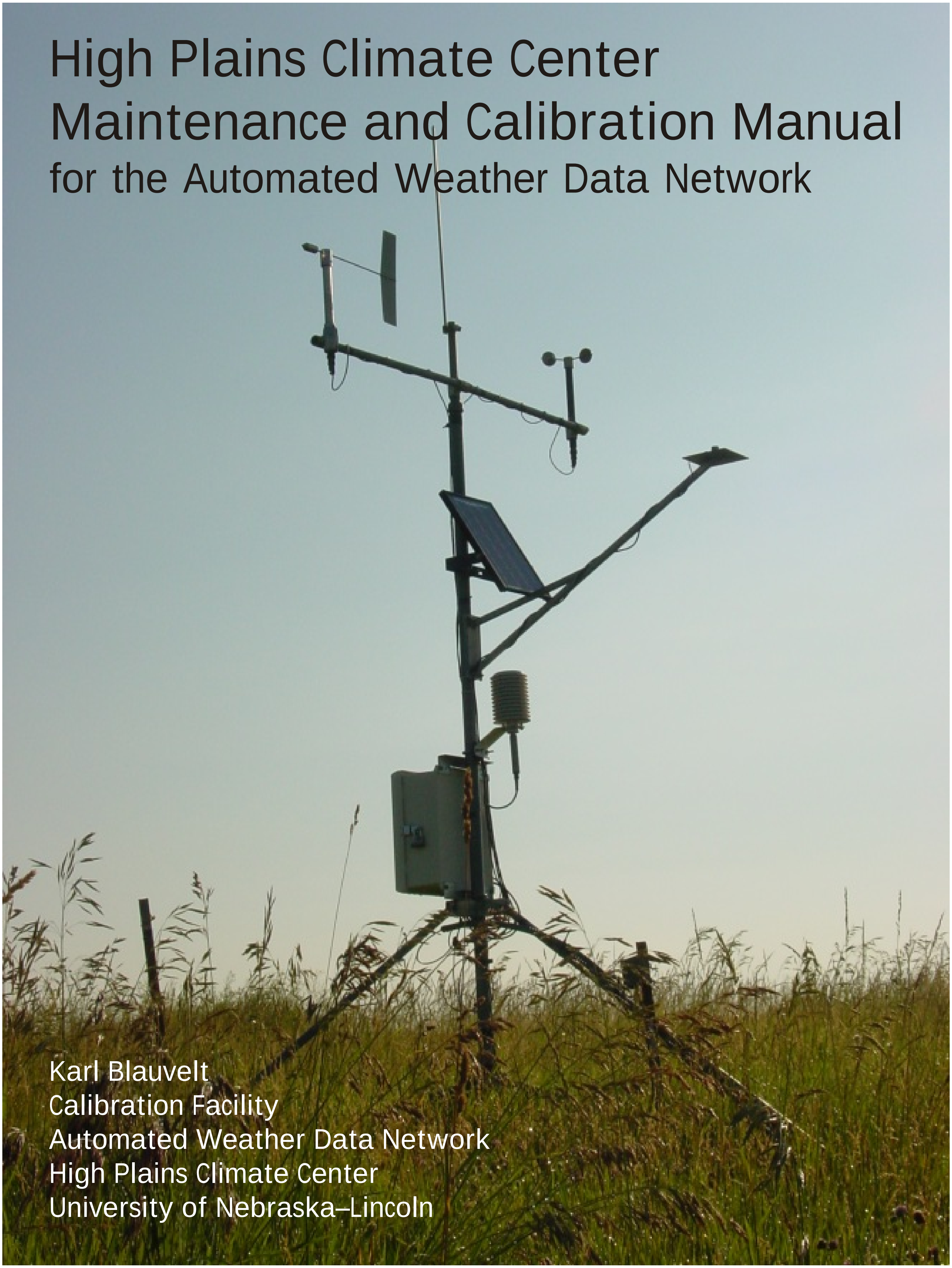
High Plains Climate Center
Maintenance and Calibration Manual
for the Automated Weather Data Network



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Contents

Temperature Probes

The manufacturer's design tolerance for all the probes I have experience with is ± 1°C. When they fail, they tend to fail spectacularly. Most will short out because of moisture, but when allowed to dry out in the shop for a month or so, they will work again. Reseal them.

Campbell has discontinued manufacture of some models. The newest 107 design is encased in an aluminum tube painted white.

If the output of the logger shows a soil temperature of about -53°, the probe is shorted to ground and should be replaced. Note that this problem can cause other problems to show up in the logger. Any other instruments connected to the same excitation port on the logger may also produce strange readings, or the entire logger output may be affected.

Calibration

Temperature probes can be calibrated using an appropriate standard calibrator. A regression of readings from the field probe (X) and a standard (traceable) probe (Y) will produce a multiplier and offset. Typically, this procedure will produce responses in the ±.2°C range.

Below are 4 graphs (Figures 1–4) generated from a typical run of an HMP35C in our Jofra dry well calibrator. These will reinforce some points I wish to make regarding the use of heated calibrators. The heating/cooling element of the Jofra is a Peltier device. The graphs demonstrate that the Jofra will not hold a specific temperature, but will range above and below the set point. This action is normal for a heated/cooled device. For this reason, we allow the temperature to stabilize for 30 minutes after changing the set point temperature, then read the temperature with a data logger at a 5-second scan rate for a period of 15 minutes. The readings are then averaged for that 15-minute period and output to final storage. The average temperatures are used in the regression.

Figure 1 shows that the Jofra is initialized at 0°C, then stepped manually at 10° increments. The hours are in the 24-hour format and represent the time of day in 30-minute increments. (We usually do the calibrations in 5° increments.)

Figure 2 shows the output of the Jofra as it seeks to reach the new set temperature of 10°C. In the electronics trade, we call the over/under cycling "ringing."

Figure 3 shows a section of Figure 2 expanded to encompass about 7 seconds of data. It shows how the Jofra rings above and below the 10° set point. Again, this is the normal output of a heated/cooled device even after it reaches stability. It is always present and shows why we need to average the tem-

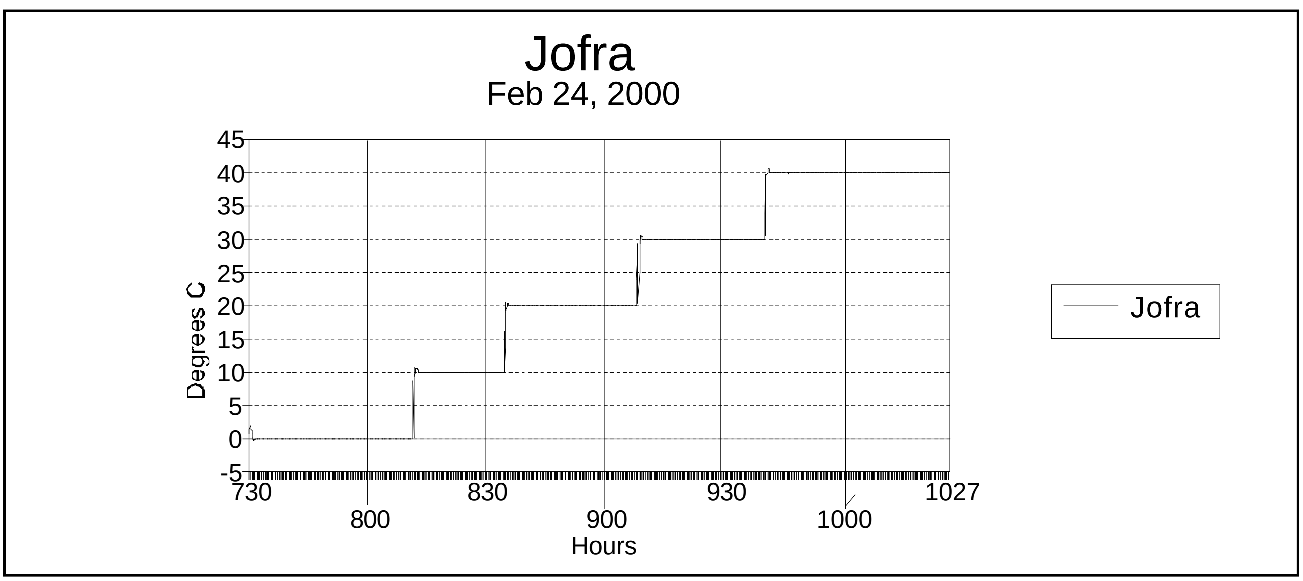

Figure 1.

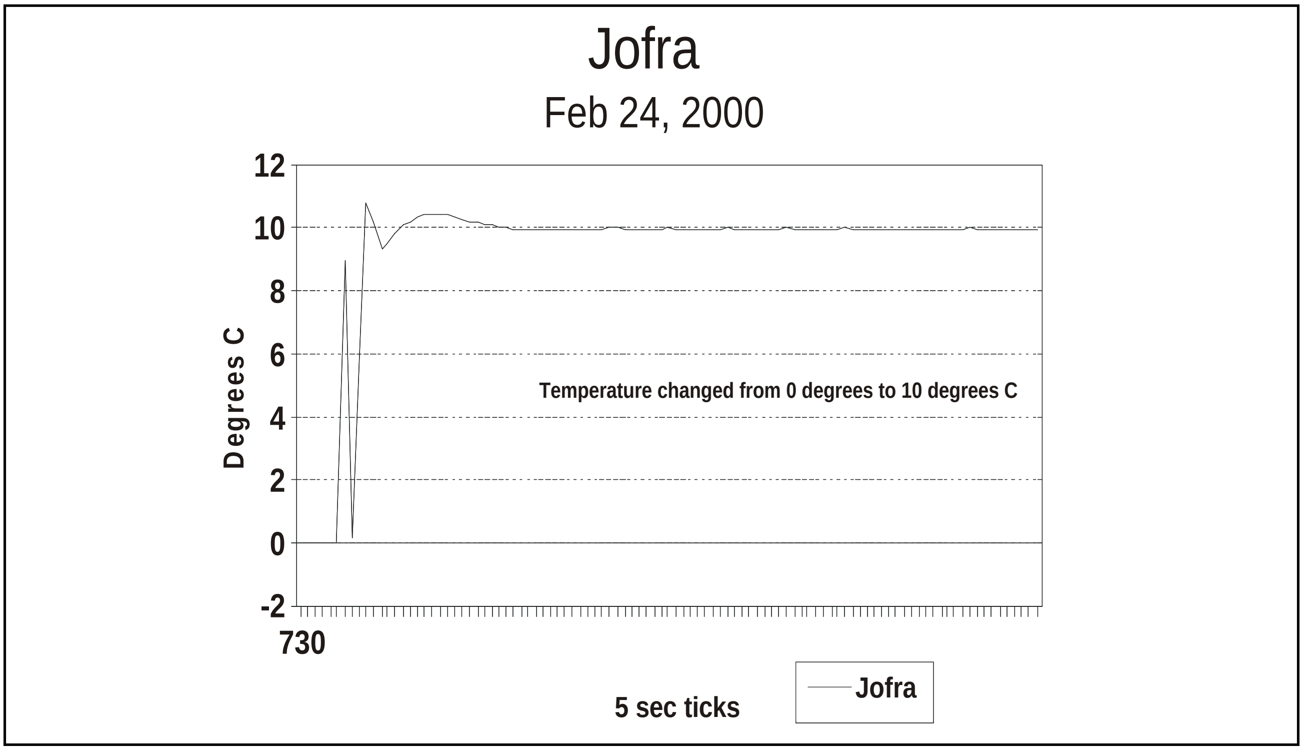

Figure 2.

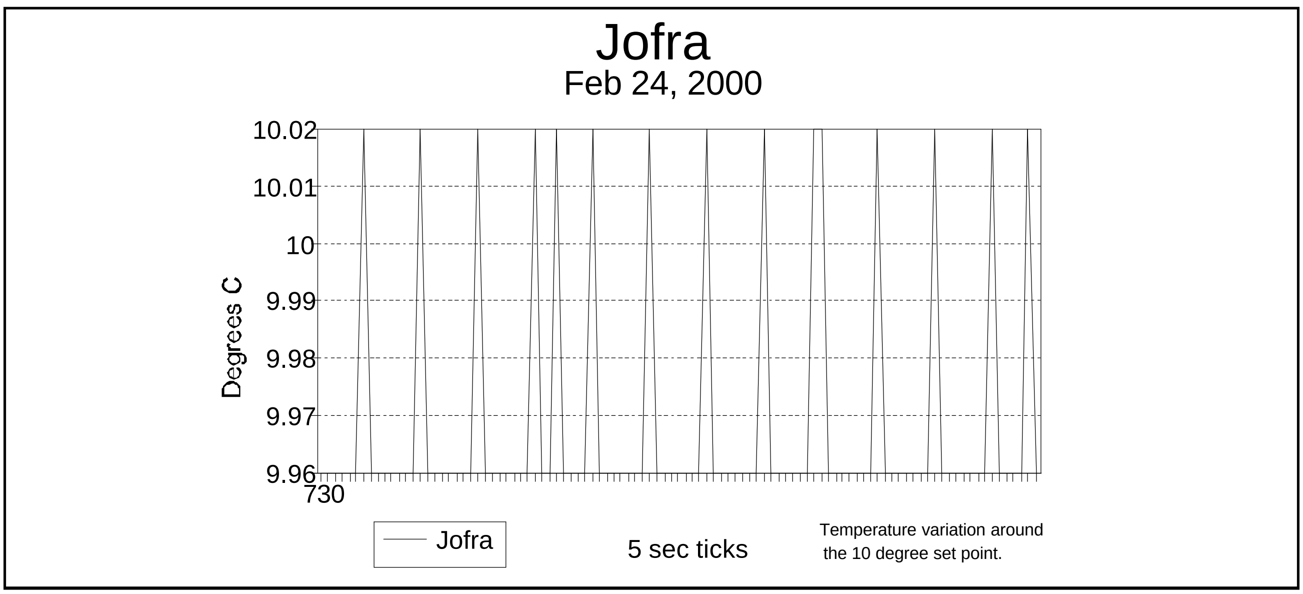

Figure 3.

perature over a 15-minute period. The averaging smooths out the ringing. If we were to take an instantaneous reading of the probe, it might be anywhere on the curve, and the reading could be off by as much as ±.1° or more.

Figure 4 shows an HMP being run inside the Jofra. The time constant of the HMP is plainly visible. You can see from the graph that it is necessary to allow about 30 minutes for the HMP to stabilize before reading its output. Note that the HMP starts above the 0° set point and finishes below the 40° set point. This is not as bad as it looks. Using the Tweener standard (NIST traceable) temperature probe, we find that the Jofra is in error here and not the HMP. This particular HMP is reading about .5° above the Tweener standard.

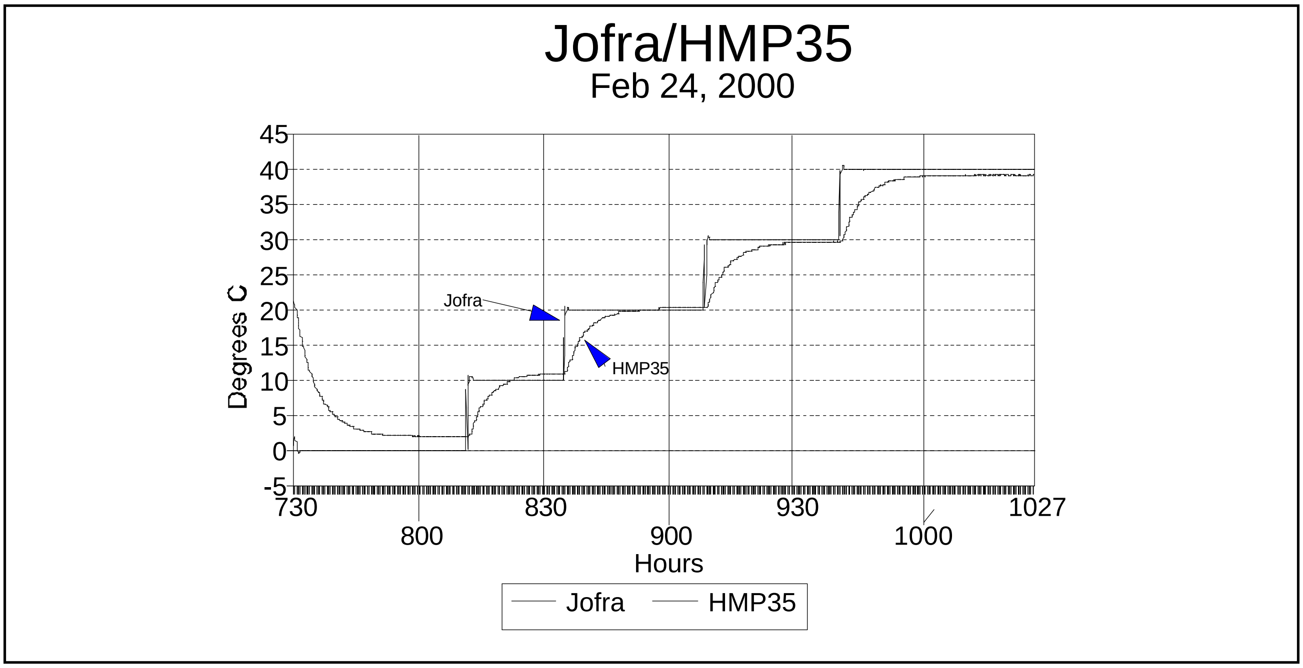

Figure 4.

Table 1 shows the regression outputs where the Tweener is taken as the standard and the HMP35C is used to estimate the Jofra.

Table 1. Regression outputs derived in the Jofra which relate HMP35C to Tweener standard.

Regression output for the Jofra vs Tweener

Regression Output:		Original mult.	= .1
Constant	= 1.357476	Original offset	= -100
Std Err of Y Est	= 0.093518		
R Squared	= 0.999954	New Mult.	= .1 x 0.944638
	= 0.0944638		
No. of Observations	= 56	New offset	= (-100) x 0.944638) + 1.357476
Degrees of Freedom	= 54		= -93.106324
X Coefficient(s)	= 0.944638		
Std Err of Coef.	= 0.000869		

HMP VS Tweener

Regression Output:		Mult. remains the same	
Constant	= -0.474089	New offset	= -0.474089
Std Err of Y Est	= 0.059901		
R Squared	= 0.999981		
No. of Observations	= 56		
Degrees of Freedom	= 54		
X Coefficient(s)	= 1.012906		
Std Err of Coef.	= 0.000597		

Rain Gauges (all makes and models of tipping bucket rain gauges)

General causes of rain gauge problems are, in order of frequency:

1. Plugged funnels:
    a. Blown-in trash
    b. Bird droppings
2. Wasp nests and spider webs
3. Mice traffic
4. Cables—defective
5. Reed switch—defective

1. Plugged funnels:

a. Blown-in trash. Clean the funnel.

b. Birds rest or roost in or on the funnel, and, being birds, they do what birds do, which plugs up the funnel. Clean the funnel.

2. Wasps and spiders:

Wasps' nests can simply be removed, but kill the wasp if you can. Female wasps are nonaggressive. Wear a pair of leather gloves and catch her. If you don't kill her, she will return.

If you go through a dry spell, spiders will build a web or cocoon in the rain gauge—in the tipping bucket, on the tipping bucket, under the bucket, or beside the bucket next to the reed switch, securing the tipping bucket so that it no longer tips. In the Texas Electronics rain gauges, the tipping bucket is molded plastic and there is a diamond-shaped space beneath the tipping bucket between the two halves. The spiders build their cocoons in this space. When you look in the bucket you cannot see anything suspicious, but when you try to calibrate the bucket, it won't balance out like it should. Sometimes it will tip and sometimes it won't. Reach into the rain gauge and feel with your fingers underneath the tipping bucket to see if there's anything in there. If you're a little leery about doing that, and I can understand why you might be, you could use a mechanic's mirror with a telescopic handle to look up underneath the tipping bucket. If you find a web/cocoon there, remove the bucket assembly and clean out the web. Re-assemble, and re-calibrate. If you can catch the offending spider, kill it. Otherwise, it will return and build again.

3. Mice:

Mice like to build their nests in the gauge. Nasty little critters.

All of the above problems can be corrected by covering the drain holes under the gauges with a piece of screen material with 1/8 in. mesh. Place it over the holes under the gauge, and secure it in place with silicone sealant. Smaller mesh will collect trash and plug up the drain over time.

The newer Texas Electronics gauges have a plastic plug in the bottom, which cures the problems with wasps and spiders. The screen should be removed and cleaned periodically.

4. Cables:

Cables deteriorate in the sun, water, and hostile environments. If the cable is in a plastic sleeve, such as black ABS tubing, be sure the ends of the tube are sealed with marine silicone sealant to keep out rain and condensation caused by humidity. If the cable sits in water for any length of time, the jacket will become saturated and short out the wires.

5. Reed switch:

The reed switches in the gauge can go bad. The switch will last about 5 million cycles under normal usage. Campbell can supply you with a kit to replace the switch. Or you can purchase the switches from

Hermetic Switch Inc., P.O. Box 1325, Chickasha, Oklahoma, 73023–1325; phone (405) 224–4046. The part number is HSR-042RT, form A. To test the rain gauge, connect a CR10KD keyboard to the logger and view the input location where the rain value is stored. Make sure the keyboard display is in a location you can see from the gauge and tip the bucket several times. A value corresponding to the volume per tip, times the number of tips, should appear on the LCD. The gauge is functioning correctly if the value in the input location is correct. If not, proceed as follows: Disconnect the cable from the logger and connect an ohm meter to the leads of the cable. Slowly move the tipping bucket back and forth so the magnet passes near the reed switch. You should see the needle of the ohm meter swing from one end of the scale to the other. If this test is successful, the wiring panel is suspect. Reconnect the wires into the panel and repeat the test. If there is no response, replace the wiring panel/data logger.

If the ohm meter test did not produce a deflection of the meter needle, proceed as follows: Move a magnet (a spirit level is good) close to the reed switch and then away. Check for a response on the meter. If there is one, check the clearance between the tipping bucket magnet and the reed switch. It should be 1/16 of an inch. The clearance is adjusted by loosening the set screw on the collet of the tipping bucket axle next to the reed switch. Move the collet closer to the reed switch and tighten the set screw. Now hold the tipping bucket against the collet near the reed switch and slowly rotate it past the reed switch. You should see a deflection of the ohm meter needle. If not, the magnet is weak. Replace the tipping bucket assembly, and re-calibrate. Remember to relocate the collet on the other side of the tipping bucket so it is tight against the tipping bucket.

If the meter needle swings, replace the wires in the wiring panel and test by moving the tipping bucket past the reed switch. You should see the results on the LCD. If not, proceed as follows: Using a lead wire with alligator clips on each end, short the two ends of the cable together at the rain gauge. If you see no indication on the ohm meter, replace the cable. If the meter indicates cable continuity, replace the reed switch. This is best done by removing the tipping bucket assembly from the gauge. Re-test and re-calibrate the gauge after replacing the switch.

Calibration

Check the gauge for level with the funnel removed. This especially needs to be checked for several years after a new installation because the rain gauge will have a tendency to settle into position off level. Depending on mounting configuration, the freeze/thaw and wetting/drying may shift the gauge. So it is advisable to check the gauge on each visit to the site. It doesn’t need to be perfectly level because you do have some adjustment of the tipping bucket, but it should be as level as possible across the top of the barrel of the rain gauge. It isn’t always necessary to dig up the base of the rain gauge (the concrete block that it’s mounted to) in order to level it. You can shim under the legs with washers to achieve level.

Calibration of the rain gauges is not all that difficult. Most of the farm supply stores carry plastic syringes in a variety of sizes, and they’re fairly accurate and well marked. Get one that has a capacity slightly larger than the volume of the gauge you are calibrating. It should be checked against a very good source to make sure that the marks on the barrel of the syringe are correct. We use a calibrated pipette for this purpose. If the markings are missing or incorrect, scratch the plastic barrel at the proper place and mark with permanent ink. The operator’s manual for your rain gauge will give you the factory volume needed to tip the bucket. Calibrate the rain gauges by filling the syringe with water to the corresponding mark. Remove the funnel, and slowly fill the “up” side of the bucket with water from the syringe (see Figure 5). Note when the bucket tips. Adjust the screw under the gauge on the opposite side of the bucket you are calibrating until that last drop that comes out of the syringe is the one that actually tips the bucket. Repeat the above steps for the other side of the bucket.

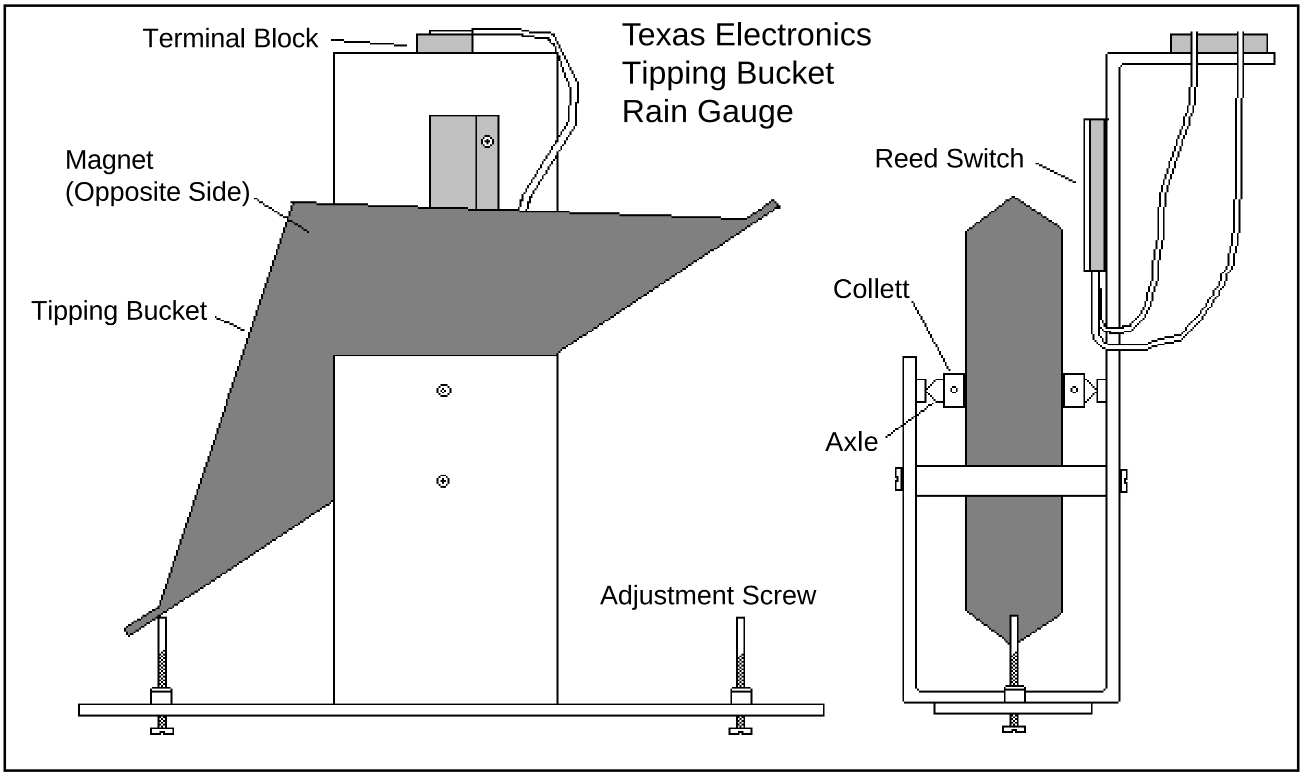

Figure 5.

Some people have poured a known quantity of water into the funnel and counted the tips. This can lead to errors because of splash and water clinging to the inside of the container. If you have a device that allows you to meter the water into the rain gauge at a slow pace and then count the tips, that may work well, but it may take up to 45 minutes for the water to flow through. Check your gauge operator's manual for other calibration hints. Taking the funnel out during calibration ensures that the volume per tip is accurate. The calibration adjustments will not remove any inaccuracies that exist because a portion of rainfall is taken up in wetting the bucket.

The best base for rain gauges is a large solid concrete building block. These blocks weigh about 45 lbs. Drill holes and use lead concrete anchors to secure the legs of the gauge to the blocks.

The wind does affect rain gauges, and that should be taken into consideration when you're calibrating. You may not get a good calibration if the wind is high because the rain gauge has a tendency to vibrate in the wind, which causes the bucket to tip prematurely. Make sure that the screws/nuts/clamps that secure the legs to the rain gauge and mounting base are tight. We just live with the fact that the rain gauge is going to tip prematurely in windy conditions. The newer Texas Electronics rain gauges supplied by Campbell do not have much problem with the wind if mounted solidly on a post. Replacement tipping assemblies are available from Texas Electronics.

Never calibrate a gauge when the temperature is below freezing, or if it's raining.

Anemometers (MET-One model 014A)

The MET-One (014) anemometer bearings should be changed each year. The bearings have a very special lubrication in them similar to the fish oil lubrication used in aircraft instrumentation. It's a very light oil and allows the bearings to have a low moment of inertia. They will start at low wind speeds, and will have little drag when running. We used some other bearings that we were told were "just like" the Met-One bearings. The indicated average wind speeds were lower then normal. We attributed the differ-

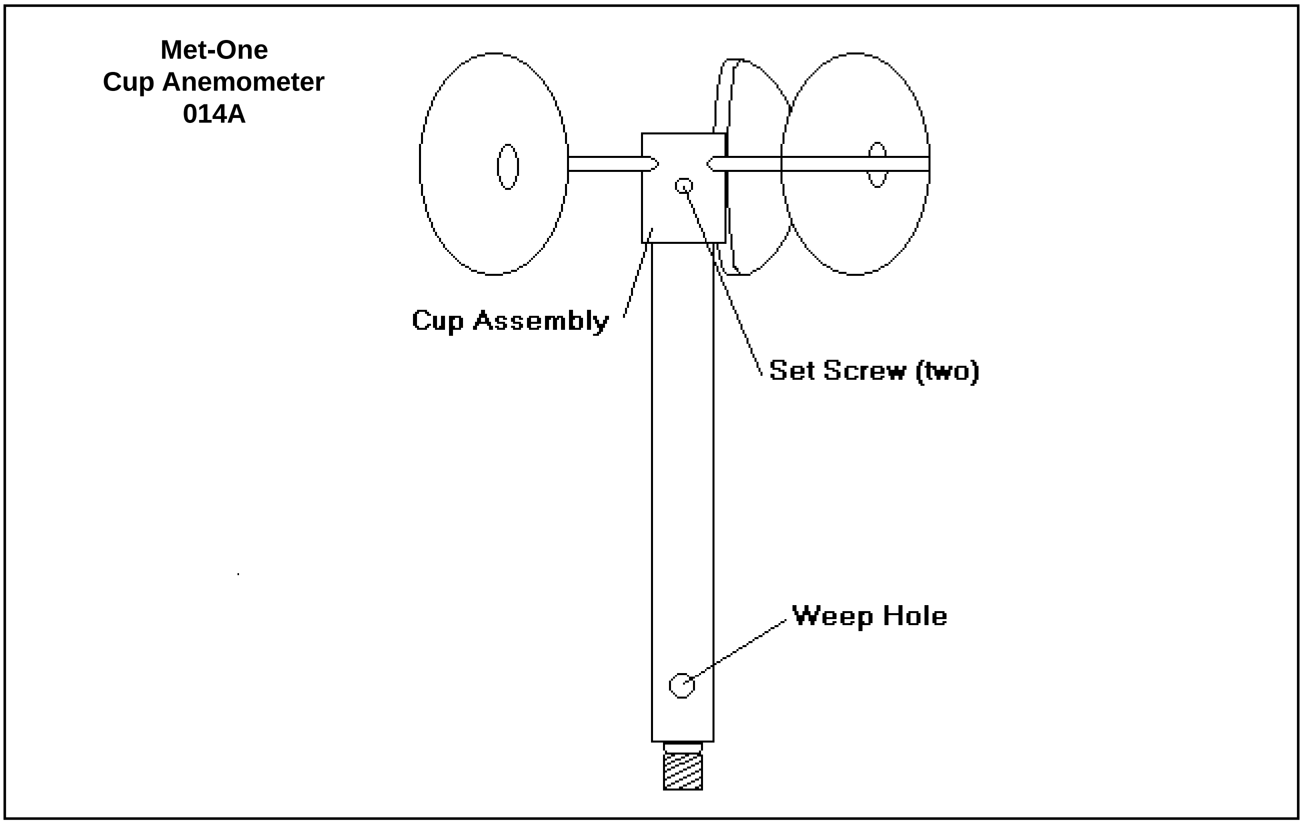

Figure 6.

ence to heavier lubricant. The anemometers at each station are swapped every year with anemometers that have been rebuilt. We replace the bearings and (if necessary) the reed switch and clean the anemometer, then test it. It is then ready for use at another site.

The instruction manual for the MET-One sensor, published by Campbell Scientific, Inc., has instructions for general maintenance and component replacement. Tools needed for changing the bearings and reed switch are a #2 cross point screw driver, .05 in. Allen wrench, 5/64 in. Allen wrench, and soldering iron.

Changing the Bearings and Reed Switch

Remove the cup assembly by loosening the 2 set screws that hold the cup assembly to the bearing assembly shaft (Figure 6). Remove the bearing mounting assembly by removing the 3 screws holding the assembly. Pull the bearing assembly out of the top of the body. Loosen the Allen set screw holding the lower axle collar. Remove only the magnet collar (lower), and pull the shaft out with the top collar in place. You will need to remove the two insulated posts that hold the reed switch to the bearing assembly to replace the lower bearing.

The reed switch is very fragile. It is not necessary to replace it each time the bearings are replaced. If the glass breaks, usually at the point where the lead enters the glass (see Figure 7), the switch must be replaced.

When removing the insulated posts from the bearing mounting, grasp the leads, switch, and top of the terminals with the thumb and forefinger and hold tightly. Alternating from one post to the other, remove the terminals from the bearing mount, so that they come out relatively parallel. You can now remove the lower bearing. Pull the top bearing off the shaft and replace. Once disassembled, clean the parts with a lint-free cloth with some silicone spray on it. Then wipe dry. Remember to re-install the

Figure 7.

washers under the bearings between the bearings and the collars. Use a piece of paper between the bearing spacer and collar when reassembling the magnet collar to the bearing axle. Hold the two collars together lightly with the thumb and forefinger and tighten the set screws in the magnet collar. This will ensure the proper end play (.003 in). Once assembled, be sure you can feel some movement of the shaft up and down in the bearing housing. The shaft should not be allowed to contact the magnet. This contact could result in the magnet being pushed off the lower collar.

The reed switch should be replaced every third year, or if broken during assembly/disassembly. It is best to do it after the bearings and shaft have been reassembled into the bearing housing. Un-solder the leads from the posts to replace the reed switch. Small loops should be formed in the new reed switch leads to allow for expansion and contraction of the assembly with changes in temperature. They also allow adjustment of the gap between the magnet and switch.

Polarity need not be observed when re-soldering the wire leads. There should be a 1/16- to 1/8-in. air space (gap) between the magnet and the reed switch. Reassemble the unit. Obtain some aluminum sticky tape at the hardware store and use it to cover the top of the anemometer to seal it from rain. Use white lithium grease on the threads of the connector and cover it with the red cap that came with the anemometer while transporting the anemometer. The grease will help keep the rain out of the connector when the anemometer is installed.

Testing the Anemometer

Use an analog ohm meter attached to the pins at the bottom of the anemometer and spin the cups. The meter needle should register in the area of mid-scale. This assures that the reed switch has the proper gap between it and the magnet, and that the anemometer is working.

We run repaired anemometers against each other for comparison. The two methods currently in use are multiple mounts located on the roof and logged by a CR10, and an anemometer test stand we have fabricated called the Hubbard Wind Table. Three anemometers can be compared to a hot-wire anemometer, or factory-fresh anemometer, by rotating the table at different speeds and logging the readings. The readings are then compared with the “standard” anemometer. The speed at which the anemometers begin to rotate can also be seen.

Field Testing

Testing an anemometer in the field consists of determining if the anemometer is functioning properly. The best way is to use another wind speed sensor and compare the readings. Hot-wire anemometers, propeller types, and another Met-One anemometer are some instruments that can be used. We generally use a fresh anemometer running next to the station anemometer.

If the anemometer is malfunctioning, test it with an ohm meter at the pins in the base of the barrel. The meter should oscillate about mid-scale if the unit is running correctly. Replace the anemometer if the test fails. If the unit is running OK, reconnect the cable to the anemometer and test the cable by disconnecting it from the wiring panel and connecting the leads to the ohm meter. Again, the meter should show oscillation. Replace the cable if there is no response. If that test is successful, the problem is in the wiring panel or the data logger.

Use an old anemometer cable and cut it off about 1 foot from the connector that screws into the anemometer. Solder an alligator clip to each lead and use it to connect to the anemometer. Push the connector into the anemometer and connect the alligator clips to a voltmeter. This is easier than trying to hold the test leads to the pins of the anemometer.

A source for bearings and other parts:

Met-One
1600 Washington Blvd.
Grants Pass, Oregon 97526
Phone: (503) 471–7111

A source for reed switches:

Hermetic Switch, Inc.
O.P. Box 1325
Chickasha, Oklahoma 73023–1325
Phone: (405) 224–4046

Solar Radiation (pyranometer)

We use an Eppley PSP standard traceable to the National Laboratories for calibration of the LI-COR pyranometer. The PSP and pyranometer are placed on the roof of the laboratory building in full sun and readings are taken at 10-minute intervals over several days. We begin calibrating in April when the sun is generating at least 800 watts m^{-2} radiation, and cease calibrations around the end of August. We do not calibrate during the winter months when the sun is low on the horizon.

Field maintenance of the pyranometer consists of keeping it clean and level. Birds rest on the mount and can get things very dirty. When I get reports of low readings, I get out the spray bottle with the soapy water solution and spray, spray, spray.

Use the portable weather station unit with a freshly calibrated pyranometer and compare the two pyranometer readings.

Figure 8 is a printout of the radiation occurring on typical cloud-free days. I like to see a good cloud-free sunrise and sunset with a nice rounded peak at noon for calibration purposes. I like to use at least two consecutive days. Figure 9 shows typical output for the Eppley PSP standard and a LI COR 200 pyranometer.

Wind Vanes (Met-One 024)

Maintenance on the Met-One wind direction instrument consists of replacement of the potentiometer. We replace them at 3-year intervals. Some harsh environments such as very sandy or dusty areas require more frequent replacement. Cattle feed lots are extremely hard on instruments. The replacement pots

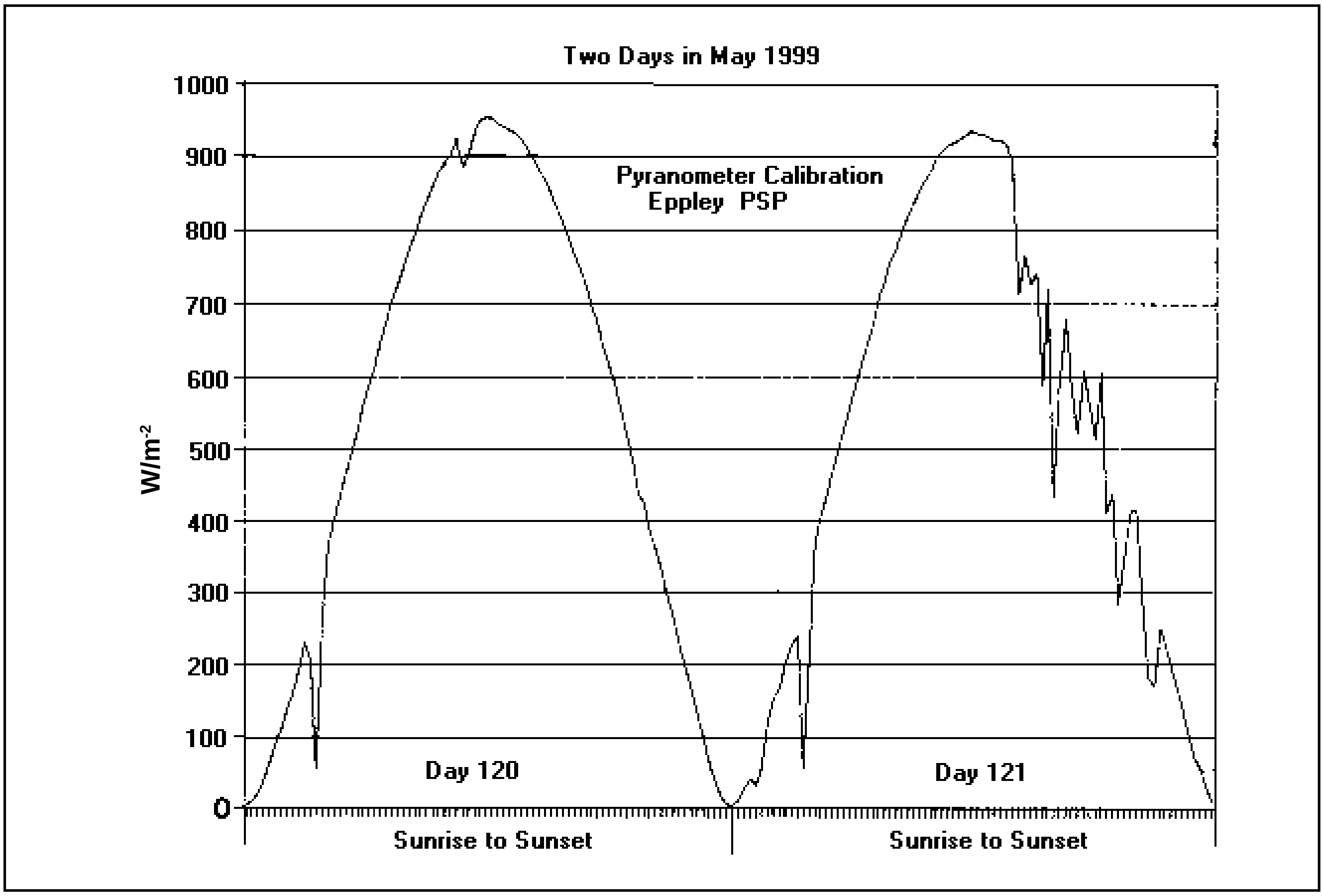

Figure 8.

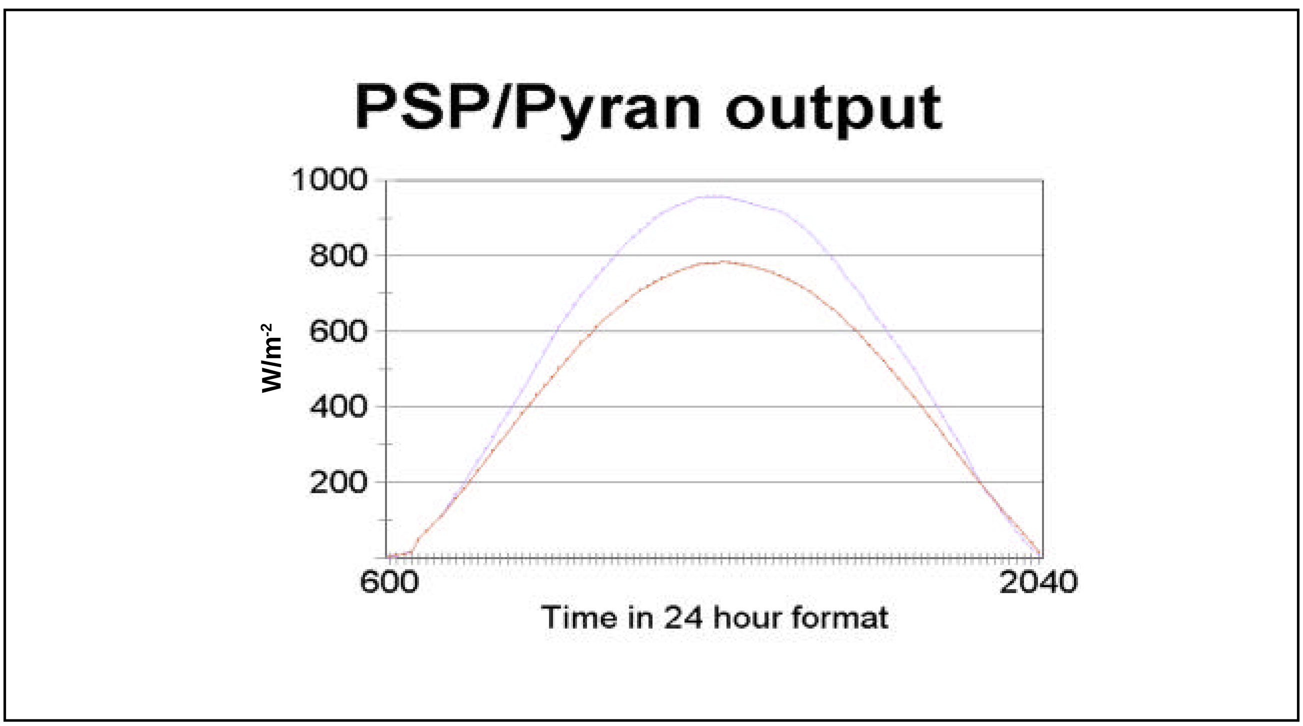

Figure 9.

can be ordered from Met-One. Be sure to specify pots without diodes. Because we use an excitation voltage of 1 volt (1000MV), the pots do not need to be equipped with diodes.

The tails of these sensors get bent down by birds. They land on the sensor and bend the tails when they take off. Birds sit on the anemometers also. I have wanted to photograph this, but I can't get close enough. Steel tail shafts are available from Met-One if the problem gets out of hand.

It was suggested at the AWDN workshop held in Lincoln, Nebraska, in March 2000 that a bird perch be provided somewhere near the tripod. I have placed three in the field to test this suggestion.

Potentiometer Replacement

Tools needed:

Soldering iron
Rosin core solder
Needle nose pliers
0.05 in. Allen wrench
5/64 in. Allen wrench

Remove the tail assembly using the 5/64 Allen wrench to loosen the two set screws holding the assembly to the potentiometer shaft. Remove the tail assembly. Carefully loosen the three set screws holding the potentiometer in the housing assembly using a 0.05 in. Allen wrench. It is very easy to strip these small set screws. If you do strip them so that they cannot be removed, it will be necessary to drill them out and re-tap the holes to accept a 4-40 screw.

Once the pot has been removed from the housing, unsolder the wires and note the color of wire and which post it is attached to. Install the new pot and tighten the set screws, being careful that the posts do not touch either side of the housing. Re-solder the wires to the correct posts.

Color code (Note: The colors are not always as listed):

Blue to post number 1
Yellow to post number 2
Orange to post number 3

Reattach the tail assembly to the housing, and loosely tighten the set screws. Proceed with the calibration.

Calibration

Calibration consists of finding the maximum voltage drop across the pot using a data logger, and adjusting the pot to the south. After the pot is replaced, connect the vane to a data logger. Using a multiplier of 1 and an offset of 0 in program 4, rotate the vane until you find the maximum reading (usually 500 + mv). Divide 360° by the maximum voltage reading. This will give you the multiplier to use for this instrument. The multiplier is normally around 0.7 and converts the mv output to degrees.

Once you have found the multiplier and inserted it into the logger instruction for the vane, install the shoulder bolt to lock the vane into the south-facing position. This assumes that the cross-arm is mounted in the east-west direction. Adjust the pot shaft through the access hole in the top of the tail assembly until the logger readout registers 180°. Tighten the set screws against the pot shaft to lock the shaft and tail assembly together.

When mounting the vane on the station cross bar, orient the screw that holds the collar to the vane to the south. Remember to remove the shoulder bolt from the tail assembly.

Field Testing
Field testing simply consists of observing the direction the vane is pointing and reading the logger input location to see if the output is correct. If the vane is incorrect, or there is no output, replace the vane. If that does not solve the problem, replace the cable.

HMP35 and HMP45 Temperature/Humidity Sensors
Cleaning
The filter cap can be unscrewed from the HMP. Remove it and place it in a soap solution consisting of dish soap. Do not use soap with any type of lotion in it. Use a container with a lid and shake the container gently. Once the heavy concentration of dirt has been removed, use a small-diameter blunt punch to press out the inner filter frame from the cap. There is a small hole on top of the filter cap where you can insert a punch to remove the insert. Use a small soft brush dipped into the cleaning solution to remove the dirt from the outside of the paper filter. Remove it from its frame and complete the cleaning cycle by putting it in an ultrasonic cleaner, again using dish soap as the cleaner. Rinse throughly in clean water.

Once the parts are cleaned, put the filter in a container containing silica gel to remove the moisture. I use an Aladdin soup container with a tight fitting lid. A fine mesh screen cut to fit is placed on top of the silica to keep the filters from contacting the gel. I clean 4 filters at a time, primarily because our calibration stand is designed to calibrate 4 HMPs at a time. We have been cleaning the filters this way for 5 years now and have not damaged or worn out the paper filters on any HMPs.

The Humi-cap can be cleaned in the ultrasonic cleaner. It must be rinsed in denatured alcohol to displace the water. There must be no film left on the Humi-cap. I don't generally clean the caps unless the HMP is clearly out of tolerance.

Notes on the Calibration of HMPs
We use a LI-COR dewpoint generator to produce a known RH value inside of a chamber into which we insert the sensor end of the HMPs. The output of the generator is set to provide 2 liters per minute of air.

The chamber used to hold the HMPs should be one liter or less in volume. If you use plastic containers such as plexiglass, paint the interior with aluminum paint or cover the inside with aluminum foil. Plexiglass and its clones will absorb moisture and affect the RH setting in the chamber. Glass is the best choice for the chamber.

We recommend that the vapor move past the sensor heads to ensure that the air around the HMP is sampling the current RH values. For this reason, the chamber we use is a cylinder with the input inserted in one end and the outlet on the other. I calibrate with the filter caps removed.

We make spot checks of the system periodically by using containers of saturated salt solution with known RH values. Specifically:

Potassium Chloride = 85.11% RH at 20°C
Magnesium Chloride = 33.07% RH at 20°C

Simply insert the HMP in the saturated atmosphere, and read the RH after a reasonable settling time. I generally do this after the calibration cycle to confirm the dewpoint generator integrity.

Calibration of the HMP can be accomplished while the unit is in the RH chamber. Adjust the WET HMP potentiometer with the dewpoint generator set at 85%. Adjust the DRY HMP potentiometer with the RH set at 30% and at least one hour of settling time, until the instrument reads 30% or a little above. Any reading up to 32% is OK. Be sure to allow enough time for the chamber and the HMP to reach equilibrium after changing the RH value. Make these adjustments in small increments and allow enough time for settling.

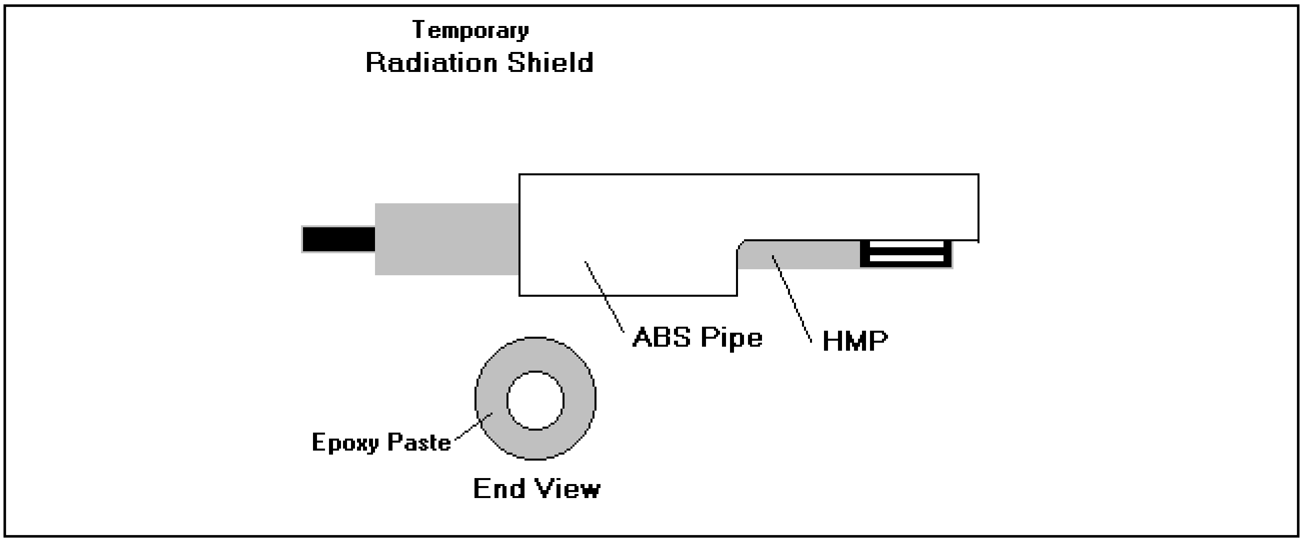

Figure 10.

We use a spreadsheet with a regression function to obtain the multiplier and offset for each instrument. The instrument is regressed against the dewpoint generator output (% RH). A Campbell Scientific CR21X is used to control the output of the dewpoint generator and read the HMPs. We start at 30% and increase to 90% in 5% increments. We allow one hour of settling time, then take 15 minutes of readings, average them, and place the result in final storage.

We read the air temperature at the same time we read the RH. This gives us a good cross section of the temperature function at ambient values to ensure that the temperature readings are within tolerance. We check to see that there is no temperature gradient between one end of the chamber and the other.

Barring total failure of an HMP, temperature values have always remained within the factory specifications.

Field tests consist of monitoring a separate HMP placed in the vicinity of the station HMP. The standard should be shielded from the sun (see Figure 10). A radiation shield can be fabricated from a piece of ABS pipe with a diameter twice the diameter of the HMP. Cut it as shown in Figure 10.

Use an epoxy paste, PC-7 or Devcon epoxy putty, and, following the directions for mixing, put a large quantity of it in the end of the ABS pipe and let it harden. Drill out the center to a diameter large enough to allow you to insert the HMP into the shield. This will hold the HMP in place in the shield.

This type of shield can be used for other instruments as well. Just adjust the diameter of the hole in the ABS to fit the instrument to be inserted.

Telephones

I would recommend that you buy a phone manual such as Radio Shack's phone installation and maintenance guide. It will give you troubleshooting tips. The objective is to determine if the problem is with the phone line, or the equipment.

In this day and time, it is almost essential to carry a cell phone in the service truck. You will need it to troubleshoot the equipment.

First, accept the fact that it is never the phone company's fault. Do not expect them to admit it. Report that there is a problem and let it go at that. You will not accomplish anything by agitating these people. If you report equipment failure erroneously too many times, you will lose your credibility. They will cease to respond to you. Make an exhaustive search of your equipment to eliminate the possibility that your equipment is at fault before you call the phone company. Having noted that, perform tests like the following.

Start by connecting a portable phone to the phone side of the line. There should be a clear dial tone. If the line sounds noisy or has static on it, call the phone company and report the static. Static on the line interferes with the transmission of digital information. Tell them the line is used for digital transmission.

More often than not, there will be no dial tone. Use a voltmeter to measure the voltage on the phone line. Red to ground should be close to 50 volts. Green to ground should be close to 50 volts. There are variations of this, however. Some systems use different colors. Some systems have voltage on one leg of the pair only. When you talk to the phone people, tell them what the voltage is. They are less likely to discount your report if you have tested the lines.

If you have a dial tone and the phone line sounds OK, call someone and talk to them to ensure that the line is working properly. If not, check the line from the phone company's pedestal to the modem.

If the phone works properly with the test phone, then it's your equipment. Start your search by replacing the blue ribbon cable. Use your cell phone to call the station. You should hear the modem squeal. If that does not work, replace the modem. Call the station. If that does not work, replace the CR10/wiring panel. Call the station again. At some point in these procedures, the system should answer.

The next test is to have someone at the office call the station (with the computer that collects the data), to verify that the computer at home can communicate with the system. If you can talk to the station with your cell phone and laptop computer but the home computer cannot, the problem may be a phone line or the home computer. If the home computer can talk to the data logger, record the serial numbers of the equipment you are leaving at the station and close the enclosures.

The last thing you should do before you leave is to call the station one more time to verify that it is still answering. (Always do this. Even if you just stopped by to say "Hi".) It is not necessary to call using your laptop. Just dial the station number and listen for the modem squeal. If the station phone is a cell phone, the window must be open for the phone to answer.

This is not an exhaustive tutorial, nor is it cut in stone. It will give you a place to start. Use your own troubleshooting techniques.

Cell Phones

These procedures refer to the Motorola bag phone (sometimes called an attaché phone). When these phones work, they are great. When they do not, they are a headache.

An installation wiring diagram is shown below (Figure 11). Location of the components in the enclosure is arbitrary.

The cell phone uses 5 amps of power when transmitting/receiving. For this reason, a larger battery is recommended. We use the CH12R charger/regulator and a solar panel with the battery. Use the data logger to turn the phone on and off several times a day so you can download the data and perform checks and maintenance by phone. We call these windows. Use a Crydom solid-state relay to switch power on and off to the phone. Campbell sells these, or they can purchased from electronic parts stores.

When you have picked the spot where you want the station to be installed, determine the signal strength of the site by observing the cell phone in the service vehicle. The LED panel should show what the strength is. Consult the cell phone manual for a clarification of the readout. If the signal is not strong, do not use a cell phone at this site.

A mirror-mount truck antenna is recommended for use with this unit. Mount it on the crossbar on the side opposite the wind speed indicator. The wind speed indicator has a magnet that can develop a magnetic field around it, which may interfere with the phone reception. In fringe areas, replace the 8-in. section of 3/4-in. pipe at the top of the tripod with a 4- or 6-ft. section. Attach the lighting rod to the top and set another crossbar below the lightning rod. Attach the antenna to the additional crossbar so that the top of the antenna is below the top of the lightning rod. The side of the crossbar that extends out on

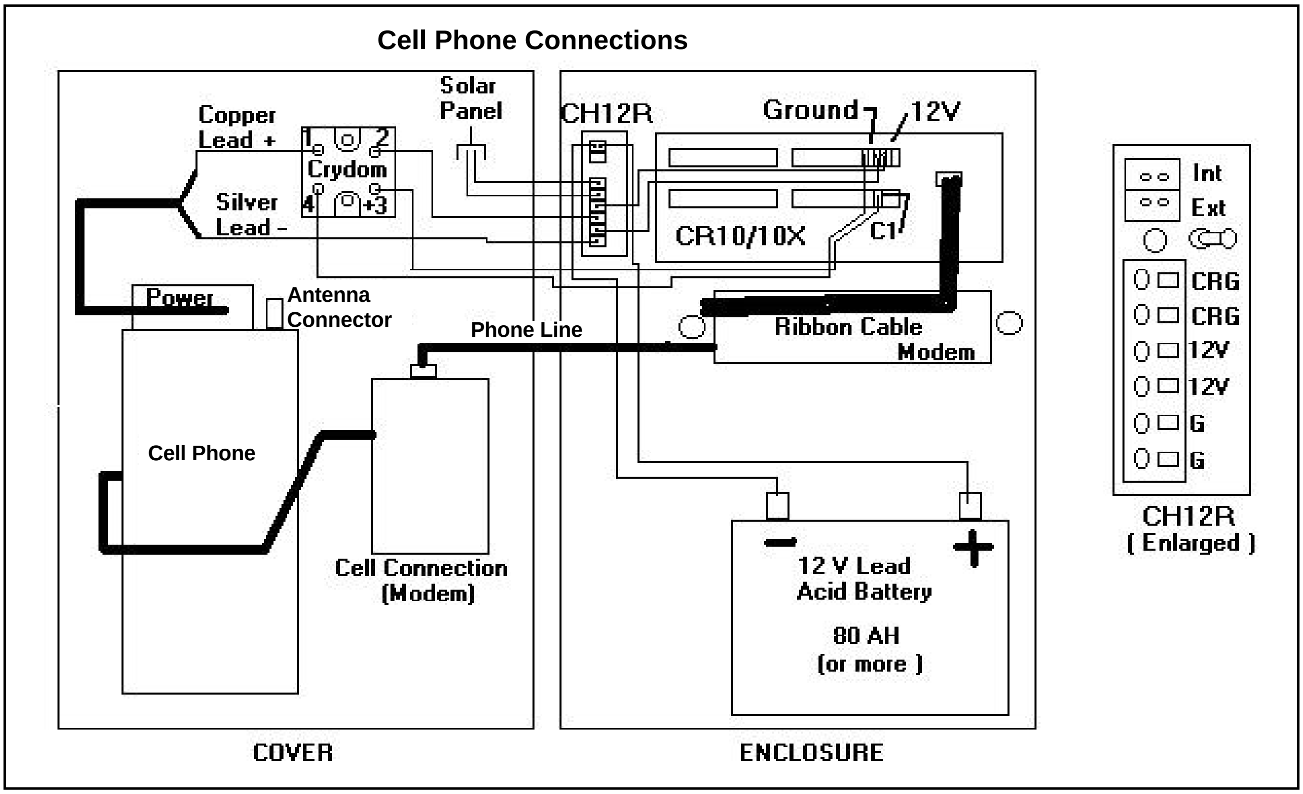

Figure 11.

the opposite side from the antenna serves as a bird perch. You can buy offset clamps to mount the extra crossbar from industrial bin and shelving stores.

Mount the equipment in the enclosure using double-sided sticky tape or velcro. Split the power lead into two wires and strip the insulation back about one-half inch on each wire. (The power lead has the cigarette lighter adaptor connected to it. Cut the adaptor off.) Look closely at the wire leads. You will see that one is copper-colored, and the other is silver-colored. Connect the copper-colored wire to the Crydom relay post labeled “1.” The silver wire is connected to one of the ground connectors on the CH12R charger/regulator.

Plug the cellular connection into the cell phone. Connect the gray phone wire to the phone jack on the cellular connection, and the other end to the Campbell modem. Connect the flat (blue) ribbon cable to the I/O port on the CR10/10X. ***Do not*** use solid wire to make these connections. It will break when flexed too many times. Using a piece of 22 gauge (size is not critical) stranded insulated wire, connect the C1 control port to the Crydom relay post labeled “+3.” Connect the post labeled “4” to a ground (G) on the CR10/10X. Connect the Crydom post labeled “2” to +12V on the CH12R.

Install the new data logger program containing the added instructions for powering up the cell phone at pre-set times.

Once the system is up and running, test it using your cell phone and computer.

You will, at times, need to operate the power relay manually when the window is not open. You can either use a logger instruction or use a test lead with alligator clips to short the “1” and “2” posts of the Crydom relay together. If you use a logger instruction, remember to turn off the relay when you are through, and remove the instruction. If you use a test lead, remember to remove it before you leave the site.

Troubleshooting
Go to the site and make sure the Crydom relay operates at the set time. When the relay is turned on, the red LED on the cellular connection will light. Call someone using the station cell phone to verify that the cell phone is working. Call the station using your vehicle's cell phone. If that works, the problem is with the cell phone company or the data computer at home. If the data computer works with other cell phones, it is probably OK.

There are usually phone numbers in your cell phone user's manual that you can call if you are having trouble with the phone. Call them and follow their instructions. They are usually good at finding the problem.

If the cellular connection is on, and you still cannot get through to the logger, connect your laptop directly to the logger and see if it will communicate. If not, replace the logger and wiring panel with a spare.

If you can communicate directly with your laptop, then work backward to the cell phone. Replace the ribbon cable and try to call the logger again. If it still will not communicate, replace the Campbell modem. If that is not the problem, the cell phone is suspect. Replace it, and test it in the lab at home.

If the cellular connection light is not on, short the relay terminals "1" and "2" and see if the light comes on. If not, the power to the relay, or the relay, is bad. Also check the battery for proper voltage. The cell phone voltage must be 12 volts to work properly. It cannot be less. With the relay shorted, test the battery voltage using your voltmeter. If it is less than 12 volts, check the battery charging system.

Cellular Connection Configuration (Modem)
As sent from the factory, your cellular connection is configured as Model S1936C to work with Series II transceivers or as Model S1688E for older transceivers. If you are experiencing difficulties in placing and receiving calls with your modem connected, it is possible that the modem is configured improperly. Follow these guidelines to verify that your modem is properly configured.

Printed circuit card:

Series II systems (S1936C)—No jumpers installed except JU3 to disable automatic volume and JU4 to disable the tone alert.

Series I systems (S1688E)—JU1 should be installed (see Figure 12), and if you are using a portable–mobile extended system, JU2 should be installed. JU4 may be installed to disable the alert tone.

Cellular Connection Circuit Board
CR10 Load Test
Testing the current drawn by the CR10 allows us to determine if the wiring panel/CR10 combination is pulling more than normal. An indication of a problem in this area would be that after the battery loses its power at an unacceptable rate and is replaced with a new one, it again loses its charge after a short time. It is necessary to determine if the wiring panel/CR10 is the cause or the battery/regulator/solar panel is the problem.

If you have a current-measuring meter (amp meter), put the meter in series with the positive lead wire from the battery regulator output as shown in Figure 13. Before starting the test, connect a backup

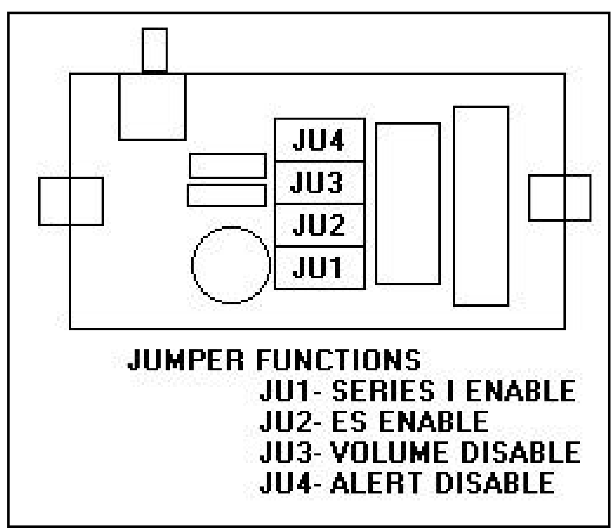

Figure 12.

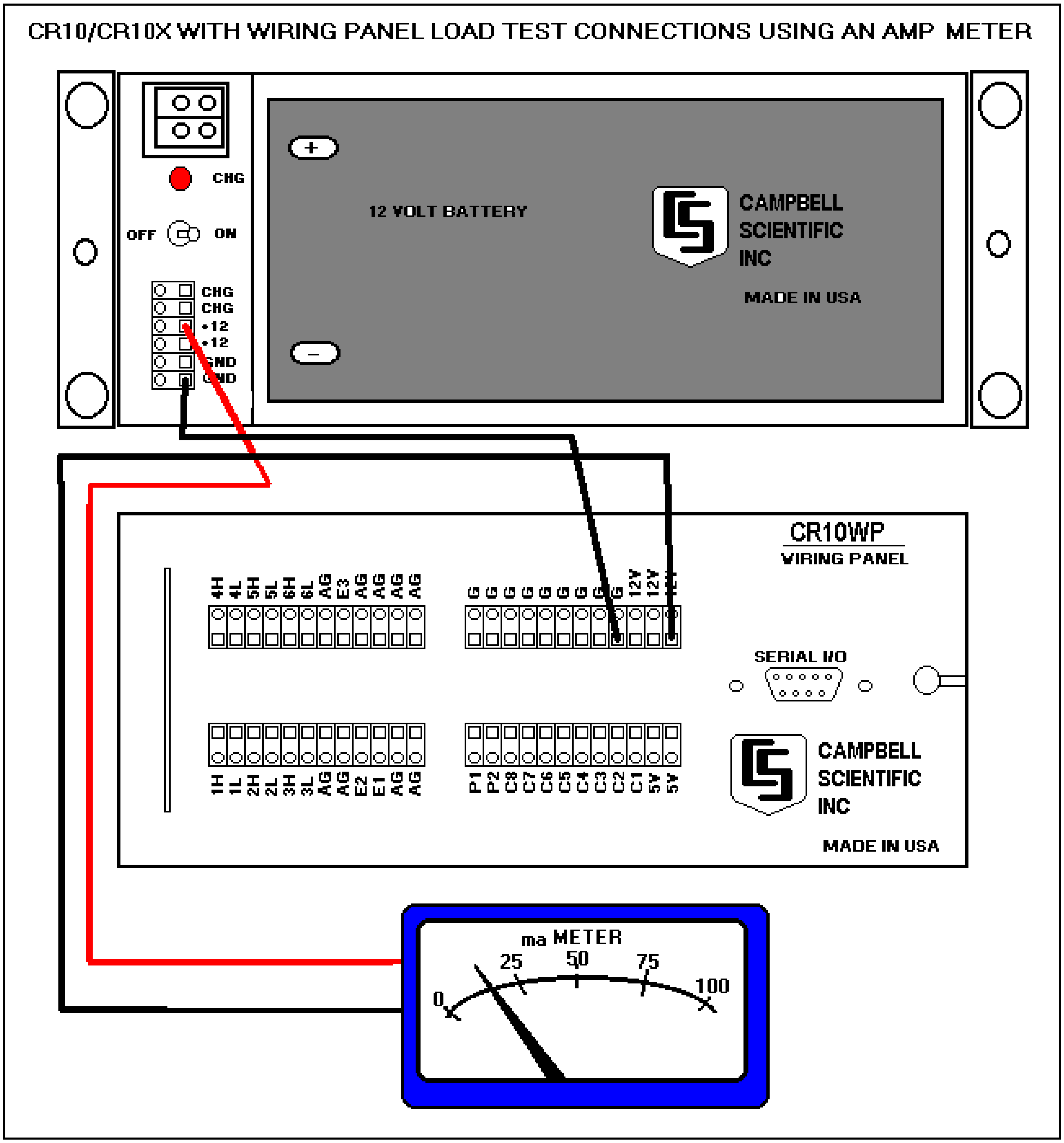

Figure 13.

battery to the wiring panel so that the program and data will not be lost. Now disconnect the battery that normally powers the data logger. Read the current through the system and consult the table below for standard current readings.

If a voltage meter is all that is available, you can determine the current being drawn by the panel/ CR10 combination by inserting a 1 ohm resistor in series with the battery pack and measuring the voltage drop across the resistor with a mv meter connected as shown in Figure 14. The voltage read on the meter is directly proportional to the current through the resistor. 10 mv = 10 ma. 100 mv = 100 ma.

To test the panel/CR10 using a current meter in series with the supply voltage as shown in Figure 13, proceed as follows:

1. Connect a backup battery to the +12 volt and ground terminals of the wiring panel power input terminals. Do not disconnect the leads coming from the PS12AL battery power supply until you have the backup battery connected.
2. Disconnect the RED +12 volt lead from the PS12AL power supply that is connected to the wiring panel and connect the red lead of the meter to it. Connect the meter's black lead into the wiring panel +12 volt terminal where the red wire was disconnected.
3. Once the PS12AL and meter are reconnected to the wiring panel, disconnect the backup battery.
4. Using the current meter set to a scale of 50 ma or higher, read the current displayed on the meter. If you are using an auto ranging DVM/DMM, it will adjust itself. If not, you may need to reset the scale yourself.

To test the panel/CR10 using a 1-ohm 1-amp resistor in series with the supply voltage as shown in Figure 14, proceed as follows:

1. Connect a backup battery to the +12 volt and ground terminals of the wiring panel power input terminals. Do not disconnect the leads coming from the PS12AL battery power supply until you have the backup battery connected.

CR10/10X with Wiring Panel Load Test Connections Using a Voltmeter

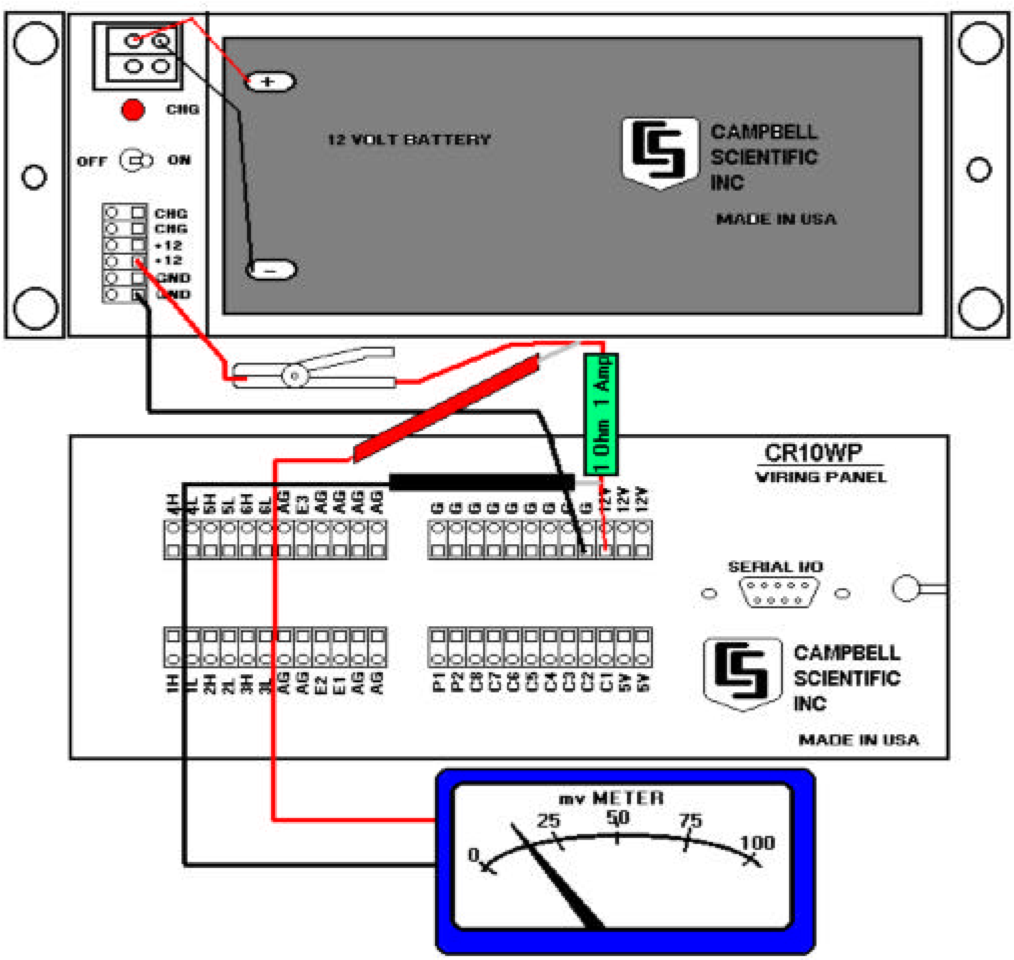

Figure 14.

2. Disconnect the RED +12 volt lead from the PS12AL power supply that is connected to the wiring panel and clip the 1-ohm resistor to the red wire. Connect the resistor's remaining lead into the wiring panel +12 volt terminal from which the red wire was disconnected.
3. Once the PS12AL and resistor are reconnected to the wiring panel, disconnect the backup battery.
4. Using a voltmeter set to a scale of at least 1 volt, read the voltage drop across the resistor. Decrease the scale of the voltmeter until the pointer moves up scale. If you are using an auto ranging DVM/DMM, it will adjust itself.

Refer to the data in Table 2 to determine if the panel/CR10 is drawing acceptable current.

Table 2. Standard current drains for the panel/CR10 (values are general).

No program in the logger	9.12 ma to 11.5 ma
While programming	15 ma
Monitoring	26 ma
Monitoring/reading	44 ma
Sleeping	10 ma or less
Reading	32 ma or less
Storing	32 ma

Any reading 10 ma higher than those listed is excessive. Check to ensure that no instrument wiring is shorting to ground. Even one strand of wire that is not clamped in the terminal may touch the case and cause trouble. If no shorts can be found, then proceed as follows.

Disconnect each of the instruments from the panel, one at a time. You will need to allow time for at least 5 scan readings to pass while observing the meter. If the ma readings decrease while one of the instruments is disconnected, then replace that instrument, and monitor the ma readings again. If that instrument was defective, the readings should return to normal. If not, reconnect the instrument and disconnect the next instrument. Continue in this manner until the offending instrument is found.

If this procedure fails to uncover the source of the problem, then the wiring panel and CR10 should be replaced and the troubled units sent to Campbell for repair.

If the ma readings are standard readings as listed above, it can be assumed that the panel/CR10 is OK. Proceed to test the PS12LA output and/or the solar panel.

Results of the March 23, 1999, test of a CR10X with instrumentation using the Fluke scopemeter set to measure ma are shown in Table 3.

Table 3. Test of CR10X.

	Max. ma	Avg. ma	Min. ma
Logging Data	31.3	2.3	0.6
Logging/Monitoring	37.6	20.2	16.8
Phone/Logging/ Monitoring	86.6	67	60.9
Data download/ Phone	77.5	67	60.9

Figure 15 shows the current drawn by a CR10 in different modes of operation. Figure 16 shows an expanded version of this chart, with explanations.

Every 5 seconds, the logger scans the instruments and reads them. Figure 15, taken with a second CR10, shows that the current draw during reading is 22.5 ma. The current when the logger is asleep (between scan cycles) is 0.6 ma.

During monitoring with a computer connected to the logger using the SC32A, the CR10 draws about 20 ma of current when not logging data and about 32 ma when monitoring AND logging data.

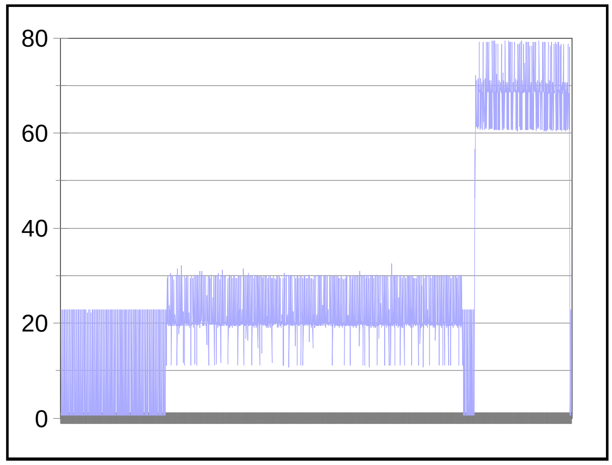

Figure 15.

When monitoring the input locations over phone lines using the DC112 modem, the CR10 draws about 62 ma. Every 5 seconds the current increases to 72 ma while logging data. At one-hour intervals, the logger sends data to final storage and pulls about 85 ma.

Bench-Testing Data Loggers

A suspect logger may be tested in the lab using readily available equipment. Several tests follow.

Testing the voltage reading capabilities consists of using the logger to measure a known voltage applied to the input channels. Use a good quality commercial voltage source. If that is not practical, use a mercury battery that will produce about 1.35 volts. Alkaline batteries are not dependable enough. You can get mercury batteries at the local photo store.

Solder leads to each end of the battery and connect it to the logger observing polarity. Use the P1 or P2 instruction to read the battery.

If you have an oscilloscope or scope meter, you can look at the output of the excitation channels by connecting the scope to the excitation channel. The scope can be used to test the control ports also. Connect the scope to the port and instruct the logger to raise the ports with the P20 instruction. You should see the voltage rise on the scope when the control port switches from low to high. Any voltage meter can be used for this test.

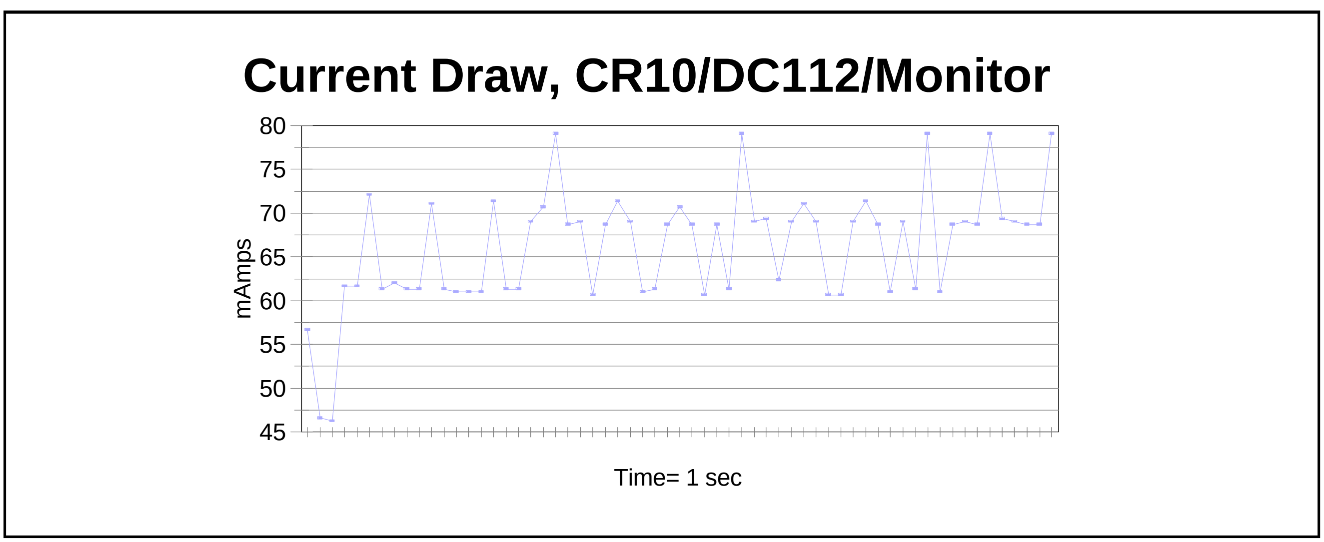

Figure 16.

Construct a "bug" to carry in the service vehicle to test the loggers in the field. It consists of 2 precision resistors, 0.1% tolerance if you can find them. A good source for the 249K resistor is an old 101 or 107 soil temperature probe. Cut the sleeving and remove the resistor with its wiring intact. Remove the thermistor from the circuit (Figure 17).

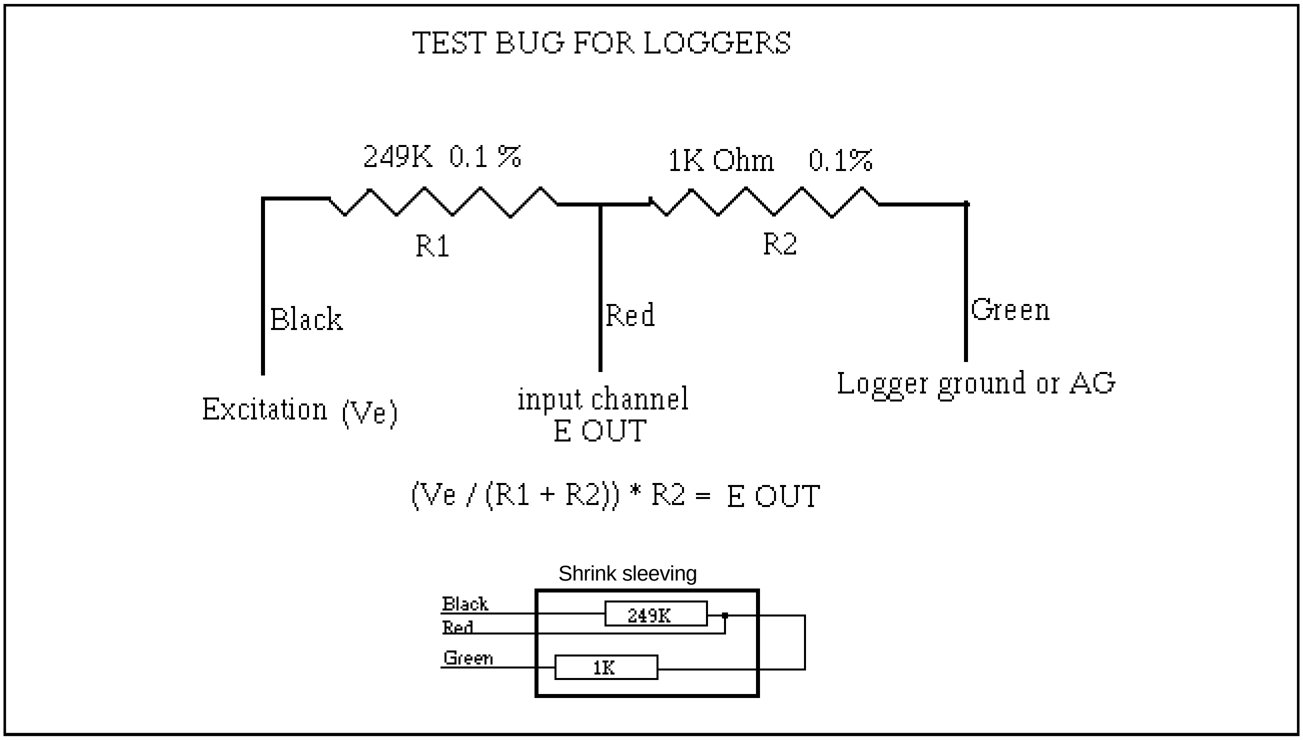

Figure 17.

When used in place of instrumentation on the data logger, readings should be in the vicinity of those listed in Table 4. This tests the excitation and voltage integrity of the logger.

Table 4. Acceptable data logger readings.

Logger instruction	Logger output
P11	+ -86
P4	+ -8
P5	+ -0.004

Miscellaneous

When extending leads for instruments, insert the new wire between the sensor and the pig-tail. Use wire of the same type as the original wire or larger (copper to copper, steel to steel, etc.).

A Note on Installation of the Tripod

Use a three-step step stool to assist you in setting up the tripod. Assemble the base of the tripod and install the vertical pipe. Then pull the tripod over and set the vertical pipe on the top step of the step stool. You can then assemble the cross bar, pyranometer arm, and instruments while standing on the ground. Then set the tripod up. This saves a lot of climbing up and down a step ladder.

Adjust the tripod base to 3 meters while you are unfolding it. Pull out each leg (Figure 18) and measure from the lower end of the leg to the lower end of the clamp. Clamp it at 16 inches. The new Campbell tripods require a different distance. I have not measured this yet.

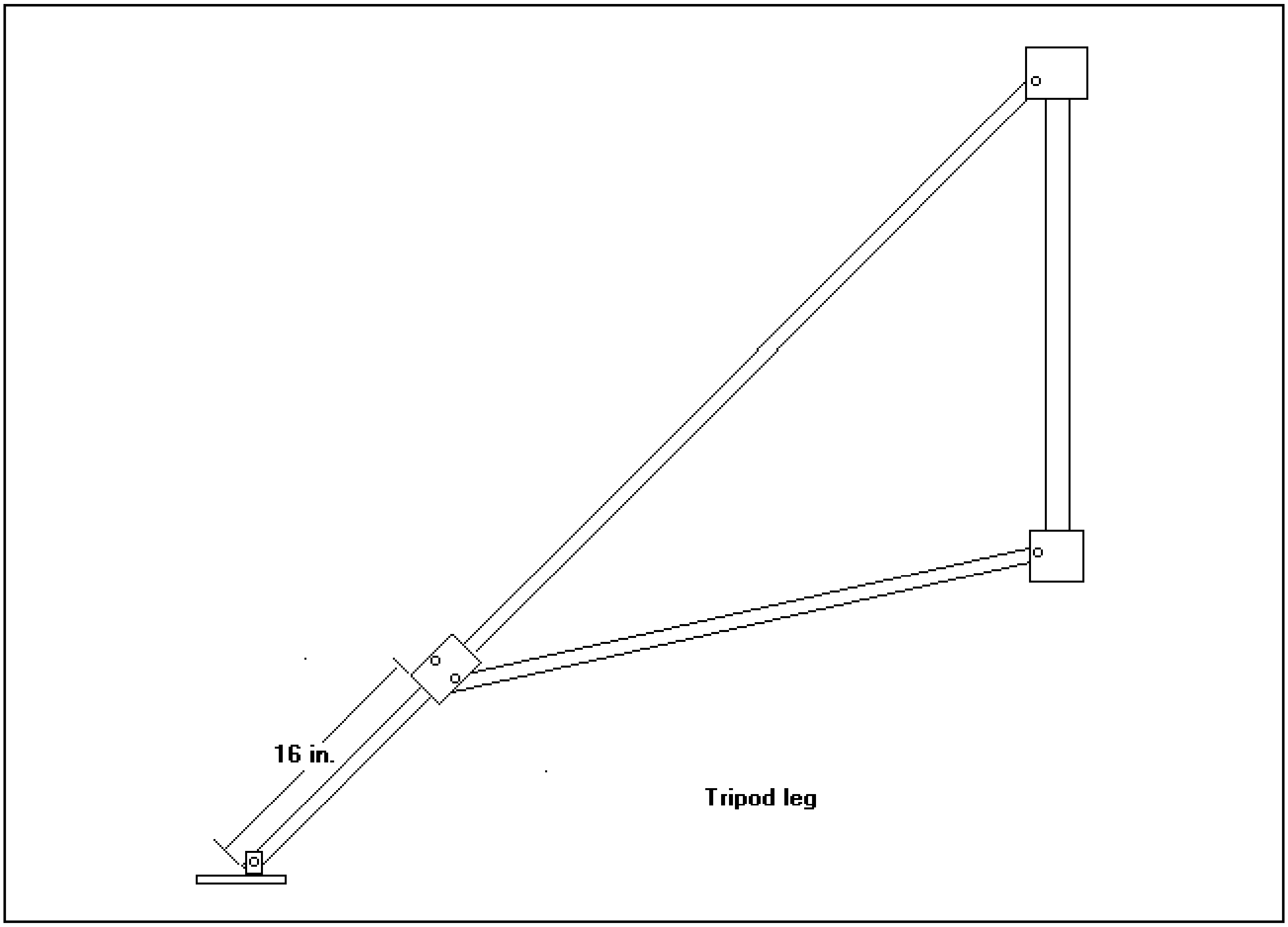

Figure 18.

Service Truck and Equipment

In general........carry everything you will ever need to install or repair a station.

Because that philosophy is not practical, here are some "must have" items.

Maps: You need to know how to get where you are going.
Tools: A basic tool kit, such as Craftsman.
An electronic tool kit.
Radio Shack zippered soft pack.
A small multimeter.
A good digital meter (scope meters are handy).
Spade and tile shovels, posthole digger.
Treated 2x4s, treated fence posts, and steel posts.
Miscellaneous nuts, bolts, and washers. (Use plastic fishing lure trays with lids.)
Small electrical parts: Wire nuts, butt end connectors, etc.
Tape: Black electrical, lots of black electrical, duct tape, carton sealing tape.
Various types of wire: Phone, hook-up, cable for the rain gauge.
Replacement reed switches for the rain gauge.

Magnets and epoxy glue. (Super glue won't work.)
A complete weather station minus the tripod.
Extra data loggers, modems, rain gauge, solar panels, cables for all instruments.
Silicone sealant.
Silicone spray. (For the rain gauges.)
Spray paint: White enamel, gray primer.
Wasp spray.
Small mesh wire for keeping critters out of the rain gauge.
Plumbers putty: To seal around the connector where the wires go into the enclosure.
Weed Eater: You know what that's for.
Extra Weed Eater cord.
Extra gas. (For when you push your luck too far.)
Barbed wire and #9 wire for fence repair.
Fence staples, large nails.
Fence pliers.
Compass: To point the station south.
Manuals for data loggers.
Cell phone.
Two PS12LA batteries and charger assemblies.
Two pyranometer bases.
Syringes for rain gauge calibration.
Butane-fired soldering iron and rosin core solder (60/40). Radio Shack.
Drill motor and drill bits.
110-volt power inverter. Plugs into the cigarette lighter socket to run the drill motor and computer.
Water: For drinking and rain gauge calibration.
Station maintenance forms for each station.
Station location forms.