculated speed from the data logger. Voltage should change smoothly and proportionally with RPM change, with no dead spots or spikes. If the sensor fails the calibration check, repair or replace the rotor unit.

The procedure to calibrate and validate wind speed anemometers in the shop or field is:

**Step 1** Remove the anemometer cups or propeller and secure the sensor on the tower or ladder for the calibration.

**Step 2** Connect the constant-RPM tachometer drive motor and operate at three speeds; in the shop, use five speeds (counterclockwise only) through the range of the sensor and document the expected results vs. the observed output.

**Step 3** Repeat steps 1 and 2 if the sensor provides variable output and the readings do not stabilize.

**Step 4** Change the wind speed bearings per the manufacturer's recommendations and specifications. Use only the bearings specified for the sensor.

**Step 5** Repeat step 1 with new bearings and document the results on the calibration form.

**Step 6** Reattach the anemometer cups or propeller and reinstall the sensor on the tower.

**Step 7** Document all shop maintenance and calibration using standard calibration and maintenance forms.

To repair the wind speed rotor unit:

**Step 1** Disassemble the rotor unit and visually inspect for damage.

**Step 2** Be sure any gaskets or fasteners are in good condition and replace if damaged.

**Step 3** Replace all bearings.

**Step 4** Wipe any dust or dirt from shaft and other parts.

**Step 5** Reassemble rotor assembly and ensure that it spins freely and quietly.

**Step 6** After complete maintenance of sensor, recheck calibration of sensor with oscilloscope, tachometer, and data logger. If the sensor continues to fail the calibration check, replace the sensor.

For more information, refer to NEH622.08.

Test/calibration equipment

The test equipment and associated tools used during calibration procedures should follow a general practice of traceability protocol based on standards maintained by the National Bureau of Standards (NBS). This results in claims of calibrations that are traceable to NBS.

Documentation

Note: Maintenance, station, and site documentation is housed online with station metadata.

**Step 1** Label all sensors that pass the shop performance test as calibrated with the date of calibration and technician initials.

**Step 2** Document all maintenance and calibration procedures with the serial number of the associated sensor.

**Step 3** Record all site visits on an official SNOTEL Data Site Form (NRCS ENG 708A) or...
other suitable maintenance and metadata form. (The data are ultimately placed into a central database.) It is the responsibility of the person visiting the site to ensure documentation is complete and entered into the database.

The minimum documentation requirement is:

- Maintenance date and calibration date
- Specific sensor, serial numbers, measured position (e.g., height aboveground)
- A narrative of the site visit, including the date, personnel at site, what maintenance was accomplished, and any maintenance that is needed on the next visit
- Complete site inventories (for new installations and site visits where a complete upgrade is done or most of the components are replaced)

Maintain all original hard copies of the documentation at the respective DCO.

622.0503 References


SNOTEL Data Site Form (NRCS ENG 708A)

SNOTEL Site Maintenance Form (NRCS MEW082176-RCE), 2011.
(a) Field calibration (DCO shop test)

Transducers are components used in the measurement of Snow Water Equivalent (SWE) and Precipitation (PCP). The recommended field procedures for verifying the proper operation and data output from SNOTEL pressure transducers are:

**Step 1** Record the fluid level in the manometer against the manometer measuring tape (mounted adjacent to the manometer tube on the shelter wall) on the SNOTEL data form.

**Step 2** Force the data logger to do several updates of the pressure transducer (at least 3).

 — Verify that the readings are stable and consistent, and then record the output from the data logger. If the readings are not within 0.1 inches, evaluate what is causing the instability and attempt to resolve the issue (e.g., bleed air from the fluid line, replace the transducer, repair poor electrical connections, etc.).

 — Record the pressure transducer reading from the data logger once the instability issues have been resolved.

 — While the data logger is updating the pressure transducer reading, use a calibrated voltmeter or handheld device to read the analog output from the pressure transducer and record it on the SNOTEL data form. Compare the voltmeter reading to the data logger reading to verify the data logger is accurately recording the pressure transducer data.

 — The calibrated voltmeter should be accurate to within 0.2 percent, and precise to the nearest millivolt.

 — The data logger and voltmeter readings should be within ±0.5 percent of each other. If a greater discrepancy exists then steps should be taken to eliminate this discrepancy (e.g., data logger should be calibrated; voltage dividers (if used) checked and replaced; corroded contacts cleaned, etc.)

 — Once the problem has been resolved, then remeasure and record the output from the data logger and voltmeter again.

**Step 3** Measure the fluid head height that the pressure transducer is measuring manually with a tape measure.

 — It is recommended to use a tape measure delineated in tenths of inches and measurements be made to the nearest 0.1 inch.

 — It is beneficial to have the pressure transducer mounted within 6 inches of its respective manometer tube to reduce errors during this step. If a pressure transducer is mounted a significant distance from the manometer it is helpful to use a level to draw a straight level line across the shelter building wall, and then measure from this line.

 — The datum point for measuring height of fluid in the manometer and the height of transducer is the floor of the instrument shelter. Measure from the floor the distance from that datum point to the fluid height. Record this measurement in inches and tenths of an inch.

 — The fluid height is read at the bottom of the meniscus.

 — If a layer of oil is used in the manometer, make sure to include this layer in your measured fluid height.

 — Manometer tubes are often stained, dirty, and hard to read. Shake the tube to see the fluid move inside if it is difficult to tell the fluid height. Replace the manometer tubing after finishing the transducer verification if it is difficult to read.

 — Ensure the selected measurement point allows the data logger to measure straight up and down to the fluid level and the pressure transducer. Measuring at an angle will induce a measurement error.

 — From the floor, measure the height of the pressure transducer, and record this measurement. Depending on the type of pressure transducer used, the...
A technician is responsible for being familiar enough with the equipment to know where and how the pressure transducer makes its measurement, and should measure to the appropriate point on the pressure transducer. The pressure (often referred to as the “head” on the transducer) is the difference between the fluid level in the manometer and the height of the transducer.

**Step 4** Since the output for pressure transducers used in the SNOTEL network is inches of water, the manual measurement must be corrected to inches of water using the fluid’s specific gravity (SG). Record the measured or calculated SG and multiply it by the measured fluid head. Record the product of these two numbers as the corrected fluid head on the data form.

**Step 5** A pressure transducer normally has a small offset so that when there is no head (0.000 in. of fluid) on the transducer, it still outputs a low voltage reading. This offset value should be determined in a lab before installation of the pressure transducer, and recorded in a place for easy reference by serial number. The offset for the particular transducer being verified should be determined and recorded. This number should be added to the SG corrected fluid head to determine the final head reading in inches of water.

**Step 6** The final head reading calculated in step 5 should be recorded and compared to the output from the voltmeter, the data logger, or both. The calculated final head and the data logger should be within the accuracy tolerance specified for the pressure transducer.

**Step 7** If possible, a pressure transducer should be verified with a large fluid head and a small fluid head to determine if its output is within tolerance over its entire range. This is easy to do with pressure transducers on precipitation gages that must be drained while on site.

**Step 8** Transducer output should be within 0.5 inch or no more than 2 percent off of the final head.

**(b) Shop calibration**

Transducers are components used in the measurement of snow water equivalence (SWE) and precipitation (PCP). Return all pressure transducers to EMF for testing and recalibration every 6 years.

**Step 1** Upon receiving new and used pressure transducers, EMF checks for signal output at zero pressure and 100 percent pressure at room temperature (23.9 °C). EMF records these values for each transducer before initial calibration. New transducers go into the test and aging cycles as they are. Used transducers are bench recalibrated to within our specs. For analog transducers, the specs are 100 mV for zero pressure and 5.100 V at full rated pressure of the transducer. EMF records the calibrated values of these used transducers in the space provided on the form. After recalibration of the used transducers, EMF plugs the calibration access ports with the cap screws before testing and aging.

**Step 2** EMF checks all transducers for performance at 25 degrees Celsius and –20 degrees Celsius. At each temperature range, transducers are tested for voltage output at zero pressure, and max pressure. These pressures will be stepped up at 10 percent full pressure steps and the output values recorded for each transducer at each pressure step on their individual forms. EMF notes the readings at –20 degrees Celsius. These readings must not exceed 1.3 percent F.S. from the same pressure readings at 25 degrees Celsius. No transducer reading at the rated pressure or temperature may be ±10 mV from expected results.

**Step 3** Transducers then will be “aged.” EMF pressure-cycles 1,000 times, between zero pressure and maximum rated pressure and temperature-cycles 100 times between +40 degrees Celsius and –40 degrees Celsius. This process usually takes 1 week.

**Step 4** After aging the transducers, EMF again step-checks the transducers at 25 degrees Celsius. They monitor the outputs of each transducer and record values at 10 percent intervals from 0 percent pressure to 100 percent rated pressure. EMF then step-checks these transducers at –20 degrees Celsius and records the results of each transducer.
**Note:** Document the drift of each transducer from the initial values and the aged values. You can expect a little drift from the new ones as they age. On the used ones, any drift between initial and aged past 0.2 percent is a cause for rejection.

**Step 5** At 25 degrees Celsius, EMF removes the new transducers from the freezer. On the bench, they recalibrate each transducer to its zero value and full scale value, seal each potentiometer with fingernail polish, and after recapping the access screws, seal the screws with fingernail polish. EMF reinstalls these new transducers in the freezer, and then records their values after calibration on the data sheet.

**Step 6** The final step is to run all these transducers again for 100 cycles of temperature and pressure cycles.

After this last step, EMF checks the final outputs of the transducers at 0 percent pressure and 100 percent pressure and records these values in the final calibration spaces on the test sheet. EMF will reject any value that deviates more than 0.2 percent from the previous calibration values.

Table 5A–1 is an example of a calibration worksheet used for shop calibration of a transducer.
Table 5A–1 Example pressure transducer worksheet

### PRESSURE TRANSDUCER WORKSHEET

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Finish Technician: ___________________

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STATUS: ________________

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<tr>
<td>100</td>
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</tr>
</tbody>
</table>

NOTES: ____________________________________________

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________
Steps for transducer verification

This is an example of how to work through the pressure transducer (PT) verification.

PT output as recorded by the data logger =
A ____________ inches of water

PT output as recorded by the voltmeter =
B ____________ inches of water

Error between data logger and voltmeter (A–B) =
C ____________

Height of fluid in manometer from shelter floor =
D ____________ inches (rounded to nearest tenth)

Height of PT from shelter floor =
E ____________ inches (rounded to nearest tenth)

Uncorrected measured head (D – E = F) =
F ____________ inches

Measured or calculated S.G. =
G ____________ Was S.G. measured or calculated?

S.G. corrected fluid head (F * G = H) =
H ____________ inches of water

Lab measured offset for PT =
I ____________ inches of water-PT SN: __

Final calculated fluid head for PT (H + I = J) =
J ____________ inches of water

Total measurement error (A – J = K) =
K ____________

Percent measurement error ((K ÷ J) * 100 = L) =
L ____________%

Consider replacing transducer if measurement error is more than 2 percent of the scale range from the correct final head.
Appendix 5B

Storage Precipitation Gage Recharge

**Step 1** Read and record the manometer tube inside the shelter.

**Step 2** Turn off the plumbing valve to the precipitation gage transducer (if available).

**Step 3** Open the drain valve and drain fluid from the precipitation gage. It is not always necessary to drain the gage completely. Support the drain hose so that the open end is positioned above the height of the J tube (about 4 in. above the bottom of the gage). This prevents the fluid from draining from the J tube and allowing air to get in the plumbing line. It also prevents the oil from being drained so that more oil does not need to be added during the recharge.

**Step 4** Precipitation gages must be periodically cleaned out by removing the large bung to access the storage tank. All debris can then be removed through the opening. This cleaning procedure might vary from an annual basis to a periodic basis of perhaps every 5 years. Frequency of cleaning should be based on the amount of debris that accumulates inside the gage. One significant factor is the forest canopy type, which might contribute a great amount of leaves and other debris. Any time problems occur with debris clogging the plumbing system, the gage must be cleaned so fluid runs freely through. The threads on the large bung are easily crossed and great care must be taken to prevent this as it can damage the gage to the point it may need to be removed for repair (fig. 5B–1).

**Step 5** After emptying and cleaning the storage tank, close the valve under the tank.

**Step 6** Remove the fill cap from the elbow. Use two wrenches to remove the cap to prevent the elbow from applying torque on the walls of the gage. Pour in the prescribed amount of propylene glycol. The amount of recharge used will be site specific and should be determined at installation. The same amount of material should be used every year (NEH622.04, Site Installation) (fig. 5B–2).

**Step 7** After ensuring the transducer valve is in the off position, remove the manometer tube from the wall and blow into the tube to force the fluid back through the tube. This allows any air trapped inside the plumbing line near the goose neck to be expelled back into the gage. (This may not be possible for gages holding large amounts of recharge.)

**Step 8** Lower the manometer tube and allow the fluid to flow freely into a gallon sized container. This process will allow any air trapped in the line to be removed through the train of draining fluid.

---

**Figure 5B–1** Large bung in SNOTEL precipitation gage

**Figure 5B–2** Checking the amount of material used
Normally about a half-gallon of fluid drainage is adequate, but the technician should observe that no air bubbles are flowing through the tube before this step is completed. A vacuum pump may be used to help the fluid move and remove the air bubbles faster. Reinstall the manometer tube back on the shelter wall.

**Step 9**  Pour the drained fluid back into the gage.

**Step 10**  Pour about one pint of mineral oil into the gage to prevent evaporation.

**Step 11**  Replace the fill cap using pipe thread compound or Teflon® tape to help seal the cap without over tightening.

**Step 12**  Turn on the valve to the transducer.

**Step 13**  Some landowners require the fluid drained during recharge to be captured and carried off site. Dispose of these fluids appropriately.
## Appendix 5C

### Example SNOTEL Site Maintenance Form

**Figure 5C-1 Example SNOTEL Site Maintenance Form**

### SNOTEL Site Maintenance Form

<table>
<thead>
<tr>
<th>Field Technicians:</th>
<th>Site:</th>
<th>Site ID:</th>
<th>Date:</th>
<th>Time:</th>
<th>AM</th>
<th>PM</th>
<th>State: OR WA CA</th>
</tr>
</thead>
</table>

#### Site Inventory

<table>
<thead>
<tr>
<th>Instrument</th>
<th>ON ARRIVAL (Type/SN#)</th>
<th>REPLACED WITH</th>
</tr>
</thead>
<tbody>
<tr>
<td>545B Radio</td>
<td></td>
<td>Tower @Pill: 10' 20' 30' none</td>
</tr>
<tr>
<td>CR10X</td>
<td></td>
<td>Tower @Shelter: 20' 30' none</td>
</tr>
<tr>
<td>Pillow T-ducer</td>
<td></td>
<td>Sensor Inventory</td>
</tr>
<tr>
<td>Precip T-ducer</td>
<td></td>
<td>ON ARRIVAL</td>
</tr>
<tr>
<td>Batteries –Radio</td>
<td>Qty</td>
<td>Added or Swapped?</td>
</tr>
<tr>
<td>Battery – CR10x</td>
<td>Qty</td>
<td></td>
</tr>
<tr>
<td>Antenna</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar Panels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar Panel Reg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air Temp Shield</td>
<td>Aluminum 6-gill white 10-gill white 6-gill white 10-gill white</td>
<td></td>
</tr>
<tr>
<td>Snow Pillow</td>
<td>Butyl Steel Qty:</td>
<td></td>
</tr>
<tr>
<td>Plumbing – PILL</td>
<td>Copper Quest Funny</td>
<td></td>
</tr>
<tr>
<td>Plumbing – PPT</td>
<td>Copper Quest Funny</td>
<td></td>
</tr>
<tr>
<td>Snow Depth</td>
<td>SN# Height:</td>
<td></td>
</tr>
</tbody>
</table>

#### SITE INVENTORY

<table>
<thead>
<tr>
<th>Total Syncs</th>
<th>Total Trans</th>
<th>Total Acks</th>
<th>Fwd Power</th>
<th>Rev Power</th>
<th>Batt. Volt</th>
<th>Detected RF</th>
<th>I-Batt Volt</th>
</tr>
</thead>
</table>

#### Raw Volt Expected Compare (%\%) S.G.

<table>
<thead>
<tr>
<th>PILL Arr</th>
<th>Dpt</th>
<th>PPT Arr</th>
<th>Dpt</th>
</tr>
</thead>
</table>

#### Equipment Test Results

<table>
<thead>
<tr>
<th>Air Temp °F (Reg 100)</th>
<th>Site Batteries</th>
<th>Volt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snow Depth (Reg 5)</td>
<td>CR10x (Reg 1)</td>
<td></td>
</tr>
<tr>
<td>CR10x ProglD (Reg 101)</td>
<td>545B (Reg 7)</td>
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</tbody>
</table>

#### Maintenance

<table>
<thead>
<tr>
<th>Maint needs check</th>
<th>Y N</th>
<th>Mano lines flushed? Pst Pill</th>
<th>Current hit list check</th>
<th>Y N</th>
<th>Oil added to ppt can? Y N</th>
<th>545B i-batt swap? Y N</th>
<th>Excess air in pillows? Y N</th>
<th>Swapped coax? Y N</th>
<th>Is SD target good? Y N</th>
<th>Is power separated? Y N</th>
<th>Site Photos (NESW) Y N</th>
</tr>
</thead>
</table>

#### Conversion to Electrical Units

<table>
<thead>
<tr>
<th>Arrival</th>
<th>Depart</th>
<th>Arrival</th>
<th>Depart</th>
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<table>
<thead>
<tr>
<th>Fluid Level</th>
<th>Transducer</th>
<th>Total Head</th>
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#### Volts

<table>
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<tr>
<th>VOLTS</th>
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</table>

#### Reason for Site Visit

<table>
<thead>
<tr>
<th>RECHARGED WITH</th>
<th>GALLONS + Oil Added</th>
<th>Qts</th>
<th>SAFETY BRIEFING DONE? Y or N</th>
</tr>
</thead>
</table>

#### Comments


**NRCS FORM MEW082175-RCE (May 23, 2011)**