FSS500 & FSS500H Tipping Bucket Raingauge

User Guide

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Campbell Scientific Ltd. acknowledges the technical expertise provided by Environmental Measurements Ltd. in their FSS500 Manual, on which this User Guide is based.

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- Batteries
- Any product which has been subjected to misuse, neglect, acts of God or damage in transit.

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FSS500/FSS500H Raingauge

The FSS500 and FSS500H are well-designed tipping bucket raingauges which combine durable construction with reasonable cost. The gauge offers less resistance to air flow than most previous designs, which helps to reduce the sampling errors that inevitably occur during wind-driven rain. The gauge is manufactured for Campbell Scientific by Environmental Measurements Ltd., and owing to its stainless steel and aluminium construction, when correctly sited, will provide many years of reliable operation in the most rigorous of environmental conditions. The FSS500H is a heated version of the FSS500.
A larger version of the gauge (model FSS1000/FSS1000H), which has a higher resolution, is available to special order.

1. General Description

The information in this manual applies to both the FSS500 and the FSS500H, except for section 7 which includes additional information applicable to the FSS500H heated version only.

The main collector body of the raingauge is constructed from 2mm thick spun stainless steel giving strength and rigidity. The base section is manufactured from marine grade aluminium, with a white powder finish. The base includes three adjustable mounting feet and a bubble level gauge for free-standing applications, or the feet can be removed and the unit bolted firmly to a suitable mounting plinth or concrete slab for more permanent applications.

Figure 1 FSS500 Series Raingauge in Situ

2. Technical Specifications

Please note that models FSS1000 and FSS1000H are available to special order only.

Funnel rim height:	370mm
Collector area (FSS500):	500cm^2
(FSS1000):	1000cm^2
Tip sensitivity:	0.2mm of rain per tip (FSS500) 0.1mm of rain per tip (FSS1000)
Output:	Contact closure – two reed switches allowing monitoring to be carried out on an additional channel. Reed contact rating: 50W (DC resistive) Reed supply voltage: 100V DC maximum
Weight (approx.):	6Kg.

Heater Specifications (model FSS500H):
Supply current: 12V supply: Heaters off – 12mA typ., Heaters on – 2.2A typ.
24V supply: Heaters off – 15mA typ., Heaters off – 1.1A typ.
Heaters are activated when internal enclosure temperature falls to 1°C and are deactivated when temperature rises to approx. 4°C.

3. Operation

The tipping bucket arrangement is similar to most other gauges of this type; precipitation is collected by the funnel and flows through a stainless steel gauze filter which traps and removes any leaves, etc. Water then passes through a nozzle into one of the two buckets situated at either end of a short balance arm. See illustrations below – see Figures 2 and 3.

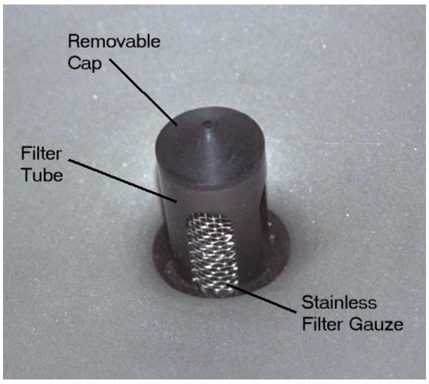

Figure 2 Filter Unit

Figure 3 Nozzle

The balance arm and bucket assembly rotates around precision rolling pivot bearings. The arm tips when the first bucket is full, emptying this bucket and positioning the second under the funnel. The tipping process repeats indefinitely as long as rain continues to fall, with each tip corresponding to a fixed quantity of rainfall. At each tip, the moving balance arm forces a magnet to pass a reed switch, causing contact to be made for a few milliseconds. A two-core cable is used to connect the gauge to the datalogger where the switch closures are counted. This mechanism is shown in Figure 4. The water is normally drained away through outlets, but adapters can be fitted if water retention is required.

Figure 4 Internal View of FSS500H (Heated Version)

The FSS500/FSS500H is adjusted at manufacture to tip once for each 0.2mm of rain (a sensitivity of 0.25mm/tip is optional). More information on gauge calibration is given in Section 8.

4. Installation and Siting

4.1 Choosing a Site

The site for a raingauge is often a compromise between optimum exposure and operational constraints. The optimum site is level ground with a uniform scattering of objects in the surrounding area, thus reducing overall wind speeds. However, these objects should not be large enough to cause eddy currents or high gust speeds to occur near to the gauge, or so close to the gauge that rain is prevented from entering the funnel. Site the gauge carefully, and try to avoid obvious sources of error, such as nearby trees or buildings or other obstructions.

A useful 'rule of thumb' is that the distance between the gauge and any obstruction should be at least as great as twice the height of the obstruction above the ground. For standard meteorological sites in the UK, the Meteorological Office specify the height at which the rim of a raingauge should be above a short grass surface, and the FSS500/FSS500H should be exposed similarly if measurements are required for comparison with those from agrometeorological or synoptic sites.

NOTE No two raingauge designs are ever likely to produce identical results, and identical raingauges can give slightly different catches even when sited within a metre of each other.

Research has shown that a raingauge obstructs the flow of air and that the flow accelerates and turbulence increases over the top of the funnel. This can cause less rain to be collected in the funnel than otherwise would have fallen on the ground.

The body of the FSS500/FSS500H has a profile which has been designed to reduce drag and turbulence using extensive practical data collected by Dr. Ian Strangeways (Strangeways, 1996) and it can therefore be sited conventionally on exposed sites with some confidence. Further details on the exposure of raingauges are given in HMSO (l956, l982) and by Rodda (l967). Another useful text on exposure and associated errors is Painter (l976).

NOTE If the gauge is sited in the area of livestock, then fencing will almost always be required to prevent damage from (and to) the animals.

4.2 Unpacking

Unpack the FSS500/FSS500H carefully. The tipping mechanism is immobilised before shipping to prevent damage in transit. To release the mechanism:

1. Remove the funnel of the gauge from its base by unscrewing the three screws and lifting the funnel.
2. Remove the piece of foam from under the bucket mechanism. Check the bucket mechanism for freedom of movement. The foam may be saved for use whenever the raingauge is transported.

4.3 Mounting

The FSS500/FSS500H weighs 6kg, and so is heavy enough that it can, in many cases, be simply placed on an appropriate flat surface, ready for use.

However, three holes adjacent to the levelling feet are provided so that steel pegs (also provided) can be fitted for extra security in softer ground. In areas of high winds, or where additional security is required, these holes can be use to bolt the gauge (after correct levelling) to a solid surface, such as a concrete slab, using appropriate anchor bolts – see Figure 3 which shows these extra bolts.

4.4 Levelling

If the raingauge is tilted by more than a few degrees, the bucket mechanism may be thrown out of balance, significantly affecting its calibration. Furthermore, during wind-driven rain the response of a gauge with a tilted funnel collector will vary with wind direction. It is therefore important to ensure that the rim of the raingauge funnel is precisely levelled, using a spirit level.

Although a small circular bubble-type spirit level is incorporated into the base assembly of the raingauge, this is provided only as a ‘quick check’ for initial setting up. Always level the rim precisely, using a separate spirit level (see Figure 5) and check regularly. Level the gauge by slackening the locking nuts on the adjustable feet, adjust the feet to achieve a perfectly level rim, and retighten the locknuts. If required, fit the pegs through the holes provided next to the adjusters.

NOTE Accurate and precise levelling of the raingauge, as described above, using a spirit level, is the simplest and most effective way to ensure accurate rainfall measurements.

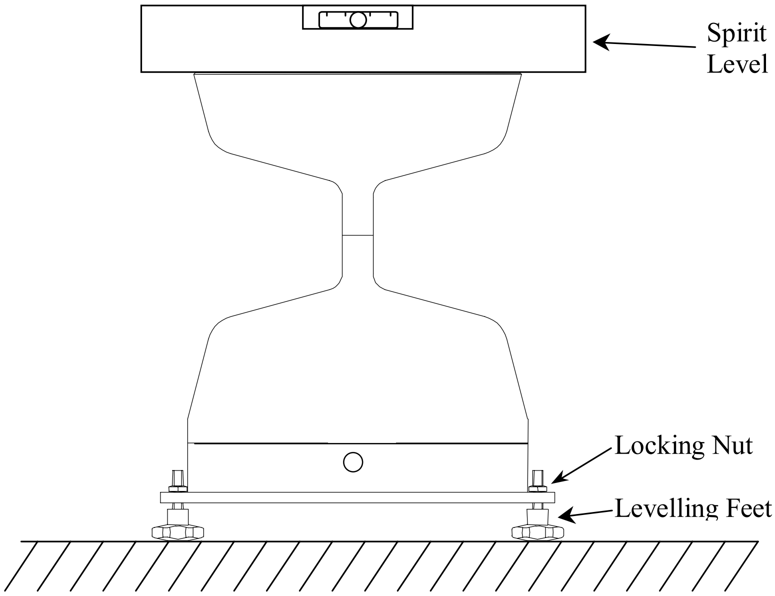

Figure 5 Levelling the FSS500/FSS500H using a Spirit Level

5. Wiring

The raingauge is supplied with a 6m cable which may be extended if required. For most applications the FSS500/FSS500H may be connected directly to a pulse counting input on the datalogger as shown in Figure 6. For a long cable, a significant capacitance can exist between the conductors, which discharges across the reed switch as it closes. As well as shortening the life of the switch, a voltage transient may be induced in any other wires which run close to the raingauge cable each time the gauge tips. A l00Ω resistor is fitted inside the gauge to protect the switch from arcing and prevent transients.

Figure 6 Wiring Diagram for FSS500/FSS500H

6. Programming

A tipping bucket raingauge is monitored with the Pulse Count instruction (Instruction 3) configured for Switch Closure. Counts from long intervals are used, as the final output desired is total rainfall (obtained with Instruction 72, Totalize). If counts from long intervals were discarded, less rainfall would be recorded than was actually measured by the gauge (assuming there were counts in the long intervals). Output is desired in millimetres of precipitation. The gauge is calibrated for a 0.2mm tip, so a multiplier of 0.2 is used.

Program Fragment Showing Pulse Count Instruction

```
1:  Pulse (P3)
 1: 1       Reps
 2: 1       Pulse Channel 1
 3: 2       Switch Closure, All Counts
 4: 1       Loc [ Rain_mm   ]
 5: 0.2     Mult          ;use actual calibration figure for greater accuracy - see Section 6
 6: 0       Offset
```

The datalogger can also be programmed using more advanced programming techniques to record the time of each tip – please refer to your datalogger manual for more information.

7. Maintenance

To ensure reliable and accurate measurements, we recommend that the following checks be carried out every month if possible.

NOTE If the gauge is connected to an operating datalogger you should try to avoid manually tipping the buckets during maintenance unless doing the balance check described in Item 5a, below.

1. Inspect the funnel for any damage or blockage and check the integrity of the connecting cable. At certain times of the year, leaves may accumulate in the bottom of the funnel, clogging the filter and preventing water flow to the buckets beneath, or reducing the flow rate to a slow drip. Remove the funnel from the base and clear any leaves or debris.
2. Clean the filter as follows:
   a) Unscrew the end cap from the filter tube.
   b) Carefully remove the stainless steel filter gauze and clean.
   c) Replace the filter and re-fit and replace the filter cap.
3. Check that the gauge is still level. It is surprisingly easy for an apparently immovable gauge to become tilted as a result of small ground movements, vandalism or just inquisitive fingers.
4. Remove any dirt from, and clean, the bucket, being careful not to tip the bucket if the gauge is still transmitting to the datalogger. If you want to check that the balance arm/bucket assembly is free to move, see Items 5a and 5b, below.

Checking the Balance Arm Assembly with an Active Datalogger Link

5a. If the datalogger is still active and logging data, you can still check that the balance arm is free to move. This can be done by slowly pouring a measured quantity of water (say 250cm^3) through the gauge and counting the tips. It is worthwhile carrying this out at regular weekly intervals (for example, every Monday at 0900) while leaving the gauge connected to the datalogger. Providing a significant volume of water is used, these weekly checks can easily be identified in the logged measurements. This simple procedure confirms that the gauge is functioning, detects any marked change in the calibration and (if carried out punctually) introduces an independent time check into the records.

Checking the Balance Arm with an Inactive Datalogger Link

5b. If the datalogger is disconnected or not logging data, it is a good idea to check the balance arm for stiffness. The simplest way to do this in the field is to attempt to balance the bucket in its centre position. It should be very difficult (if not impossible) to do this. If the bucket balances easily, then examine the assembly for any dirt or wear on the pivot pin and bucket tubes.

A spares kit is available, comprising filter, filter cap etc. Please contact Campbell Scientific for spare parts requirements.

8. Calibration

The sensitivity of the FSS500/FSS500H is set at manufacture to a nominal figure of 0.2mm/tip (optionally 0.25mm/tip) and each gauge is subsequently calibrated as described in Section 8.l. The calibration factor is given on a certificate and is also recorded on the inside of the raingauge. For precise measurements use this calibration value in your program instead of the nominal value of 0.2 shown in the program fragment in Section 6, above. Update this figure if the value changes on recalibration.

Before any re-calibration is undertaken, take the opportunity to check and carry out any maintenance that may be required.

8.1 Static Adjustment and Calibration

The following procedure is carried out during manufacture and may be repeated if the calibration appears to have shifted.

1. Install the gauge over a sink unit as illustrated in Figure 7, ensuring that it is correctly levelled.

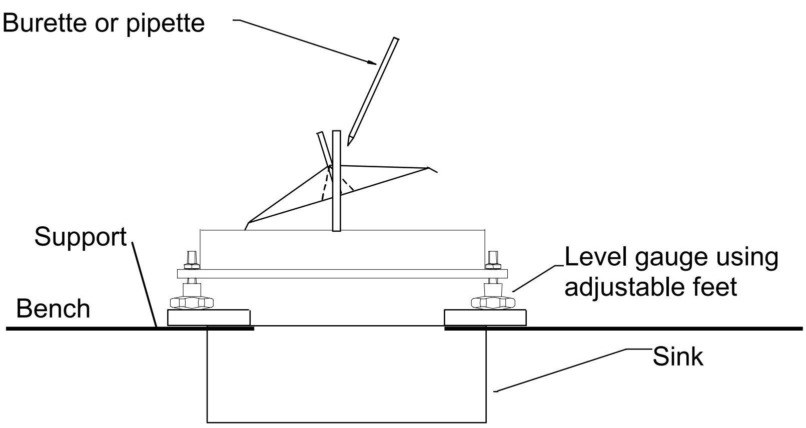

Figure 7 Setup for Static Calibration

2. Using a burette or pipette, slowly drip in $10cm^3$ of water (for the 0.2mm/tip gauge) into one side of the bucket. The bucket should tip on the last drip of water. Adjust the relevant calibration screw, situated under the tipping bucket, until this condition is met. Repeat for the other side of the bucket.

It may not be possible to set the screws very precisely using this method, but it should be done with as much care as possible. It is obviously very important to ensure that both buckets tip in response to the same amount of water. Many manufacturers and users of tipping bucket gauges aim to adjust the bucket settings until exactly the correct calibration is achieved. However, a dynamic test (see below) is required to check this calibration precisely after each readjustment and the process becomes very time-consuming. In any case, it is virtually impossible to get the adjustments absolutely correct, and it is generally preferable to adjust the settings as closely as is reasonably practical, and then to derive a calibration factor for each gauge individually after a dynamic calibration.

8.2 Dynamic Calibration

The FSS500/FSS500H can be calibrated dynamically in two ways – by using a measured quantity of water or, preferably, by using the 'constant head' method. These two methodologies are described below.

1. Set up the gauge as illustrated in Figure 8a or Figure 8b, carefully levelled and connected to the datalogger.

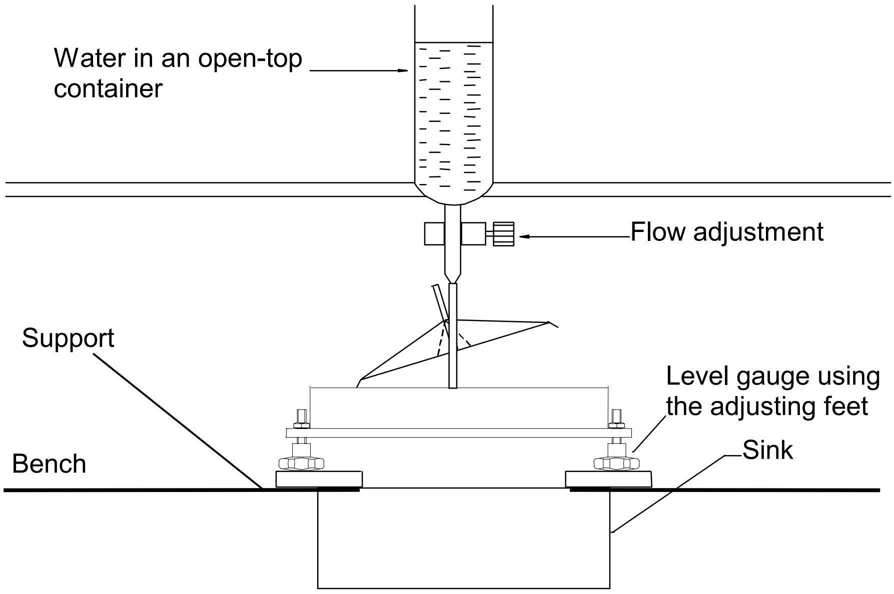

Figure 8a Dynamic Calibration using a Measured Quantity of Water

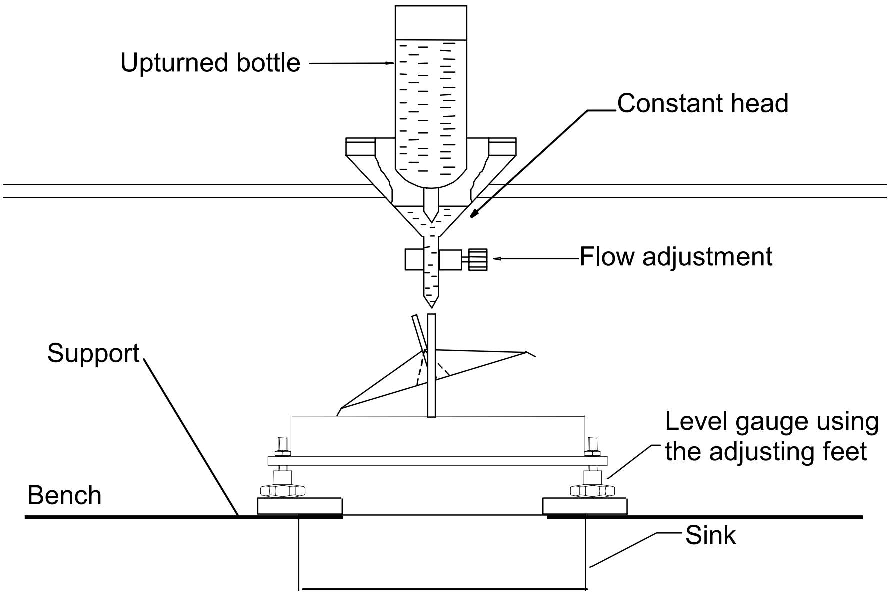

Figure 8b Dynamic Calibration using the Constant Head Method

2. Fill the water container with 1000cm^3 of water for a 0.2mm calibration. This is usually achieved most precisely and consistently by weighing the water on a balance capable of measuring to 0.lg (0.lcm^3). An alternative is to use a good quality graduated measuring cylinder.
3. Allow the water to drip slowly into the gauge, allowing at least 60 minutes for the container to empty (approximately 40 seconds for each tip). This is a rate equivalent to a rainfall of 10mm/hour, as recommended in BS7843 Section2.1 for calibration purposes. At the end of this period approximately 100 tips will have occurred. The exact number is obtained from the datalogger, together with an estimation of what fraction of a 'tip' is left in whichever bucket is still filling as the flow of water finishes. This fraction can either be assessed visually, or, for a more exact estimate, a graduated syringe can be used.

8.3 Calculating the Calibration Factor

Using the figurse from the dynamic calibration tables, the calibration factor can be read from Table 1.

Table 1 Calibration Factors

Number of Tips	Calibration Factor
97.8 to 98.2	0.204mm/tip
98.3 to 98.7	0.203mm/tip
98.8 to 99.2	0.202mm/tip
99.3 to 99.7	0.201mm/tip
99.8 to 100.2	0.200mm/tip
100.3 to 100.7	0.199mm/tip
100.8 to 101.2	0.198mm/tip
101.3 to 101.7	0.197mm/tip

Alternatively, the calibration factor can be calculated using the formula shown below:

The nominal number of tips for a 0.2mm bucket is 100.

Let N equal the *actual* number of tips plus the fractional part left in the one bucket.

The calibration factor (CF) is then:

CF = 0.2 (optionally 0.25) x 80/N

For example, if N = 78.8, then:

CF = 0.2 (optionally 0.25) x 80/78.8

= 0.203mm/tip

In other words, each tip corresponds to 0.203mm of rainfall. Provided that CF lies between 0.197 and 0.204mm, it will be acceptable for most purposes. If the CF lies outside these limits, repeat the static and dynamic calibration procedures.

The amount of rainfall in any particular interval is obtained by multiplying the number of recorded tips by the calibration factor.

This type of dynamic calibration gives repeatable results indoors, but it is not a true representation of the gauge's sensitivity to natural precipitation. Useful results can be obtained by comparing the output from the FSS500/FSS500H with the catches from a standard 'Snowdon pattern' gauge (HMSO, l956) sited nearby.

Care should be taken when studying such comparisons, however, as even two identical raingauges can give different readings if spaced a few metres apart.

As discussed above, the design of the gauge and its exposure are important factors. The aerodynamic design of the FSS series of raingauges should produce readings close to the true precipitation on the ground, in a wider range of weather conditions, than conventional raingauges (even 'standard' designs such as the 'Snowdon' gauge). For sites with poor exposure characteristics, comparison of different types of gauges may vary with weather conditions.

9. FSS500H Heated Version

The following describes the additional parts for the heated version of the raingauge. See Figure 4 for an internal view of the FSS500H, showing the heaters, control unit and terminals.

The heating system is designed to prevent the bucket assembly and pivot freezing and icing up in cold temperatures, and to return the raingauge to full operation as quickly as possible. It consists of:

1) Two series of heater elements.
2) An electronic sensor.
3) The heater control unit.

NOTE The heating system is not designed to melt heavy accumulations of snow, although any snow that does melt within the funnel assembly will be recorded as precipitation.

9.1 Operation of Heating Circuit

A separate power supply must be connected to the heating system before it will function. The supply must be capable of providing a current of 2.2A from a 12V system, or 1.1A from a 24V system. Such a supply should normally be independent of the datalogger power supply. A Campbell Scientific PS12E-LA Power Supply unit is not rated to provide the required current.

The heaters require a direct current (DC) supply. When attaching a power cable to the heater connections, either use a separate cable from the signal cable, or use a cable with individually screened pairs to avoid inducing false readings when the heater turns on and off.

When power is connected, the temperature is controlled automatically. The temperature sensor, mounted above the tipping bucket, monitors the air temperature within the raingauge.

The controller automatically activates the heaters when the temperature inside the raingauge enclosure drops to 1°C. The heaters will remain on until the temperature inside the enclosure reaches 4°C.

The heaters consist of six wire-wound ceramic resistors as shown in Figure 9. They are arranged in two blocks of three resistors.

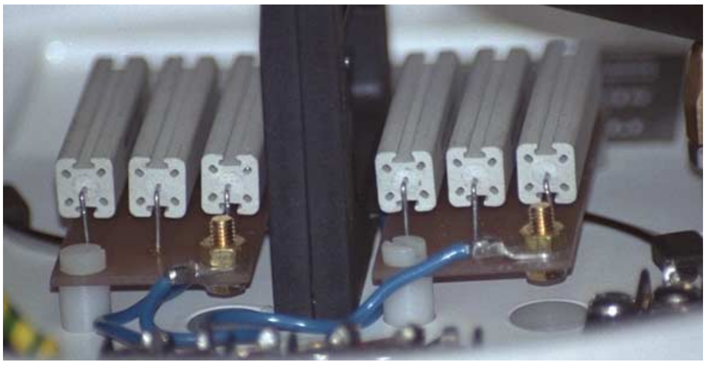

Figure 9 Heater Elements

The heaters operate from a 12V supply. A 24V version is available to special order. The appropriate schematic wiring diagrams, showing links for the 12V and 24V versions, are shown below.

CAUTION Ensure that you use the appropriate configuration and set the link(s) for 12V or 24V input supply to suit your heater control unit.

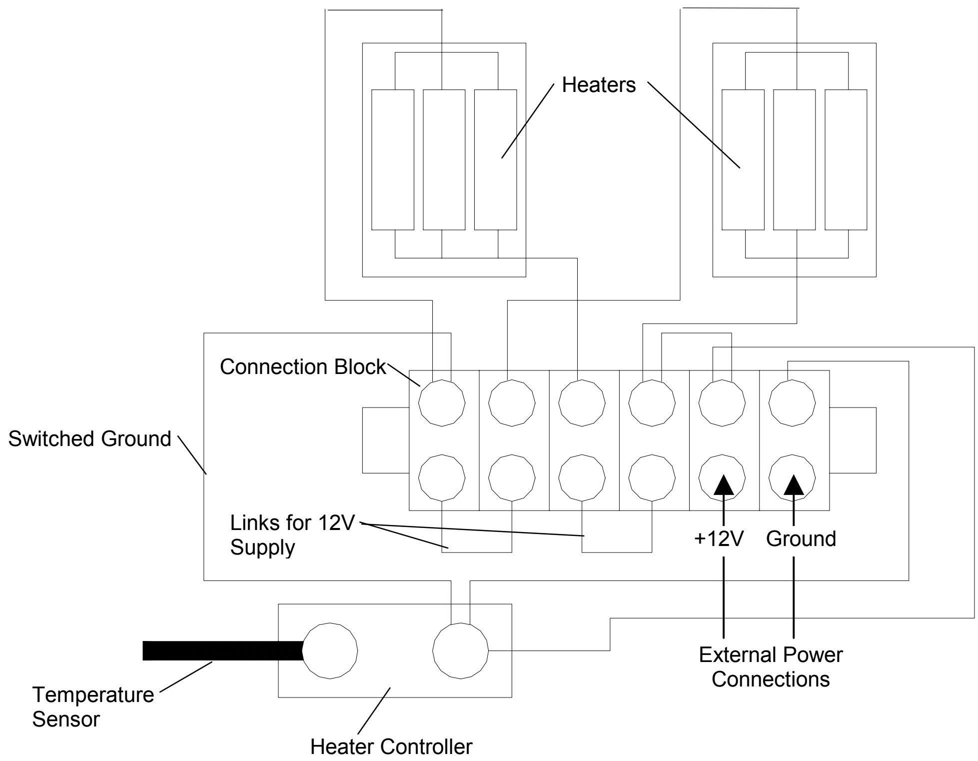

Figure 10 12V Heater System Wiring

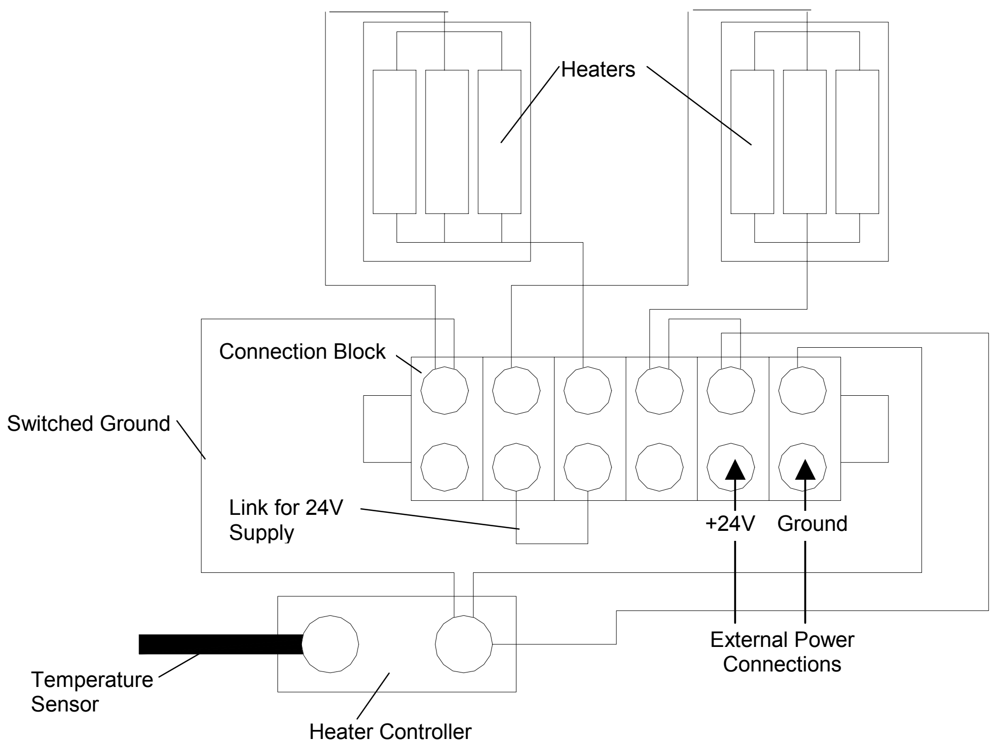

Figure 11 24V Heater System Wiring

10. Advantages and Limitations of a Tipping Bucket Gauge

Gauges which operate on the tipping bucket principle provide a digital output, which simplifies connection to a datalogger. The pulses returned during rainfall may be counted over any time interval desired allowing accurate determination of the rainfall rate (this variable, sometimes called 'intensity', is frequently used in soil erosion studies and is relevant to some aspects of crop pathology).

A tipping bucket gauge responds to discrete quanta of rainfall, and the accuracy and reproducibility of this quantum are determined not only by factors such as friction in the bearings, etc. but also by the rate of fill of the buckets. When the rainfall rate is high, a bucket may *start* to tip when the necessary volume of water has been collected, but while the bucket is moving away from the funnel outlet, an extra volume will have been collected and lost through spillage. The resulting degradation in accuracy is of the order of 4% at rainfall rates of 25mm/hr and 8% at 133mm/hr for most gauges (Parkin et al, 1982). This is important when results from gauges of different designs are compared. These errors worsen when gauge sensitivity is increased. It follows that gauge design is always a compromise between the need for good resolution and good overall accuracy in rainfall totals.

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