

USER GUIDE

PWS100 Present Weather Sensor



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PLEASE READ FIRST

About this manual

Some useful conversion factors:

Area: 1 in² (square inch) = 645 mm²

Length: 1 in. (inch) = 25.4 mm
1 ft (foot) = 304.8 mm
1 yard = 0.914 m
1 mile = 1.609 km

Mass: 1 oz. (ounce) = 28.35 g
1 lb (pound weight) = 0.454 kg

Pressure: 1 psi (lb/in²) = 68.95 mb

Volume: 1 UK pint = 568.3 ml
1 UK gallon = 4.546 litres
1 US gallon = 3.785 litres

Recycling information



At the end of this product's life it should not be put in commercial or domestic refuse but sent for recycling. Any batteries contained within the product or used during the products life should be removed from the product and also be sent to an appropriate recycling facility.

Campbell Scientific Ltd can advise on the recycling of the equipment and in some cases arrange collection and the correct disposal of it, although charges may apply for some items or territories.

For further advice or support, please contact Campbell Scientific Ltd, or your local agent.



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Precautions

DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND **TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.** FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at www.campbellsci.eu or by telephoning +44(0) 1509 828 888 (UK). You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

General

- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations, such as those of the FAA in the USA.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical

- **You can be killed** or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in **contact with overhead or underground utility lines.**
- Maintain a distance of at least one-and-one-half times structure height, or 20 feet, or the distance required by applicable law, **whichever is greater**, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.

Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

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Section 1. General Information



Important Safety Instructions – please request a translation or further advice if you cannot understand this document.

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1.1 About This Manual

This manual is the operational guide and reference for the Campbell Scientific Present Weather Sensor unit (PWS100). This manual consists of the following sections:

- Section 1 – Consists of general information on manual revisions and safety considerations.
- Section 2 – Provides a product overview with specifications of the optical, electronic and physical aspects of the system. Advantages and features of the system are described in detail.
- Section 3 – Is a guide for installation of the PWS100 including choosing cables, locating the sensor and assembly of the unit.
- Section 4 – Describes the operation of the sensor including the sensor command set and an introduction to the Present Weather Sensor Viewer program.
- Section 5 – Is a functional description of the PWS100, including a description of algorithms used for particle classification.
- Section 6 – Provides information on maintenance routines and cycles for the PWS100.
- Section 7 – Is a troubleshooting guide for the PWS100.
- Appendix A – A list of output codes used for particle classification under a number of different common code structures.
- Appendix B – Gives software flowcharts for the PWS100 system.
- Appendix C – Gives a menu system map for the PWS100.

1.2 General Safety

This manual provides important safety considerations for the installation, operation and maintenance of the PWS100. These safety considerations are classified into three levels:

WARNING	Warnings alert the installer or user to serious hazards. Ignoring these warnings could result in injury or death and/or irrevocable damage to the sensor unit.
CAUTION	Cautions warn of potential hazards. Ignoring these cautions could result in the sensor being damaged and data being lost.
NOTE	Notes highlight useful information in the installation, use and maintenance of this product. These should be followed carefully in order to gain the maximum benefit from the use of this product.

1.3 Sensor Unit Safety

The PWS100 sensor has been checked for safety before leaving the factory and contains no internally replaceable or modifiable parts.

WARNING	Do not modify the PWS100 unit. Such modifications will lead to damage of the unit and could expose users to dangerous laser light levels and voltages.
WARNING	In unusual failure modes and environmental conditions the sensor hood could become hot. In normal operation they will be at ambient temperature or slightly above.
CAUTION	Ensure that the correct voltage supply is provided to the sensor.

1.4 Laser Safety

The PWS100 sensor incorporates a laser diode which is rated as a class 3B device. This is an embedded laser where the output from the sensor unit, through the optics, is minimised to class 1M. This classification indicates that viewing of the beam with the naked eye is safe but looking directly into the beam with optical instruments, e.g. binoculars can be dangerous.

From the laser head the output has the following characteristics:

Maximum pulse energy: 73 nJ

Pulse duration: 5.2 μ s

Wavelength: 830 nm

EN 60825-1:2001

The sensor is marked with the following warning:

INVISIBLE LASER RADIATION
DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS
CLASS 1M LASER PRODUCT

WARNING

Opening the laser head unit with the power applied to the PWS100 may expose the user to hazardous class 3B laser radiation. To open the unit requires the use of tools and should not be carried out except by trained personnel.

The laser should not be operated outside of the housing.

WARNING

Check that the laser warning label on the sensor is still visible and can be clearly read on an annual basis.

When installing the sensor avoid pointing the laser housing towards areas where binoculars are in common use.

Section 2. Product Overview

2.1 Introduction

The PWS100 Present Weather Sensor is a laser based sensor capable of determining precipitation and visibility parameters for automatic weather stations including road weather and airport stations. Due to its advanced measurement technique and fuzzy logic algorithms the PWS100 can determine each individual particle type from accurate size and velocity measurements and the structure of the received signal.

The system can output visibility and precipitation related weather codes such as those detailed in the World Meteorological Organisation (WMO) SYNOP code, those used as part of a METAR weather report and those previously used by the US National Weather Service (NWS).

Further details of precipitation can be given in terms of drop size distributions (DSD) and particle size / velocity maps to give better indications of precipitation intensity. Such distributions can then be used in soil erosion studies.

The PWS100 comprises a Digital Signal Processor (DSP) housing unit connected to a sensor arm, comprising one laser head and two sensor heads. Each of the sensor heads is 20° off axis to the laser unit axis, one in the horizontal plane, the other in the vertical plane. The DSP housing is fixed via a mounting bracket to a mast, though a tripod can be used for temporary sites. Figure 2-1 shows the PWS100 mounted on a pole.

An optional CS215 temperature and humidity sensor is normally supplied and plugs directly into the PWS100. That sensor is used to improve the accuracy of weather coding by the PWS100, in particular in respect of discriminating between snow and rain and also fog/mist and dust.



Figure 2-1. PWS100

2.2 Specifications

2.2.1 Mechanical Specifications

Measuring Area: nominally 40 cm²

Housing Materials: Iridite NCP conversion coated aluminium (RoHS compliant) and hard anodised aluminium. Outer parts also coated with marine grade paint.

Weight: 8 kg Excluding mounting pole and power supply / communications enclosure.

Dimensions: 1150 mm × 700 mm × 400 mm

Mountings: PWS mounting bracket to pole (diameter 32 mm to 52.5 mm).

2.2.2 Electrical Specifications

Power Requirements: DSP power 9 - 28 V. Current requirement (maximum at 9V supply) 200mA with the dew heater off. 1 A with dew heaters and SDI-12 sensors. These currents are lower at higher supply voltages as the sensor uses SMPS technology. Optional hood heater 24 V AC or DC, 7 A.

CAUTION

If used with older CS215 sensors, before S/N E13405, the maximum voltage is 16V.

NOTE

It is the responsibility of the user to ensure that any local safety regulations, regarding the use of power supplies, are adhered to.

Communication: RS-232, RS-422, RS-485. Baud rate 300 bps to 115.2 kbps supported.

Control Unit: Custom DSP board.

EMC Compliance: Tested and conforms to BS EN 61326:1998. Class A device. This may cause interference in a domestic environment.

2.2.3 Optical Specifications

2.2.3.1 Laser Head Specifications

Laser Source: Near-IR diode, eye safe Class 1M unit output.

Peak wavelength: 830 nm.

Modulation Frequency: 96 kHz.

Laser Head Lens Diameter: 50 mm

2.2.3.2 Sensor Head Specifications

Receivers: Photodiode with band pass filters.

Spectral Response: Maximum spectral sensitivity at 850 nm, 0.62 A/W (0.6 A/W at 830 nm)

Sensor Head Lens Diameter: 50 mm

Lens Check Light Source: Near-IR LED.

2.2.4 Environmental Specifications

Standard Operating Temperature Range: -25°C to +50°C

Optional Extended Operating Temperature Range: -40°C to +70°C

Relative Humidity Range: 0 to 100%

Maximum Wind speed: 60 ms⁻¹

IP Rating: IP 66

2.2.5 CS215 Sensor Specifications

Please refer to the CS215 sensor manual for detailed of the accuracy and specifications of this optional probe.

2.3 Measurement Capabilities and Limitations

2.3.1 Visibility Measurements

Visibility Range: 0 to 20000 m.

Visibility Accuracy: ± 10% (0 to 10000 m)*

Measurement interval: User selectable from 10 seconds to 2 hours.

2.3.2 Precipitation Measurements

Particle Size: 0.1 mm to 30 mm*

Size Accuracy: ± 5% (for liquid particles >0.3 mm)*

Particle Velocity: 0.16 ms⁻¹ to 30 ms⁻¹

Velocity Accuracy: ± 5% (for particles >0.3 mm)*

Basic Types Of Precipitation Detected: Drizzle, Rain, Snow Grains, Snow Flakes, Hail, Ice Pellets, Graupel (heavily rimed solid precipitation), Freezing Rain, Freezing Drizzle, Mixed (combination of types above).

Rain Rate Intensity Range: 0 to 999 mmh⁻¹ (M-P Distributed)

Rainfall Total Resolution: 0.0001 mm

Rain Total Accuracy: ± typically 10%* (accuracy will be degraded in windy conditions, for frozen precipitation and very high rainfall rates)

DSD bin sizes: 0.1 mm (diameter) 0.1 ms⁻¹ (velocity)

Data Output: Raw parameter output (particle size, particle velocity, signal peak value, signal pedestal value), WMO SYNOP codes (4680, $W_a W_a$ - precipitation and obscurant type), WMO METAR codes (4678, $W_a W_a$ - precipitation and obscurant type), NWS code, drop size distribution (DSD) statistics, particle type distribution, size / velocity intensity maps, precipitation rate, precipitation accumulation, visibility range and internal checks (temperatures, lens contamination, processing limits).

External Sensors: CS215 supported for temperature / RH measurement OR this data can be sent to it from the controlling system from a remote sensor.

*The accuracy figures quoted are for laboratory conditions with reference particles and visibility standards. In practice, the proportion of particles detected will fall off significantly below about 0.5 mm diameter.

2.3.3 Data Storage and Buffering

The PWS100 has a large internal memory that is split up to store different types of data. One buffer, the particle buffer, is used to hold raw signal data captured from the detectors. The size of this buffer and the speed at which it can be processed is a limit on the maximum rainfall rates the sensor can measure. For most users this is not a limitation, if it may be please read the description below.

The particle buffer is able to hold raw data for 500 typical particles. The processor is able to process the particles at a rate of 120 particles per second, typically. This means if more than 120 particles per second fall through the sample area of 40 cm² the particle buffer will start to fill up. If the rain rate exceeds 120 particles per second for a prolonged period the buffer could run out of space and particles will be lost.

The fact that the processor is running behind real-time and/or particles are being missed can be monitored in the alarm message which can be selected for data output.

The particle processor then places data about each particle in the Large Particle Array (LPA). The LPA is 100000 records long. It uses 5 records every 10 seconds plus a record for every processed particle that passes through the volume. For example if 20 particles per second are processed then 20.5 records are used per second. Since 100000 records can be stored, the system can store $100000 / 20.5 = 4878$ seconds worth of data in the LPA. The user needs to be aware of the size of this buffer as it is used to hold data that is processed when a message is output. The size of the buffer may become a limiting factor if a very long message interval is selected and rainfall rates are high.

The PWS100 has the capability to store measured data in a buffer called the message storage buffer which is 1 MByte (1000000 characters in size). All ASCII characters including CrLf must be included in any storage calculations. This buffer stores the user defined messages (see Section '4.5 Message Related Commands' for the types of messages available to the user). A typical message containing 120 characters can be stored $1000000 / 120 = 8333$ times which at minute intervals for the data output would be over 138 hours' worth of storage.

Section 3. Installation

3.1 Location and Orientation

The PWS100 measures environmental variables and is designed to be located in harsh weather conditions. However there are a few considerations to take into account if accurate and representative data from a site are to be obtained.

NOTE

The descriptions in this section are not exhaustive. Please refer to meteorological publications for further information on locating weather instruments.

The PWS100 should be sited in a position representative of local weather conditions and not of a specific microclimate (unless the analysis of microclimate weather is being sought).

To give non-microclimatic measurements the PWS100 should be sited away from possible physical obstructions that could affect the fall of precipitation. The PWS100 should also be positioned away from sources of heat, electrical interference and in such a position as to not have direct light on the sensor lenses.

Whenever possible, the PWS100 should be located away from windbreaks. Several zones have been identified upwind and downwind of a windbreak in which the airflow is unrepresentative of the general speed and direction. Eddies are generated in the lee of the windbreak and air is displaced upwind of it. The height and depth of these affected zones varies with the height and to some extent the density of the obstacle.

Generally, a structure disturbs the airflow in an upwind direction for a distance of about twice the height of the structure, and in a downwind direction for a distance of about six times the height. The airflow is also affected to a vertical distance of about twice the height of the structure. Ideally, therefore, the PWS100 should be located outside this zone of influence in order to obtain representative values for the region (see Figure 3-1).

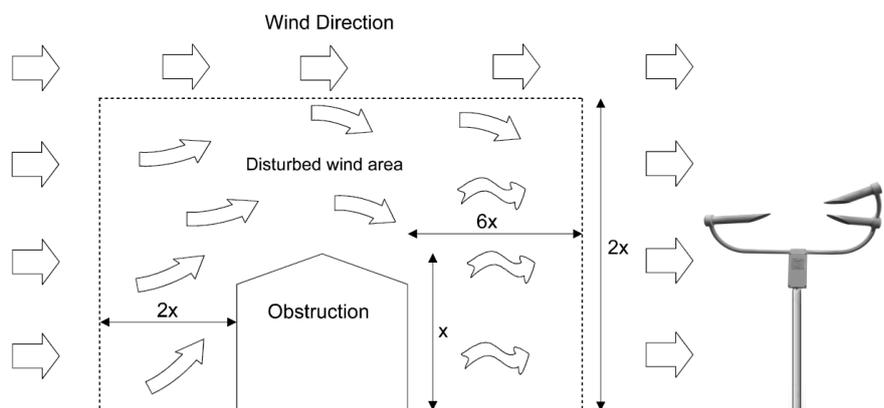


Figure 3-1. Effect of structure on air flow

In order to reduce the service frequency with the unit, the PWS100 should be placed away from sources of contamination, in the case of roadside monitoring, larger mounting poles can be used. More regular maintenance will be required when the instrument is placed in areas where contamination is unavoidable or where measurements may be safety critical.

The PWS100 has good resistance to background light but it is a good idea to avoid locations where the transmitter is pointing at a light scattering or reflecting surface. Ideally, the horizontal sensor head should point north in the northern hemisphere and south in the southern hemisphere but this is not critical.

High frequency light sources can lead to increased system noise and hence erroneous weather classification so the PWS100 should be positioned in a location where such interference is minimised. Ideally this should be a minimum of 100 m from the nearest high frequency light source, with the sensor heads pointing away from the light source. In any case the sensor heads should be positioned to be away from any high frequency light source.

Avoid locations where the transmitter is pointing at a light scattering or reflecting surface.

WARNING

When installing the sensor avoid pointing the laser housing towards areas where binoculars are in common use.

Any risk to health is minimal as to be at any risk at all from the laser light source the operator would need to look directly down the beam of light, so would need to be at the same height and in exact alignment with the sensor. In addition the beam diverges slightly so the risk decreases with distance from the sensor.

3.2 Grounding and Lightning Protection

3.2.1 Equipment Grounding

The present weather sensor must be properly grounded by taking a ground wire with a minimum cross sectional area of 8 mm² and maximum length of 10 m from the brass grounding lug in the lower face of the electronics enclosure to an adequate grounding point. The pole and foundations of a pole mounted installation will provide some basic lightning protection and protection against radio frequency interference.

WARNING

An optional grounding/lightning protection system can be supplied with the PWS100 which is designed to give the system some protection against induced transients and secondary lightning discharges. Whilst the system does offer some protection against lightning damage, if the present weather sensor is installed at a site where frequent lightning strikes are likely, Campbell Scientific recommends that you seek the advice of a specialist lightning Protection Company.

3.2.2 Internal Grounding

The DSP enclosure of the unit and associated electronics are grounded through the power cable assembly. The sensor components are in contact with each other or have internal copper contacts.

3.2.3 Lightning Rod (Optional)

If a lightning rod is to be fitted to the PWS pole fit it as shown in Figure 3-2 using the special clamp supplied. Connect grounding cable between the lightning rod clamp and the clamp on a grounding spike.

It is suggested that a lightning rod is only fitted where there is significant risk of lightning strike. During rainfall events water can accumulate and shed from the rod into the PWS100 sensing volume and cause erroneous measurements. The rod itself can also interfere with the passage of precipitation particles and ice accumulation can exacerbate the situation.

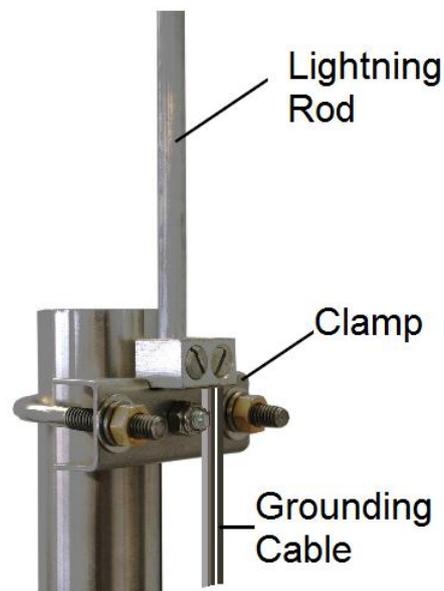


Figure 3-2. Attaching a lightning rod

3.2.4 Grounding Spike Kit (Optional)

Campbell Scientific can supply a grounding kit for the PWS100 consisting of two copper-covered steel grounding spikes, grounding wire and associated clamps and connectors.

Install the grounding kit as follows:

1. Screw the black Allen screw into the straight brass connector and then screw the connector onto the blunt end of one of the copper-coated grounding spikes. Drive the spike into the ground using the Allen screw as a driving head. Position the spike as close as possible to the base of the pole.
2. Remove the Allen screw and screw the second spike into the straight connector. Drive the second spike into the ground leaving about 100 mm exposed above ground. This will drive the first spike to a depth of about 2.3 m into the ground and should provide a good ground for lightning protection purposes.

NOTE

If the ground type does not permit you to drive the spikes in to a total length of 2.3 metres then drive in the two rods individually, spaced at least 2 metres apart, and join them together using a length of the heavy gauge grounding wire, using additional clamps (available from Campbell Scientific).

3. A lightning rod may already have been installed on the top of the pole as shown in Section 3.2.3. Grounding cable should be connected to the lightning rod clamp.
4. Connect a grounding cable to the grounding lug in the lower face of the PWS100 electronics enclosure.
5. Connect grounding cables from the enclosure and any lightning rod to the exposed ground spike using the brass grounding-bond clamp provided. If you had to install the spikes separately, because of ground conditions, take the cable to the nearest spike. Try to keep the length of wires used to a minimum, without coiling the wires.
6. Apply Waxoyl (or similar rust proofing compound) to the areas around the lightning rod clamp, the grounding lug clamp and where the grounding cable connects to the ground spike.

3.3 Cable Selection

NOTE

Some older units were shipped with different cables. These would have been described in the User Guide current at that time.

3.3.1 Heater Cable

The PWS100 is provided pre-wired with a default 10 m heater cable. This cable should be grounded using the cable screen at both ends. One end is to be connected to the power sources for the hood heaters (24V) the other is fed through the cable gland on the base of the PWS100 DSP enclosure and fixed in the terminal strip as shown in Figure 3-3. The cable supplied is 10 m long and is the longest of this type that can be used.

If another cable is to replace the pre-wired cable then it is normally recommended that the same type of cable is used and the wiring colour scheme shown in Figure 3-3 is followed to avoid confusion

However, alternative cable can be used and may be required for longer cable runs to reduce voltage drops in the cable. Wire with larger diameter conductors may be needed as any reduction below 24V, due to voltage drops along the cable, will limit the heaters effectiveness.

To remove the existing cable, unscrew the cable gland until the cable is loose then locate the individual termination points of the wires. Using a small flat blade screwdriver, press down the tab on the top of the terminal strip at the point of the wire connection and pull the wire from the front slot. Carry this out for all of the wires in the cable and then pull the cable from the cable gland until free. Insert the new (stripped) cable and insert the wires into the corresponding positions one by one by again depressing the tab on top of the terminal strip and then securely pushing the stripped end of the wire fully into the front slot.

ENCLOSURE WIRING DETAILS

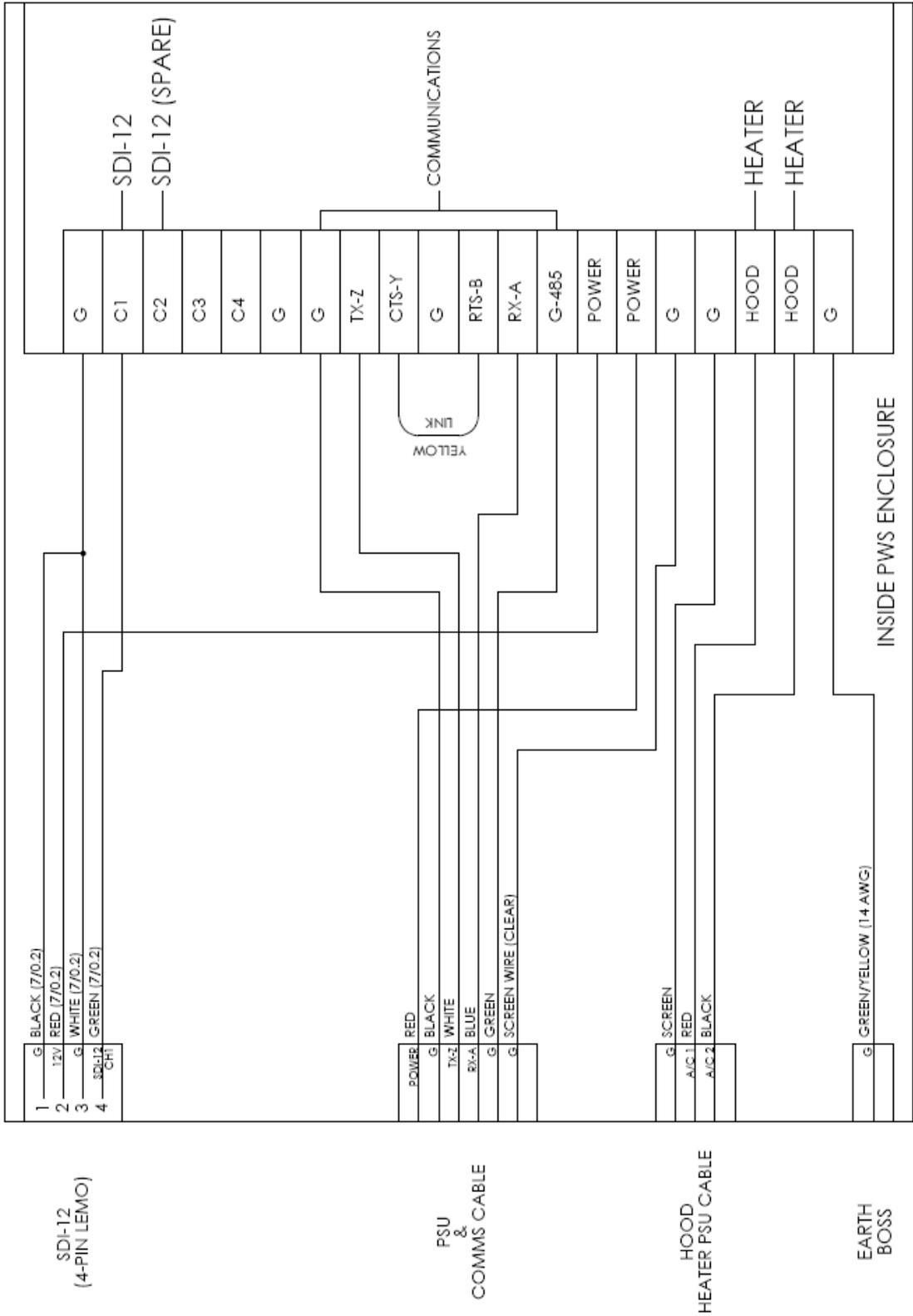


Figure 3-3. Enclosure wiring details

3.3.2 Power and Communication Cable

The PWS100 is provided pre-wired with a default 10 m power and communications cable which is terminated at one end with a 9 pin D-connector (DB9). The D-connector can be connected directly to a PC or datalogger such as the Campbell Scientific CR1000 using a suitable interconnecting cable such as the SC110. If another type of connection is required then the D-connector should be removed. The other end is fed through the cable gland on the base of the PWS100 DSP enclosure and fixed in the DSP terminal strip as shown in Figure 3-3. The cable connections for RS-232 and RS-485 are shown in Table 3-1.

Additional RS485 cable should be twisted pair.

A USB-serial adaptor is available part number 010777.

If another cable is to replace the pre-wired cable then ensure that the correct cable is used and the wiring colour scheme shown in Figures 3-3 and 3-4 is followed exactly.

To remove the existing cable, unscrew the cable gland until the cable is loose then locate the individual termination points of the wires. Using a small flat blade screwdriver, press down the tab on the top of the terminal strip at the point of the wire connection and pull the wire from the front slot. Carry this out for all of the wires in the cable and then pull the cable from the cable gland until free. Insert the new (stripped) cable and insert the wires into the corresponding positions one by one by again depressing the tab on top of the terminal strip and then securely pushing the stripped end of the wire fully into the front slot.

Table 3-1. Power and Communication cable connections.

Colour	PWS Terminal	RS-232	RS-485 half-duplex
Red	Power	+ve supply	+ve supply
Black	G	power and signal ground	power and signal ground
Green	RS485-G	-	RS485G
Blue*	RX-A	RX	-
Blue*	CTS-Y	-	RS485 (A)
White	TX-Z	TX	RS485 (B)
Screen	G	Ground	Ground

*Note the blue wire has to be moved to use RS485 communications

NOTE

As shipped the PWS100 does not support hardware handshaking. However if hardware handshaking is required, remove the yellow wire link between the RTS and CTS terminals inside the PWS enclosure. Extra cable cores will then be required and the cable supplied will need to be replaced. See Figure 3.3.

3.3.3 Full duplex RS485 operation

Full duplex RS485 operation is possible with the PWS100. However the supplied cable does not have sufficient cores. To use RS485 duplex communications with another cable the connections are as follows. `CTS-Y` and `TX-Z` are outputs. `RX-A` and `RTS-B` are inputs. The yellow link between `CTS-Y` and `RTS-B` should be removed.

NOTE

Dip switch 3 must be set `off` for full duplex operation. See Section 3.5.6.

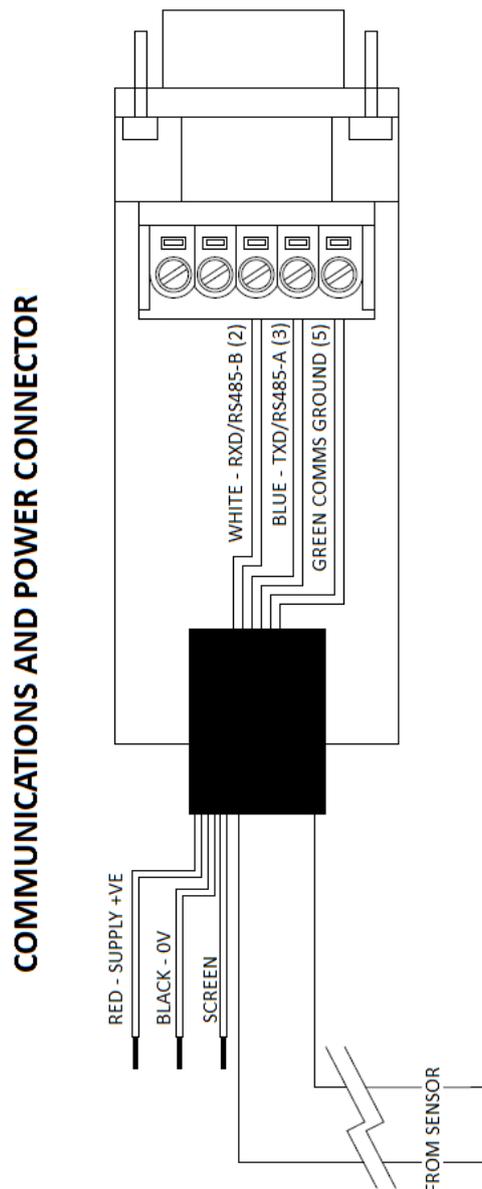


Figure 3-4. PWS100 Comms and Power Cable Connector

3.4 Unloading and Unpacking

3.4.1 Unpacking Procedure

Depending on the power and mounting options selected for the PWS100 there will be a number of boxes containing the PWS sensor unit, Optical Sensor mount, power supply/ external communications enclosure and grounding equipment.

CAUTION

Handle the boxes carefully, taking care not to drop them as the sensor can be damaged if dropped.

Unpack the boxes carefully and check the contents, ensuring that the contents match those listed on the packing slip. Carefully remove the items and replace all packing materials back into the empty boxes and store in case the unit is required to be repacked for shipping.

3.4.2 Storage Information

The PWS100 should be stored between -40°C to $+70^{\circ}\text{C}$ in a dry place, preferably with the enclosures securely fastened with desiccant in place. The optics should be protected from possible accidental damage.

3.5 Installation Procedures

3.5.1 Mounting the PWS100

A pole mounting kit is supplied with the PWS100. This kit includes a DSP plate, two brackets and suitable bolts for clamping the pole between the DSP plate and brackets. To mount the PWS100 onto a pole:

1. Fasten the bracket to the pole using one u-bolt, two flat washers, two split washers, and two nuts (see Figure 3-5).
2. Place the DSP plate on the bracket. The tabs of the bracket fit in the notches at the top of the DSP plate (see Figure 3-6).
3. Fasten the bottom of the DSP plate using the remaining u-bolt, washers, and nuts (see Figure 3-7).
4. If a power supply enclosure has been supplied with the sensor it can be mounted on the pole, near its base using the brackets supplied with the enclosure. Alternatively the power supply can be mounted elsewhere, e.g. on a wall at some distance from the sensor. The power supply enclosure should be mounted away from the sensor head to avoid wind flow disturbance or rain drops bouncing back up into the sensor's sensing volume.

CAUTION

Take care not to over tighten the nuts on the bolts, as it may be possible to distort and/or damage the brackets or DSP plate by doing so, and/or the nuts may seize up. Only tighten the nuts to a degree necessary to hold the PWS100 firmly in place.

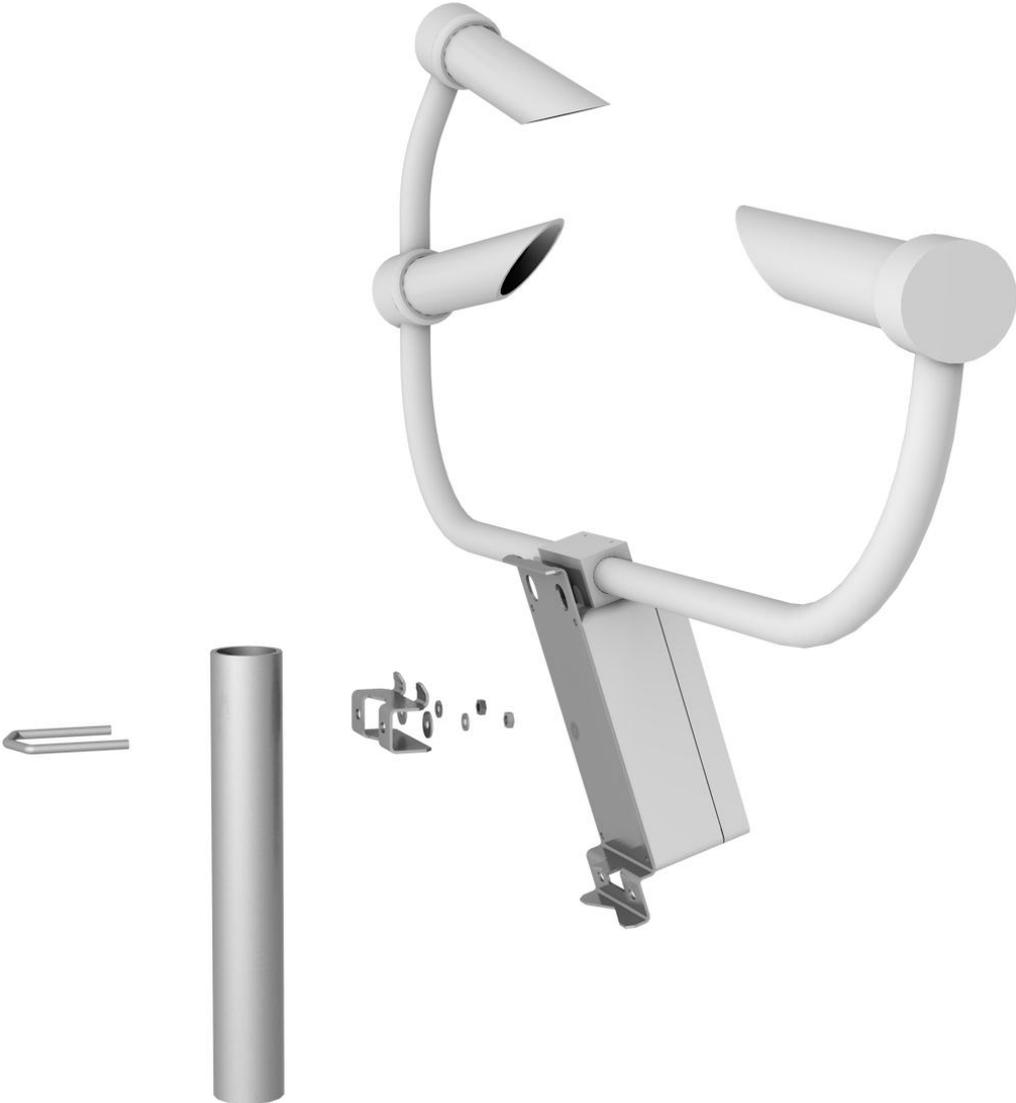


Figure 3-5. Hardware for mounting the top of the DSP plate to a pole

Where the PWS100 is to be mounted onto another type of mast please refer to the mast manual for mounting details.



Figure 3-6. Placing the PWS100 onto the bracket



Figure 3-7. PWS100 mounted to a mast or pole

CAUTION

Ensure that the PWS100 is mounted according to Figure 3-5 through 3-7. Do not reposition, once fixings are tightened, by forcing the arms of the unit as this can damage the unit.

3.5.2 Optional Campbell Scientific Mount

A Campbell Scientific 'optical sensor mount', part number 009354, is available. This will put the sample volume at about 1.5 m in compliance with the WMO 'Guide to Meteorological Instruments and Methods of Observation', 7th Edition, Section 9.3.4.

If one is to be used follow the installation instructions below.

The mount should be installed on a concrete foundation. If one does not already exist then a concrete foundation should be constructed at least 600 mm square and 600 mm deep. Ensure the ground consistency is not too loose and will be able to support the mount and concrete foundation.

Drill four 12 mm diameter holes using the mount base as a template to a depth of 77 mm.

Clean the holes of all debris.

Place washers and nuts on the ends of the wedge anchors supplied (to protect the threads during installation).

Hammer the wedge anchors into the holes until the start of the threads are below the surface.

Tighten the nuts until about 25 mm of thread protrudes above the surface.

Remove the washers and nuts from the protruding length screw. Then lower the mount into place.

Finally, secure the mount with the washers and nuts.

If the surface is not level and flat it may be necessary to add washers under the base on one or more of the foundation screws.

3.5.3 Connecting Cables

The sensor unit comes with the DSP control unit fixed to the sensor arm. All cabling between the sensor heads and the DSP unit is premade. The SDI-12 connections are wired to a LEMO socket on the lower face of the DSP housing. This is primarily wired for the CS215 sensor but is also used for the PWS calibrator. Power, communications and additional sensor connections are routed through the cable glands on the lower face of the DSP housing to the DSP terminal strip. As a factory default 10 m cables are pre-wired in the unit (these may have been specified differently and so may be of different length on this specific unit). The third cable gland will be sealed off by default but can be used for further external sensor connections or a separate power cable for the hood heaters, rather than sharing the main power cable.

There should be no need to alter any wiring within the DSP housing and the housing cover should only be removed periodically to renew desiccant packs or if any of the hardware switches need to be used. However if cable lengths are to be changed then these will have to be rewired in the DSP housing (see '3.3.1 Power Cable' and '3.3.2 Communication Cable' sections for further details).

3.5.4 Desiccant

Two bags of desiccant are supplied. One is inside the enclosure, the other is separate and sealed in a plastic bag. Desiccant use depends on your application (see below) but for use in typical temperate conditions one bag is sufficient for a twelve month period. The desiccant should be firmly strapped to the DSP cover inside the PWS electronics enclosure using the strap provided and as shown in Figure 3-8.



Figure 3-8. Mounting the desiccant pack on the DSP cover

The second bag of desiccant should be kept in the plastic shipping bag as a replacement for when the initial bag needs to be dried out. The bags can be rotated in this way many times. Desiccant bags can be dried out by the following method:

1. Arrange the bags on a wire tray in a single layer to allow for adequate air flow around the bags during the drying process. The oven's internal temperature should be room or ambient temperature (25°C - 30°C). A convection, circulating, forced air type oven is recommended for this regeneration process. Seal failures may occur if any other type of heating unit or appliance is used.
2. When placed in a forced air, circulating air, or convection oven, allow a minimum of 4 to 5 cm of air space between the top of the bags and the next metal tray above the bags. If placed in a radiating exposed infrared element type oven, shield the bags from direct exposure to the heating element, giving the closest bags a minimum of 40 cm clearance from the heat shield. Excessive surface film temperature due to infrared radiation will cause the Tyvek material to melt and/or the seals to fail. Seal failure may also occur if the temperature is allowed to increase rapidly. This is due to the fact that the water vapour is not given sufficient time to diffuse through the Tyvek material, thus creating internal pressure within the bag, resulting in a seal rupture. Temperature should not increase faster than 0.1°C to 0.3°C per minute.
3. Set the temperature of the oven to 118°C, and allow the bags of desiccant to reach equilibrium temperature.

CAUTION

Tyvek has a melting temperature of 121°C - 127°C.

(NON MIL-D-3464E activation or reactivation of both silica gel and Bentonite clay can be achieved at temperatures of 104°C).

4. Desiccant bags should be allowed to remain in the oven at the assigned temperature for 24 hours. At the end of this period, the bags should be immediately removed and placed in a desiccator jar or dry (0% relative humidity) air tight container for cooling. If this procedure is not followed precisely, any water vapour driven off during reactivation may be re-adsorbed during cooling and /or handling.
5. After the bags of desiccant have been allowed to cool in an airtight desiccator, they may be removed and placed in either an appropriate type polyliner tightly sealed to prevent moisture adsorption, or a container that prevents moisture from coming into contact with the regenerated desiccant. Some care should be taken when re-activating desiccant bags. If heated in an oven which is too hot, the bags may burst. If in any doubt, we recommend purchasing new desiccant packs instead of oven drying. Failure to use or exchange the desiccant may lead to condensation inside the enclosure. Not only will this lead to corrupted data but, in the long term, can also cause corrosion which is expensive to repair.

3.5.5 Basic Wiring

The PWS100 wiring block is shown on the internal layout diagram in Figure 3-3. Connection points for power and communications are shown in the diagram. There are two power inputs (one 24V for the hood heaters and one 12V for the processor board) one communications connection and two SDI-12 ports for peripheral connection. For RS-485 communications in half-duplex mode a 120 Ω termination resistor may need to be placed across the CTS-Y and TX-Z connections within the PWS100 and the A and B connections of the device being connected to. This is normally not required for most installations unless electronic noise interference is prevalent or cable runs are very long.

A 1K LEMO socket (IP66 rated) is used for connection of a peripheral (often the CS215 temperature / relative humidity probe fitted with a LEMO plug). The cable for any peripheral to be connected to the LEMO socket should be terminated with the appropriate 4 pin 1K series LEMO plug. Ensure when fitting the peripheral plug into the socket that the red tabs are aligned.

The power and communications cables are routed through two of the three cable glands on the base of the PWS100 DSP enclosure. If power and communications cables are replaced refer to Sections 3.3.1 and 3.3.2 for further details.

N.B. Some older units were fitted with LEMO connectors for all connections – these can be supplied if required to special order for an extra cost.

Figure 3-9 shows the lower face of the DSP enclosure with the cable gland and LEMO connector positions.

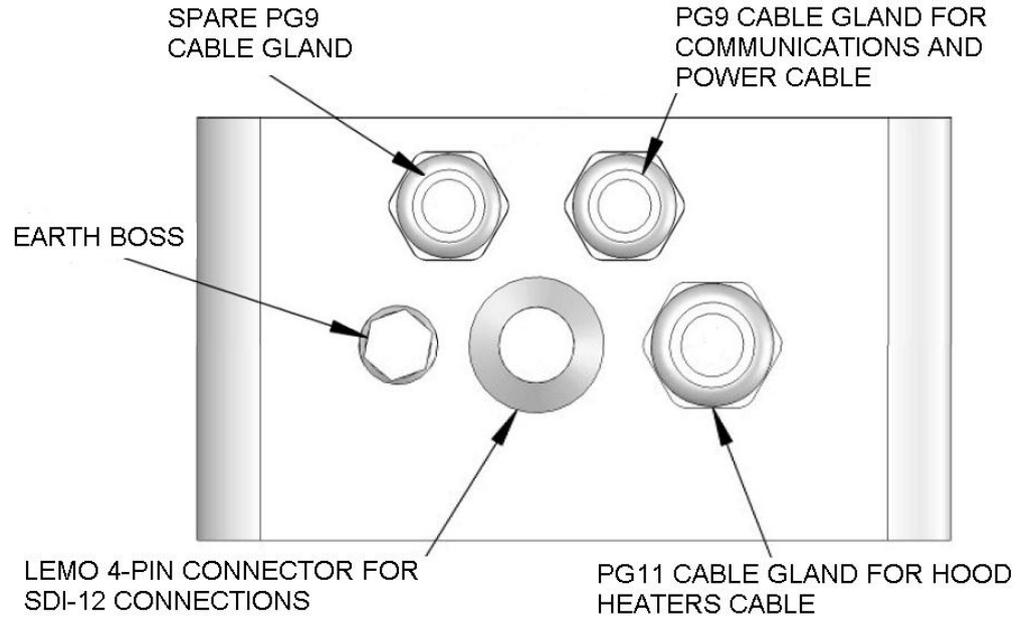


Figure 3-9. Underside of DSP enclosure

3.5.6 Communication Options

The communications options are RS-232, RS-422 and RS-485. Baud rate is selectable between 300 bps and 115.2 kbps. The communications are set on a series of dip switches on the DSP board itself. To get to the board the DSP cover must be removed as shown in Figure 3-10. Unscrew the four retaining screws and carefully lift off to expose the board as shown in Figure 3-11.



Figure 3-10. Removal of DSP cover



Figure 3-11. Exposing the DSP board

The location of the dip switches on the board is shown in Figure 3-12 and the dip switches themselves are shown in detail in Figure 3-13. The following settings are available:

PWS100 dip switch settings:-

0 = off; 1 = on.

switch 1 slew rate

0 slow slew rate (default)

1 fast slew rate

switch 2 communication mode

0 RS232 (default)

1 RS485 (note to use RS485 also requires a wiring change, see 3.3.2)

switch 3 duplex mode

0 full duplex

1 half duplex, default (RS485 – see 3.5.6.1 below)

switch 4-6 serial communication baud rate

switch

654	Baud Rate
000	300
001	1200
010	9600
011	19200
100	38400
101	57600
110	76800
111	115200 (default)

switch 7 reserved for future use (default off)**switch 8 load factory defaults at power up**

0	normal operation (default)
1	load factory defaults

3.5.6.1 RS485 Half-duplex mode

In half duplex mode the transition from transmits (Tx) to receive (Rx) modes and vice versa are subject to the following timing rules which may need to be considered when interfacing to other devices:

- The sensor waits for a gap of 1 byte period plus 10ms without receiving data before switching from Rx to Tx and echoing/responding.
- The sensor has a 1 millisecond Tx to Rx turnaround time.

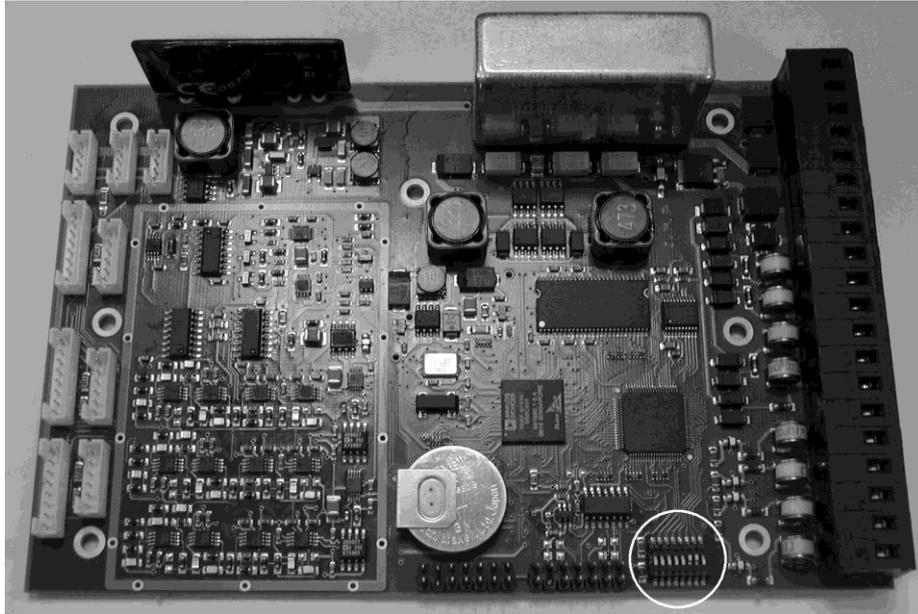


Figure 3-12. DSP board dip switch location (circled)

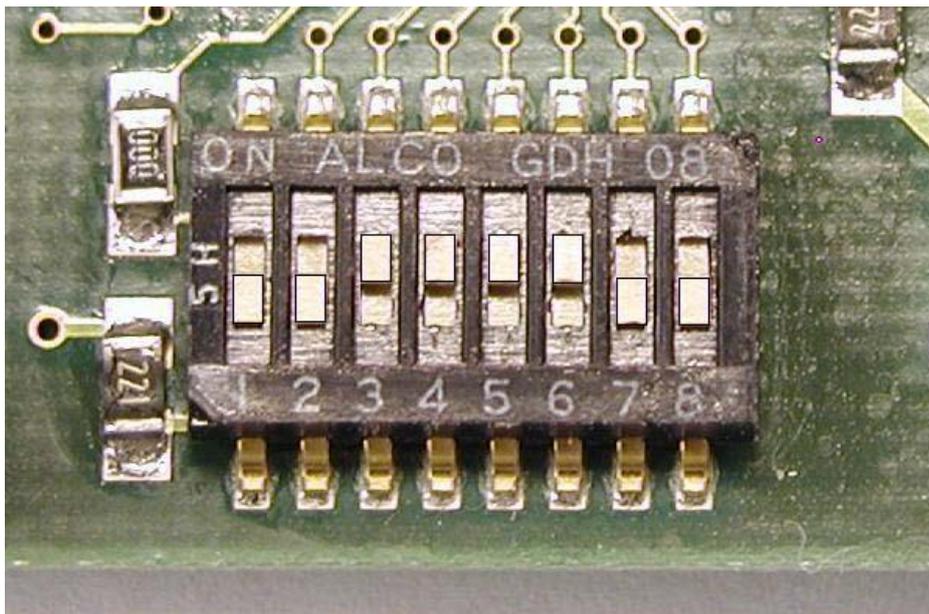


Figure 3-13. Dip switches (defaults set - 00111100)

3.5.7 PWS Power supply

The PWS100 may be supplied with or without a power supply. The design of the power supply sold by Campbell Scientific varies depending on locality and the application.

A typical power supply comprises a PS200 12V supply with a 7 Ah back-up battery. This is itself supplied by a switched mode supply taking mains input and providing 24 VDC for power to the PS200 and hood heating.

In most cases additional information will be provided specific to the power supply. Please refer to that documentation.

WARNING **Read carefully any documentation supplied with a power supply before installation.**

The wiring within the enclosure will be clearly labelled for the connections for the mains AC input and the outputs to which the cables of the PWS100 should be connected.

Prior to connecting the power supply first check the local safety regulations in regards of required isolators, fuses and earth leakage detectors for the mains connection.

WARNING **Normally a qualified electrician will be required to install the mains cable.**

The enclosure is rated for external use for electrical switch gear. To comply with local regulations a lock may need to be fitted to the enclosure and sometimes extra warning labels, in addition to those fitted, may need to be attached.

Check the power supply input voltage matches the mains supply to be used, e.g. check for the 110/230 V setting. In some cases the power supply can be reconfigured to either voltage by changing a jumper or switch setting. Recent supplies provided by Campbell Scientific accept either voltage without adjustment.

3.5.8 Start-Up Testing

On start-up the PWS100 will run internal diagnostic tests and check the status of any connections to the instrument, e.g. whether the CS215 is present.

3.5.9 Initial Settings

Initially the PWS100 will be set up with a series of default programmable options. These can be altered by entering the command mode of the sensor.

3.5.10 Load Factory Defaults

To load the factory default settings (retaining only the time, date and calibration values) power down the sensor move dip switch 8 to position 1 and power up the sensor. Once powered switch dip switch 8 back to position 0. This removes the password and all other user entered values. It also resets the sensor to switch back to the default messages, so any user defined messages will need to be reloaded.

3.5.11 Lubricating the enclosure screws

The PWS100 enclosure screws should be lubricated with a suitable anti-seize grease (often copper loaded) to protect the threads from corrosion. This should be reapplied when resealing the enclosure at regular intervals, normally after replacing the desiccant. This is of particular importance if using the sensor in corrosive or salt laden atmospheres.

Section 4. Operation

4.1 Introduction

The best way of becoming familiar with the sensor is to setup the sensor and connect it to a PC running Windows and the Campbell Scientific Present Weather Viewer program,

This software allows easy setup of the sensor and a graphical display of the measurements being made. It also provides an easy way of upgrading the firmware of the sensor. It is not intended to capture or store data on a permanent basis but is provided as a demonstration, test and setup tool. Brief details of use of the program are described below. The program includes a more detailed multi-lingual help system which can be accessed from the Help menu option once the program is running.

The PWS100 Present Weather Sensor is capable of outputting a range of data, from single particle parameters, to codes representing those from WMO and other standard meteorological tables. The sensor is setup with some factory defined output messages but the user will often need to change these to meet their own requirements. The setup can be done using either the Present Weather Viewer program or using a terminal emulator by interacting directly with the sensor.

4.2 Using the Present Weather Viewer program

The latest copy of which can be downloaded from:

<http://www.campbellsci.co.uk/downloads>

Click on “Download the software” and follow the on-screen instructions.

When Present Weather Viewer is running a “Help” icon on the top left hand corner of the screen gives access to detailed instruction on its use.

The PW viewer also provides a simple terminal emulator screen which can be used to setup the sensor using it’s built in menu system rather than the graphical interface the viewer provides.

To understand the operation of the sensor and the relevance of the settings in the graphical interface it is necessary to understand the messages and configuration options. These are discussed below within the context of setting up the sensor using a terminal emulator.

4.3 Terminal Mode

In normal operating mode the sensor will respond to a number of “root” commands, shown in Table 4-1. Those commands allow the configuration of the sensor in a non-interactive fashion, the polling of data and also switching the sensor into an interactive user menu mode.

They are accessed via the command TERM PWS_ID Password ↵
 Commands are entered in the format `Command Pws_ID Password ↵

PWS_ID is the sensor ID and is only required for the following commands:

- HELP
- OPEN
- TERM
- MSEND
- RSENSOR

Password is the sensor password (if set). It is only required for the following commands:

- OPEN
- TERM

Terminal commands are described in more detail in Sections 4.5 to 4.9.

Table 4-1. Command set.

Command	Description
PASSWORD	Sets user password
HELP*	Gives a list of available commands
OPEN*	Activate setup menu
TERM*	Enter command mode
CLOSE	Exit command mode
MSEND*	Poll messages
MSET	Set message parameters
HDATA	Retrieve historical particle data from sensor
SETPARAM	Set weather parameters
FUZZY DIAG*	Extra particle information see 4.6.2 for details
CONFIG	View system configuration
SETCONFIG	Set system configuration
LOADOS	Load a new operating system
DIAGSET	Set diagnostic test parameters
DIAG	Run diagnostic test
TIME	Display or set time and date
RSENSOR	Receive remote sensor values (T °C and RH %)

RESET	Reset hardware
STATUS	View system status
CREDITS	Lists credits to PWS100 developers
XHMDATA	Historic 'MSET' data download using Xmodem
HMDATA	Output historic data to the command line
RUNDISC	Rotate the calibration disc for test / demonstration purposes

*Commands marked with a * are available outside terminal mode.

The most commonly used commands are MSEND, HELP and OPEN.

In the descriptions which follow ↵ symbolises the pressing of the ENTER key. Input parameters in italics should be user defined characters appropriate for the command. Unless otherwise stated, all command parameters should be separated by a space.

To support addressed RS485 networks each PWS100 is assigned an identifier, shown as *Pws_Id* below. By default the PWS_Id is set to 0 (zero).

NOTE

When operating at the root level, commands are not echoed back to the terminal as this mode is intended primarily for polled data collection and echoed commands will complicate the issue of decoding the responses sent back from the sensor. Local echo can be turned on in Hyperterminal if required. Start Hyperterminal, select the pull-down 'File' menu and select 'Properties'. Click the 'ASCII setup' tab and check the 'Echo typed characters locally' checkbox.

4.3.1 Using the Help Command

To list available commands, the HELP command can be used as follows with the correct PWS100 *Pws_Id*:

```
HELP Pws_Id↵
```

e.g. HELP 0↵

The PWS100 will respond with a list of available commands and their basic function.

4.3.2 Entering / Exiting the Interactive Menu System

The user can enter the menu system by using the OPEN command with the correct *Pws_Id*. If a password is set, then it should also be entered. The command is then as follows:

```
OPEN Pws_Id Password↵
```

e.g. OPEN 0 campbell↵

The PWS100 will then display the SETUP menu of the menu system

To close the menu system and return the PWS100 to operation, option 9 should be chosen from the SETUP menu, see Figure 4-1. At this point either option 1 should be chosen to save changes and quit the menu system, or option 2 should be chosen to lose changes made and quit the menu system. Option 0 will return the user to the SETUP menu.

NOTE Changes made to the unit calibration and time and date settings whilst in the menu system are immediate and as such will remain changed independent of the quit option chosen from the menu.

NOTE The data storage function will not store data whilst the terminal or menu is active. This means data will be missing during these periods. To reduce data losses reduce the amount of time that the terminal or menus are active.

4.3.3 Message Polling

Whilst the menu system or terminal modes are closed, it is possible to poll data from a suitable set sensor (see Sections 4.4.1 and 4.6.1 for information on how to set up messages for polling). In order to poll a message the MSEND command must be used with the correct *Pws_Id*, *stats_period* & *message_ID*. Statistics are calculated over the *stats_period* in seconds which completely overrides any period defined within the message. The message can be either a fixed or user defined message from 0 to 19. The command for message polling is as follows:

```
MSEND Pws_Id stats_period message_ID ↵
```

e.g. MSEND 0 3600 10↵

In the example given above the PWS100 will respond with fixed *message_ID* 10 statistics calculated or sampled over the *stats_period* of 3600 seconds for the PWS100 with a *Pws_Id* of 0. If the *stats_period* is zero then the statistics are calculated from the last collection interval. So the polling interval controls the interval at which statistics are calculated over, up to a maximum of 2 hours.

Setting *stats_period* to less than 10 seconds will result in repeated data due to the ten seconds measurement cycle in the sensor (see Section 5.5).

4.4 The PWS100 Menu System

From the command line the use of the OPEN command, as detailed in Section 4.3.2, will initiate the menu system which can be used to set up the operation of the PWS100.

NOTE If there is no activity for 10 minutes with the menu system open it will automatically close.

The menu system map is shown in Appendix C. The menu is controlled by means of numeric selections followed by the enter key. Pressing enter by itself will return the user to the previous menu. A selection followed by the enter key will lead to the display of a specific menu or allow a specific parameter value to be input. Entering an incorrect selection or parameter value will return the user to the same menu. Pressing the delete key will delete the current entry. Pressing the escape key will clear the current entry and return to the previous menu.

NOTE

Entering the command line (terminal mode) from the menu system will lead to a loss of all changes made during navigation of the menu system.

Section 4.5 gives further details of how to set up the PWS100 with the command set in the terminal mode (option 7 from the SETUP menu).

```

WELCOME TO THE PWS100 SETUP MENU
ID 0
SN 1069
(0) message 0
(1) message 1
(2) message 2
(3) set time & date
(4) configuration
(5) password
(6) weather & alarm parameters
(7) terminal (changes will be lost)
(8) info
(9) done

Make a selection:

```

Figure 4-1. PWS100 setup menu

4.4.1 Top Menu Options 0, 1 and 2 (Message n)

The options 0, 1 and 2 from the SETUP menu are entitled 'message 0', 'message 1' and 'message 2'. These are used to setup the message outputs for messages with ID 0, 1 and 2. Selecting one of these brings up the MESSAGE menu as shown in Figure 4-2. Each message allows the user to select message intervals, modes and fields (option 1).

```

MESSAGE 0

(1) edit message
(2) delete message

Make a selection:

```

Figure 4-2. Message menu

If option 1 is chosen from the MESSAGE menu then the system will display the MESSAGE PARAMETERS & FIELDS menu for that message as shown in Figure 4-3. From here 19 fields can be filled in. Field 0 is the message interval. This is set in seconds and will be the interval between which output messages are given. Field 1 is the message mode and fields 2 to 19 are output parameters which can be user set.

NOTE If building a new message this has to be done in sequence starting with the Message interval and mode.

```

                                MESSAGE 0 PARAMETERS & FIELDS

(0) Message interval = Polled
(1) Mode = Store & Output
(2) 49 Vis range Av (m) over 10 minutes
(3) 21 SYNOP code (full)
(4) 22 METAR code
(5) 23 NWS code
(6) 24 Alarms
(7) 25 System fault status 0=ok 1&2=degraded 3=maintenance
    4=laser_fault
(8) 30 Temp Av (C), RH Samp (%), Wetbulb Av (C)
(9) 31 Temp Max (C), Temp Min (C)
(10) 40 Precipitation Intensity (mm / hour)
(11) 41 Precipitation accumulation (mm)
(12) 42 Particle size distribution (300 values 0.1 to 30mm)
(13) 43 Particle Av velocity (m/s), Av size (mm)
(14) 44 Particle type distribution (d, fd, r, fr, sg, sf,
    ip, h, g, e, u)
(15) 47 Size & velocity map Campbell 34x34
(16) 48 Ped ratio distribution (50 values 1.0 to 6.0)
(17) 156 Date (year, month, day)
(18) 157 Time (hours, minutes, seconds)
(19) 159 CRC16-CCITT

Make selection:

```

Figure 4-3. Message parameters and fields menu

Selecting field 0 brings up the MESSAGE INTERVAL menu shown in Figure 4-4. Here the interval is input. (i.e. will be given when the user requests it, either manually or in an automated fashion using a datalogger). Setting the interval to less than 10 seconds will result in repeated data due to the ten seconds measurement cycle in the sensor (see Section 5.5).

```

MESSAGE 0 INTERVAL

(0) polled message
(1..21600) message interval in seconds

Enter interval 10 :

```

Figure 4-4. Message interval menu

From the MESSAGE PARAMETERS & FIELDS menu if field 1 is chosen then the MESSAGE MODE menu, Figure 4-5, will be displayed. Here the options are to store and output to the serial port (option 0) which is useful for on screen analysis of real-time data, or store only (option 1) more useful when logging data.

If option 1 is chosen, data can be polled from the PWS100.

<p>MESSAGE 0 MODE</p> <p>(0) store & output (1) store only</p> <p>Make selection 0 :</p>

Figure 4-5. Message mode menu

From the MESSAGE PARAMETERS & FIELDS menu if fields 2 to 19 are chosen then the MESSAGE FIELD menu will be displayed as shown in Figure 4-6. Here an output parameter for that message field can be chosen from a number of different output parameters as detailed in Table 4-2 and described in Sections 4.4.1.1 to 4.4.1.37

All messages start with the message number and sensor ID e.g. 1_2 for message 1 from sensor ID2.

Table 4-2. Message Field parameters

Message Field	Parameter Output
0 – 2	User set message types
10 – 19	Fixed messages
20	Average visibility (m)
21	Present weather code (SYNOP)
22	Present weather code (METAR)
23	Present weather code (NWS)
24	Alarms
25	Fault status of PWS100
26	Present weather code (SYNOP) generic
30	Average temperature, RH%, wet bulb
31	Minimum and maximum temperature
33	Reserved
34	Reserved
40	Precipitation intensity (mmh^{-1})
41	Precipitation accumulation
42	Drop size distribution bin values (0.1 mm increment per value)

43	Average velocity (ms^{-1}), average size (mm)
44	Type distribution
45	Size / velocity map type 1 (20×20)
46	Size / velocity map type 2 (32×32)
47	Campbell Scientific standard size / velocity map (34×34)
48	Peak-to-Pedestal ratio distribution histogram (50 values)
49	Visibility range in metres averaged over 10 minutes
100	Internal LED temperatures: upper LED, lower LED
101	Internal detector temperatures: upper, lower
102	Laser hood temperature, laser temperature & laser current
103	DC offsets: upper, lower, laser
104	Dirty window: upper, lower, laser
105	Battery voltage, hood %, dew %
106	Upper and lower detector differential voltage (mV) and calibrated visibility voltage (mV)
150	Device s/n, operating system and hardware versions
151	Date & time: day count (from 01/01/2007) HH MM SS
152	Product name "PWS100"
153	Statistics period (s)
154	Watchdog count, maximum particles per second, particles not processed, time lag
155	Processing statistics
156	Year, month, day
157	Hours, minutes, seconds
158	Averaged corrected visibility voltage (mV) and average upper head voltage (mV)
159	CRC16-CCITT Checksum

Note that user defined messages cannot make field references to other user defined messages but can make reference to fixed messages from field 10 to 19 and all other message fields.

4.4.1.1 Message 0 (the Default Output)

User message 0 can be set by setting the Message Field parameters as required using other message fields from 10 upwards.

By default and after a hardware reset (see '3.5.10 Load Factory Defaults') or a software reset (see '4.9.2 Resetting the System') this outputs the message fields below (in the format as seen in the interactive menu). These fields have been used as defaults so they give a full display of the PWS100's capabilities when used with the Present Weather Sensor Viewer program.

The user can delete and completely reconfigure this message as required.

- (0) Message interval = 60 seconds
- (1) Mode = Store & Output
- (2) 49 Vis range Av (m) over 10 minutes
- (3) 21 SYNOP code
- (4) 22 METAR code
- (5) 23 NWS code
- (6) 24 Alarms
- (7) 25 System fault status 0=pws_ok 1=possible_degraded_performance
2=degraded_performance 3=maintenance_required 4=laser_fault
- (8) 30 Temp Av (C), RH Samp (%), Wetbulb Av (C)
- (9) 31 Temp Max (C), Temp Min (C)
- (10) 40 Precipitation Intensity (mm / hour)
- (11) 41 Precipitation accumulation (mm)
- (12) 42 Particle size distribution (300 values 0.1 to 30mm)
- (13) 43 Particle Av velocity (m/s), Av size (mm)
- (14) 44 Particle type distribution (fd, d, fr, r, sg, sf, ip, h, g, e, u)
- (15) 47 Size & velocity map Campbell 34x34
- (16) 48 Ped ratio distribution (50 values 1.0 to 6.0)
- (17) 156 Date (year, month, day)
- (18) 157 Time (hours, minutes, seconds)
- (19) 159 CRC16-CCITT

Note that in the default message, the start and end characters (STX/ETX) are included in the message – see "Output options" described in Section 4.4.3.

4.4.1.2 Messages 1 & 2 User Defined Messages

These user messages are set in the same way as message 0 but are cleared and do not output as default after a master reset.

4.4.1.3 Message Field 10 To 19 Fixed Messages

No Fixed messages have been defined yet. The user cannot change the fixed messages.

4.4.1.4 Message Field 20 Visibility Range (m)

This field will output the average visibility range (m) calculated over the *Message_Interval* or *stats_period* defined. If the sensor is in polled mode this will be the average since the last poll command.

4.4.1.5 Message Field 21 Present Weather Code (SYNOP)

This field will output the Present Weather Code (SYNOP) according to WMO code table 4680 calculated over the *Message_Interval* or *stats_period* defined. To follow WMO recommendations *Message_Interval* should be set to 180s.

4.4.1.6 Message Field 22 Present Weather Code (METAR)

This field will output the Present Weather Code (METAR) calculated over the *Message_Interval* or *stats_period* defined.

4.4.1.7 Message Field 23 Present Weather Code (NWS)

This field will output the Present Weather Code (NWS) calculated over the *Message_Interval* or *stats_period* defined.

4.4.1.8 Message Field 24 Alarms

This field will output the Alarms. The alarms are output as a string of 16 '0's and '1's delimited with spaces, for example 1 0 0 1 1 1 1 1 0 1 1 1 1 0 0.

Each alarm has the following definition starting from the left hand side:

1. Visibility range less than alarm 1 trigger point set by user. The factory default is 5Km*.
2. Visibility range less than alarm 2 trigger point set by user. The factory default is 1.5Km*.
3. Visibility range less than alarm 3 trigger point set by user. The factory default is 0.5Km*.
4. Laser drive current greater than 80mA. This may indicate the laser is failing or recalibration is required.
5. Power supply voltage less than 11.0V.
6. Laser window needs cleaning. There is sufficient build up on the window that if not cleaned could reduce accuracy.
7. Upper detector window needs cleaning. There is sufficient build up on the window that if not cleaned could reduce accuracy.
8. Lower detector window needs cleaning. There is sufficient build up on the window that if not cleaned could reduce accuracy.
9. DC voltage of laser dirty window detector greater than 1.5V. This can be caused by sun directly shining into lens or a pws fault.
10. DC voltage of upper detector greater than 1.5V. This can be caused by sun directly shining into lens or a pws fault.
11. DC voltage of lower detector greater than 1.5V. This can be caused by sun directly shining into lens or a pws fault.
12. Particle processor is unable to process all particles due to limited time and buffer resources. Particles are missed and data could be inaccurate. This alarm may activate when there are 120 or more particles per second going through the volume, sustained for a period that fills all available space in the buffers.
13. Particle processor lags real time by more than 5% of the user requested statistics interval.
14. Particle stripper is unable to process all particles due to limited time and buffer resources. Particles are missed and data will be inaccurate. This alarm may activate if there are more than ~150 particles per second going through the volume.
15. Reserved for future use, Outputs '0'.
16. Reserved for future use, Outputs '0'.

*The alarms are set based on the value of visibility at the set output interval – not on the 10 min averaged output.

4.4.1.9 Message Field 25 Fault Status of the PWS100

This field will output the fault status of the PWS100. The value output is from 0 to 4. 0 = no fault, 1 = Possible degraded performance, 2 = Degraded performance, 3 = Maintenance required, 4 = Laser fault.

4.4.1.10 Message Field 26 Present Weather Code (SYNOP) Generic

This field will output the Present Weather Code (WMO) calculated over the *Message_Interval* or *stats_period* defined but simplified to give generic codes, for example 70 for 'snow'.

4.4.1.11 Message Field 30 External Sensor Temperature, RH% and Wetbulb

This field will output the averaged temperature (°C), sampled relative humidity and averaged wetbulb temperature (°C) calculated over the *Message_Interval* or *stats_period* defined.

4.4.1.12 Message Field 31 External Sensor Maximum and Minimum Temperature

This field will output the maximum and minimum temperature (°C) calculated over the *Message_Interval* or *stats_period* defined.

4.4.1.13 Message Field 33 Reserved**4.4.1.14 Message Field 34 Reserved****4.4.1.15 Message Field 40 Precipitation Intensity**

This field will output the precipitation intensity (mm / hour) calculated over the *Message_Interval* or *stats_period* defined.

NOTE The PWS100 only measures particles / visibility 90% of the time so precipitation intensity is scaled appropriately.

4.4.1.16 Message Field 41 Precipitation Accumulation

This field will output the precipitation accumulation (mm) calculated over the *Message_Interval* or *stats_period* defined.

NOTE The PWS100 only measures particles / visibility 90% of the time so precipitation totals are scaled appropriately.

4.4.1.17 Message Field 42 Drop Size Distribution

This field will output the drop size distribution table which is output as 300 values, starting with the 0 - 0.1mm bin, in steps of 0.1mm up to 30mm. This is calculated over the *Message_Interval* or *stats_period* defined.

NOTE The PWS100 only measures particles 90% of the time. Particle numbers are NOT scaled appropriately.

4.4.1.18 Message Field 43 Average Velocity (ms^{-1}) and Average Size (mm)

This field will output the average velocity and average size values ignoring any particle type classifications.

4.4.1.19 Message Field 44 Type Distribution

This field will output the type distribution which is a series of 11 values for each particle type which shows the number of each type of particle classified. The order of the output is: drizzle, freezing drizzle, rain, freezing rain, snow grains, snowflakes, ice pellets, hail, graupel, error, unknown.

4.4.1.20 Message Field 45 Size / Velocity Type Map 1 (20 x 20)

This field will output a size and velocity map with the following classes:

Particle diameter class		
Class	Diameter [mm]	Class width [mm]
1	=>0.00	0.24
2	=>0.24	0.12
3	=>0.36	0.14
4	=>0.50	0.25
5	=>0.75	0.25
6	=>1.00	0.25
7	=>1.25	0.25
8	=>1.50	0.25
9	=>1.75	0.25
10	=>2.00	0.50
11	=>2.50	0.50
12	=>3.00	0.50
13	=>3.50	0.50
14	=>4.00	0.50
15	=>4.50	0.50
16	=>5.00	0.50
17	=>5.50	0.50
18	=>6.00	0.50
19	=>6.50	0.50
20	=>7.00	93.00

Particle speed class		
Class	Speed [m/s]	Class width [m/s]
1	=>0.0	0.2
2	=>0.2	0.2
3	=>0.4	0.2
4	=>0.6	0.2
5	=>0.8	0.2
6	=>1.0	0.4
7	=>1.4	0.4
8	=>1.8	0.4
9	=>2.2	0.4
10	=>2.6	0.4
11	=>3.0	0.4
12	=>3.4	0.8
13	=>4.2	0.8
14	=>5.0	0.8

15	=>5.8	0.8
16	=>6.6	0.8
17	=>7.4	0.8
18	=>8.2	0.8
19	=>9.0	1.0
20	=>10.0	90.0

If $s[n]v[m]$ equals the number of particles in velocity class n and speed class m then the output string for field 45 will be as follows:-

$s[1]v[1]_s[1]v[2]_....._s[1]v[20]; s[2]v[1]_s[2]v[2]_....._s[2]v[20];....._s[20]v[1]_....._s[20]v[20]$

There is a space separation between values.

4.4.1.21 Message Field 46 Size / Velocity Type Map 2 (32 x 32)

This field will output a size and velocity map with the following classes:

Particle diameter class		
Class	Average Diameter [mm]	Class width [mm]
1	0.060	0.12
2	0.180	0.12
3	0.300	0.12
4	0.420	0.12
5	0.540	0.12
6	0.665	0.13
7	0.795	0.13
8	0.925	0.13
9	1.055	0.13
10	1.185	0.13
11	1.375	0.25
12	1.625	0.25
13	1.875	0.25
14	2.125	0.25
15	2.375	0.25
16	2.750	0.50
17	3.250	0.50
18	3.750	0.50
19	4.250	0.50
20	4.750	0.50
21	5.500	1.00
22	6.500	1.00
23	7.500	1.00
24	8.500	1.00
25	9.500	1.00

26	11.000	2.00
27	13.000	2.00
28	15.000	2.00
29	17.000	2.00
30	19.000	2.00
31	21.500	3.00
32	=>23.000	77.00

<i>Particle speed class</i>		
Class	Average Speed [m/s]	Class width [m/s]
1	0.05	0.1
2	0.15	0.1
3	0.25	0.1
4	0.35	0.1
5	0.45	0.1
6	0.55	0.1
7	0.65	0.1
8	0.75	0.1
9	0.85	0.1
10	0.95	0.1
11	1.10	0.2
12	1.30	0.2
13	1.50	0.2
14	1.70	0.2
15	1.90	0.2
16	2.20	0.4
17	2.60	0.4
18	3.00	0.4
19	3.40	0.4
20	3.80	0.4
21	4.40	0.8
22	5.20	0.8
23	6.00	0.8
24	6.80	0.8
25	7.60	0.8
26	8.80	1.6
27	10.40	1.6
28	12.00	1.6

29	13.60	1.6
30	15.20	1.6
31	17.60	3.2
32	=>19.20	80.8

If $s[n]v[m]$ equals the number of particles in velocity class n and speed class m then the output string for field 46 will be as follows:-

$s[1]v[1]_s[1]v[2]_....._s[1]v[32]; s[2]v[1]_s[2]v[2]_....._s[2]v[32];....._s[32]v[1]_....._s[32]v[32]$

There is a space separation between values.

4.4.1.22 Message Field 47 Campbell Scientific Standard Size / Velocity Map (34 x 34)

This field will output the standard Campbell Scientific size and velocity map with the following classes:

Particle diameter class		
Class	Diameter [mm]	Class width [mm]
1	=>0.00	0.1
2	=>0.10	0.1
3	=>0.20	0.1
4	=>0.30	0.1
5	=>0.40	0.1
6	=>0.50	0.1
7	=>0.60	0.1
8	=>0.70	0.1
9	=>0.80	0.1
10	=>0.90	0.1
11	=>1.00	0.2
12	=>1.20	0.2
13	=>1.40	0.2
14	=>1.60	0.2
15	=>1.80	0.2
16	=>2.00	0.4
17	=>2.40	0.4
18	=>2.80	0.4
19	=>3.20	0.4
20	=>3.60	0.4
21	=>4.00	0.8
22	=>4.80	0.8
23	=>5.60	0.8
24	=>6.40	0.8
25	=>7.20	0.8
26	=>8.00	1.6
27	=>9.60	1.6
28	=>11.20	1.6

29	=>12.80	1.6
30	=>14.40	1.6
31	=>16.00	3.2
32	=>19.20	3.2
33	=>22.40	3.2
34	=>25.60	74.4
Particle speed class		
Class	Speed [m/s]	Class width [m/s]
1	=>0.00	0.1
2	=>0.10	0.1
3	=>0.20	0.1
4	=>0.30	0.1
5	=>0.40	0.1
6	=>0.50	0.1
7	=>0.60	0.1
8	=>0.70	0.1
9	=>0.80	0.1
10	=>0.90	0.1
11	=>1.00	0.2
12	=>1.20	0.2
13	=>1.40	0.2
14	=>1.60	0.2
15	=>1.80	0.2
16	=>2.00	0.4
17	=>2.40	0.4
18	=>2.80	0.4
19	=>3.20	0.4
20	=>3.60	0.4
21	=>4.00	0.8
22	=>4.80	0.8
23	=>5.60	0.8
24	=>6.40	0.8
25	=>7.20	0.8
26	=>8.00	1.6
27	=>9.60	1.6
28	=>11.20	1.6
29	=>12.80	1.6
30	=>14.40	1.6
31	=>16.00	3.2
32	=>19.20	3.2
33	=>22.40	3.2
34	=>25.60	74.4

If $s[n]v[m]$ equals the number of particles in velocity class n and speed class m then the output string for field 47 will be as follows:-

$s[1]v[1]_s[1]v[2]_....._s[1]v[34]; s[2]v[1]_s[2]v[2]_....._s[2]v[34];....._s[34]v[1]_....._s[34]v[34]$

There is a space separation between values.

4.4.1.23 Message Field 48

This field outputs a histogram which contains the number of particles counted within the measurement period that have a given peak- to-pedestal ratio (see Section 5.6 – this gives a measure of the number of crystalline particles). This is a histogram of 50 bins for ratios for 1.0 to 6.0 in steps of 0.1.

Note that the ratios for particles less than 0.5 mm in size are not accurate so are not included in this histogram. The total number of particles in this histogram can therefore be less than the total particles detected.

4.4.1.24 Message Field 49 Visibility (m), 10 minute average

This field will output the average visibility range (m) calculated over the previous 10 minutes, independent of the message interval – this is a 10 minute rolling average.

4.4.1.25 Message Field 100 Upper, Lower LED temperature

This field will output the sampled internal upper and lower LED temperatures (°C).

4.4.1.26 Message Field 101 Upper, Lower Detector Temperature

This field will output the sampled internal upper and lower detector temperatures (°C).

4.4.1.27 Message Field 102 Laser Hood, Laser Temperature and Laser Drive Current

This field will output the sampled internal laser hood temperature (°C), laser temperature (°C) and laser drive current (mA).

4.4.1.28 Message Field 103 Laser, Upper, Lower Detector DC Voltage Offsets

This field will output the sampled internal laser dirty window detector, upper and lower detector DC offsets (mV).

4.4.1.29 Message Field 104 Laser, Upper and Lower Dirty Window Detector

This field will output the sampled internal laser, upper and lower dirty window detector voltage levels (mV).

4.4.1.30 Message Field 105 DSP PSU Voltage, Hood and Dew Heater % Duty

This field will output the sampled DSP PSU voltage (V), hood and dew heater duty (0-100%)

4.4.1.31 Message Field 106 Upper, Lower Detector Differential Voltage, Calibrated Visibility mV

This field will output the sampled upper, lower detector differential voltage (mV) and the calibrated visibility (mV).

4.4.1.32 Message Field 150 Serial Number, Operating System and Hardware Version

This field will output the system serial number, operating system and hardware version numbers.

4.4.1.33 Message Field 151 Day Count, Hours, Minutes, Seconds

This field will output the day count (from 01/01/2007), hours, minutes and seconds.

4.4.1.34 Message Field 152 Product Name

This field will output the product name "PWS100".

4.4.1.35 Message Field 153 Statistics Period

This field will output the statistics period in seconds.

4.4.1.36 Message Field 154 Watchdog Count, Maximum Particles Per Second, Particles Not Processed, Time Lag

This field will output a watchdog count which indicates the number of resets of the system due to error, the maximum number of particles stripped per second over the measurement interval, the number of particles stripped in real time but not processed and a time lag in seconds indicating how far behind processing has got at some point during the measurement interval.

4.4.1.37 Message Field 155 Processing Statistics

Shows the statistical distribution of particle processing methods used on each particle and is generally intended for debug purposes only – contact Campbell Scientific for more details.

4.4.1.38 Message Field 156 Year, Month, Day

This field will output the year, month and day.

4.4.1.39 Message Field 157 Hours, Minutes, Seconds

This field will output hours, minutes and seconds.

4.4.1.40 Message Field 158 Averaged Corrected Visibility Voltage and Averaged Upper Head Voltage

Shows the average voltage (mV) value corresponding to the corrected visibility value (i.e. adjusted for atmospheric conditions) and the average mV value for the upper head.

4.4.1.41 Message Field 159 Output a CCITT CRC-16 (checksum) of the message

This outputs a two byte checksum in hex format (four ASCII characters). This is normally included at the end of a message to allow the validity of the message to be checked. The CRC does not include the checksum itself or STX/ETX characters.

4.4.1.42 Message Field Error

If “Error - message field nnn not valid” is output then this indicates the message you have defined has an invalid field which is not in the list above. You must go and check / re-edit your message definition.

```

MESSAGE 0 FIELD 20

(20) Average visibility (m)
(21) SYNOP code (full)
(22) METAR code
(23) NWS code
(24) Alarms
(25) System fault status 0=ok 1&2=degraded 3=maintenance
4=laser_fault
(26) SYNOP code (generic)
(30) Temp Av (C), RH Samp (%), Wetbulb Av (C)
(31) Temp Max (C), Temp Min (C)
(33) Reserved
(34) Reserved
(40) Precipitation Intensity (mm / hour)
(41) Precipitation accumulation (mm)
(42) Particle size distribution (300 values 0.1 to 30mm)
(43) Particle Av velocity (m/s), Av size (mm)
(44) Particle type distribution (d, fd, r, fr, sg, sf, ip,
h, g, e, u)

(999) delete field
(1000 + field number) insert field
(0) more...

```

Figure 4-6. Message field menu

Choosing option 0 on the MESSAGE FIELD menu will display more output parameter options. Choosing option 999 will delete the field (note that subsequent fields already selected shift up to fill the gap in the fields). Choosing option 1000 + field number will insert the chosen parameter in the field selected and shift subsequent filled fields down one field.

Also available on the MESSAGE menu is the option to delete the message (option 2). If the message is to be deleted the DELETE MESSAGE menu, Figure 4-7, will be shown. Choosing option 1 will not delete the message and will return the user to the previous menu; option 2 will delete the message. If a message is deleted a new message can be created for that message ID. Messages not deleted will retain their message ID. Therefore if all messages are set and message 1 is deleted then messages 0 and 2 are still active and will still be output. Message 1 can be redefined if required.

```
DELETE MESSAGE 0

(1) no
(2) yes

Make selection:
```

Figure 4-7. Delete message menu

4.4.2 Top Menu Option 3 (Set Time and Date)

Choosing option 3 from the SETUP menu brings up the TIME AND DATE menu, Figure 4-8. On this menu it is possible to set the time and / or date for the PWS100. To change the time alone enter it as hh:mm:ss, for example 16:30:00. To change the date alone enter it as yyyy/mm/dd, for example 2007/02/04. To set the time and date simultaneously enter both of these parameters on the same line, for example 16:30:00 2007/02/04. Leading zeroes are not required on the values but the colons (:) and forward slashes (/) are and a space is required between the time and date values.

```
TIME & DATE

Set time using hh:mm:ss
Set date using yyyy/mm/dd
Set date & time using yyyy/mm/dd hh:mm:ss
Set time & date using hh:mm:ss yyyy/mm/dd

NOTE: Changes have immediate effect

Enter any combination of time and or date as above :
```

Figure 4-8. Time and date menu

4.4.3 Top Menu Option 4 (Configuration)

Choosing option 4 from the SETUP menu brings up the CONFIGURATION menu, Figure 4-9. From this menu the basic configuration of the sensor is set.

```

CONFIGURATION

(1) PWS100 ID
(2) TRH probe type
(3) Reserved
(4) Reserved
(5) Hood heater temperature (C)
(6) Dew heater mode
(7) Output mode
(8) Calibration
(9) Terminal mode
(10) PSU shut down voltage

Make selection:

```

Figure 4-9. Configuration menu

Option 1 of the configuration menu gives the PWS100 ID menu, Figure 4-10. Here a PWS100 ID can be set. This is effectively the station address which is required on any communication with the PWS100. If the PWS100 is on a network with more than one PWS100 then each station should have its own PWS100 ID. The default PWS100 ID is zero.

```

PWS100 ID

(0..100) Id range

Enter ID 0 :

```

Figure 4-10. PWS100 ID menu

Option 2 of the configuration menu gives the TRH PROBE TYPE menu, Figure 4-11. Choose the correct temperature / relative humidity probe that is connected to the PWS100 from the list given.

```

TRH PROBE TYPE

(0) no trh fitted
(1) CS215
(2) remote trh

Make selection 1 :

```

Figure 4-11. TRH probe menu

Selecting probe type 2 configures to sensor to expect a temperature and humidity reading to be sent to it from a remote system using the RSENSOR command.

Options 3 and 4 are reserved for future use.

Option 5 of the configuration menu gives the HOOD HEATER TEMPERATURE menu, Figure 4-12. The value that is to be set needs to be between 0 and 50°C. The hood temperature is maintained by the system at the value set.

```
HOOD HEATER TEMPERATURE

(0) off
(1..50) on temperature (C)

Make selection 10 :
```

Figure 4-12. Hood heater temperature menu

Option 6 of the configuration menu gives the DEW HEATER MODE menu, Figure 4-13. The dew heaters can be set to on, off or auto. Auto-mode turns the dew heaters on except when the hood heaters are set to heat.

```
DEW HEATER MODE

(0) off
(1) on
(2) auto

Make selection 2 :
```

Figure 4-13. Dew heater mode menu

Option 7 of the configuration menu gives the OUTPUT MODE menu, Figure 4-14. This refers to the use of packetized output. The message framing is done by using STX (ASCII character 02) and ETX (ASCII character 03); these act as start and end delimiters. The default value is 1 (STX / ETX on). These framing characters are useful for programmers writing code to pick up data coming from a sensor outputting data asynchronously to the device collecting it.

Messages end with CR LF characters. The ETX character is added after these if the output mode is set to (1).

```
OUTPUT MODE

(0) STX / ETX off
(1) STX / ETX on

Make selection 1 :
```

Figure 4-14. Output mode menu

Option 8 of the configuration menu gives the initial warning screen for the calibration procedure, Figure 4-15. Unless the correct procedure is followed and calibration entries are correctly input the PWS100's performance can be seriously degraded. In order to perform a calibration a PWS calibration unit is required which affixes to the PWS and performs several checks of the PWS100. This unit is connected via the LEMO socket of the PWS100 and automatically provides values to the PWS100 system which can be used to alter the calibration.

See the PWS calibrator manual for further instructions on how to run the calibration device. The device itself can be run at any time during the operation of the PWS100. It then provides size, velocity and visibility calibration values which can be checked and accepted by the user using the PWS100 menu system described below.

In order to proceed with the calibration routine 'confirm' must be typed followed by the return key.

```
PWS100 Calibration

CAUTION! INCORRECT ENTRIES CAN SERIOUSLY DEGRADE ACCURACY

to edit or view instrument calibration, type 'confirm' :
```

Figure 4-15. Calibration warning screen

Once 'confirm' is typed followed by the return key. The CALIBRATION top menu, Figure 4-16, will appear. The options available to the user are 0 to view and enter the calibration disc constants and 1 to view and adjust the PWS100 calibration and 2 for a visibility only calibration.

```
PWS100 Calibration

(0) view / enter calibration disc constants
(1) view / adjust PWS100 calibration
(2) visibiliy only calibration

Make selection :
```

Figure 4-16. Calibration top menu

Options 0 or 1 are for a calibration using the PWC100 calibration kit. Please refer to the PWC100 calibrator manual for details. Option 2 is for a visibility only calibration using only the PWS100 visibility calibrator. Figure 4-17 shows the procedure to be followed from on screen commands to carry out the visibility only calibration.

```
Enter visibility calibrator plate constant (mV) 42.355 :  
38.293  
  
Place visibility blanking plug into upper sensor head, any  
key to continue  
  
wait 70 seconds for measurement...  
  
Remove visibility blanking plug  
  
Place visibility calibrator plate onto mount in central  
position, any key to continue  
  
wait 70 seconds for measurement...  
  
Remove visibility calibrator plate, any key to continue
```

Figure 4-17. Visibility only calibration process

Finally the VIEW / ADJUST CALIBRATION menu, Figure 4-19 is shown. On this menu the latest calibration values will be evident in the left hand column of values headed 'latest'. Selecting option 0 on the VIEW / ADJUST CALIBRATION menu will return the user to the previous menu without invoking any calibration changes. Selecting option 1 from the VIEW / ADJUST CALIBRATION menu will allow the user to update the calibration value for visibility.

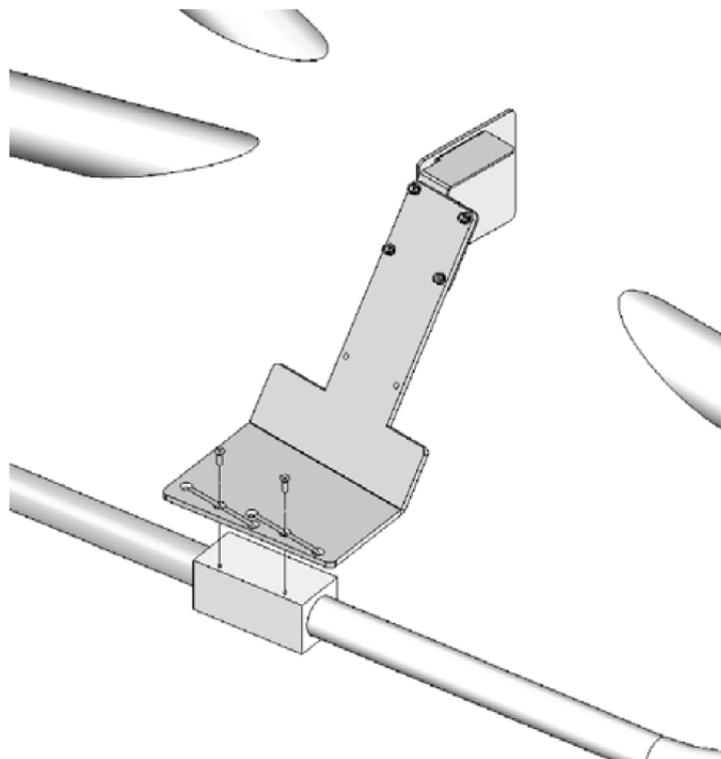


Figure 4-18. Mounting visibility calibrator

NOTE The calibration should only be carried out during non-precipitation conditions and during clear atmospheric conditions (>10 km visibility).

```

PWS100 View / Adjust calibration

Latest results from calibrator date 27:5:2009

Velocity_Centre      latest      target--range      calibration date
Velocity_Left        4.983      4.900  5.100      22:4:2009
Velocity_Right       4.984      n/a      n/a      n/a
Size_Centre          2.158      2.108  2.258      22:4:2009
Visibility (mV)      36.554     32.590  39.832     6:4:2009
Visibility Offset (uV) -1.574     -3.000  3.000      n/a

(0) no change
(1) adjust calibration (THIS WILL TAKE IMMEDIATE EFFECT)

Make selection :

```

Figure 4-19. View / adjust calibration menu

Option 9 of the configuration menu gives the TERMINAL MODE menu, Figure 4-20. Choose whether CRC16-CCITT checksum verification is required.

NOTE When terminal mode is set to 1 all terminal commands need a CRC. For example “open 0;d2d5” a semi-colon is used to indicate start of CRC in 4 byte ASCII hex. Once the menu is opened menu commands do not need a CRC and will be ignored if one is added. The CRC is calculated either from the start of a new line or after a [STX] up to but not including the semi-colon. ETX can follow the CRC if required. The valid CRC can be read back for any command if the CRC after the semi-colon is replaced with four ‘?’. For example “open 0;????” the response will be [CRLF]CRC>D2D5<CRC[CRLF] so d2d5 is the CRC.

```

TERMINAL MODE

(0) CRC16-CCITT off
(1) CRC16-CCITT on

Make selection 0 :

```

Figure 4-20. Terminal mode menu

Option 10 of the configuration menu gives the PSU SHUT DOWN VOLTAGE menu, Figure 4-21. Enter the PSU input voltage level below which the PWS100 will enter low power mode. Enter `0.0` to disable this feature (default).

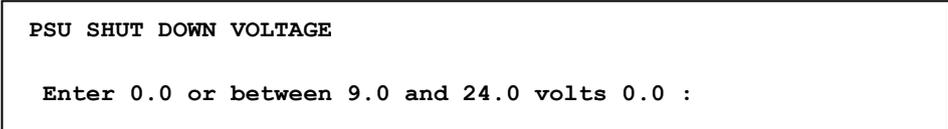


Figure 4-21. PSU shut down voltage menu

NOTE This feature is usually used to protect batteries from deep discharge. There is a hysteresis of 0.9V applied. For example, if the PWS100 goes into low power mode at 10V it will return to normal operation when the voltage rises to 10.9V. Current will be limited to about 120mA at 9V. Communications are still possible and a message “PSU voltage too low nn.n”, where nn.n is the supply voltage, will be output every 60 seconds.

A typical Campbell Scientific power supply will include a 7 Ah back-up battery as described in 3.5.7. A shut-down voltage of 11.5 V is appropriate if this is used.

Table 4-3. Configuration Defaults

Parameter	Default	Description
ID	0	Sensor ID = '0'
TRH	1	CS215 temperature and RH sensor fitted
-	0	Reserved
-	0	Reserved
Hood heater	10	Hood heater on below 10 degrees
Dew heater	2	Dew heater automatic
Output	1	STX/ETX characters applied to output
Terminal mode	0	CRC16-CCITT checking on incoming commands off
PSU shutdown	0.0	No supply voltage shutdown applied

These default settings are restored by a hardware reset (see 3.5.10).

4.4.4 Top Menu Option 5 (Password)

Choosing option 5 from the SETUP menu brings up the PASSWORD menu, Figure 4-22. Pressing enter deletes the password. To set a password type up to 10 alpha-numeric characters and press enter.

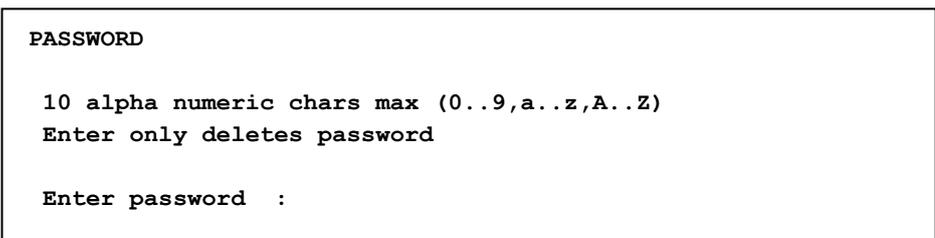


Figure 4-22 Password menu

4.4.5 Top Menu Option 6 (Weather and Alarm Parameters)

Choosing option 6 from the SETUP menu brings up the WEATHER AND ALARM PARAMETERS menu, Figure 4-23. This menu allows for the setup of the visibility range alarms, snow water content factor and the mixed precipitation thresholds.

```
WEATHER PARAMETERS

(1) visibility range alarm 1 = 5000
(2) visibility range alarm 2 = 1500
(3) visibility range alarm 3 = 500
(4) snow water content = 1.00
(5) mixed liquid & liquid precipitation threshold = 0.5
(6) mixed liquid & solid precipitation threshold = 0.1
(7) mixed solid & liquid precipitation threshold = 0.9
(8) mixed solid & solid precipitation threshold = 0.5
(9) visibility SYNOP mist RH% threshold = 95.0
(10) visibility METAR mist/haze RH% threshold = 80.0
(11) visibility METAR fog/haze RH% threshold = 95.0
(12) SYNOP snow_flake to snow_grain weighting = 1.00
(13) drizzle probability weighting = 1.00
(14) freezing drizzle probability weighting = 1.00
(15) rain probability weighting = 1.00
(16) freezing rain probability weighting = 1.00
(17) snow grain probability weighting = 1.00
(18) snow flake probability weighting = 1.00
(19) ice pellet probability weighting = 1.00
(20) hail probability weighting = 1.00
(21) graupel probability weighting = 1.00

Make a selection:
```

Figure 4-23. Weather parameters menu

There are three visibility alarms each of which is set separately by selecting 1, 2 or 3, followed by enter on the WEATHER PARAMETERS menu. Selection of one of the visibility range alarms brings up the individual alarm menu, Figure 4-24. Select an alarm range from 0 to 20 000 m. These alarms are triggered and stored in the sensor and can be output as part of a message or used as flags as part of a monitoring system.

```
VISIBILITY RANGE ALARM 1

Alarm = vis range < limit 0..20000m

Enter alarm limit 5000 :
```

Figure 4-24. Visibility range alarm menu

The snow water content scaling factor (SWCF) can be adjusted by choosing option 4 on the WEATHER PARAMETERS menu. This will bring up a line asking for a value.

Depending on atmospheric conditions likely to be encountered, a wide range of snow water content figures can be observed dependant on the bulk density of the particle. Particle bulk density depends on the structure of the particle e.g. whether it is dendritic, columnar or plate-like as the surrounding air or encapsulated air occupies some of the particle space. The conversion from a measurement of size (which in itself is not precise for irregular snowflakes) to water content can at best be considered approximate.

The PWS100 assumes a relationship between snow flake size and bulk density published in the literature (Brandes, E. A., K. Ikeda, G. Zhang, M. Schönhuber, and R. M. Rasmussen, 2007: A statistical and physical description of hydrometeor distributions in Colorado snow storms using a video disdrometer. *J. Appl. Meteor.*, **46**, 634–650). That equation and the values it assumes for other identified particle types are given in Table 4-4. The equation for snowflakes has the scaling factor for snow water content that can be adjusted to suit local conditions. Entering a value of 1 assume this relationship is correct, e.g. if the snow at the site of installation is typically more dense and wet (as is common in temperate climates) a higher scaling factor may be needed.

Table 4-4. Assumed bulk density of various particle types.

Particle Type	Bulk Density assumed
Liquid	1.0 g cm ⁻³
Graupel	0.6 g cm ⁻³
Snow grain	0.4 g cm ⁻³
Ice pellet	0.7 g cm ⁻³
Hail	0.8 g cm ⁻³
Snow Flake	SWCF* 0.178*D ^{-0.922} g cm ⁻³ (D is the flake diameter in mm)

This figure should not be confused with equivalent water to snow depth calculations which require further knowledge of packing structures, wind effects, ground temperature, ground type and a myriad of other parameters related to snow depth. The ratio of water accumulation to snow depth will be lower than the snow water content figure and is typically in the order of 0.1 (i.e. the snow pack is 10 times deeper than the water accumulation of the melted snow pack).

NOTE

Changing the snow water content parameter will also affect the determination of precipitation intensity, which is defined by water equivalent precipitation rates. See 5.6.2 and Appendix A for more details.

WEATHER PARAMETERS

- (1) visibility range alarm 1 = 5000
- (2) visibility range alarm 2 = 1500
- (3) visibility range alarm 3 = 500
- (4) snow water content = 1.00
- (5) mixed liquid & liquid precipitation threshold = 0.5
- (6) mixed liquid & solid precipitation threshold = 0.1
- (7) mixed solid & liquid precipitation threshold = 0.9
- (8) mixed solid & solid precipitation threshold = 0.5
- (9) visibility SYNOP mist RH% threshold = 95.0
- (10) visibility METAR mist/haze RH% threshold = 80.0
- (11) visibility METAR fog/haze RH% threshold = 95.0
- (12) SYNOP snow_flake to snow_grain weighting = 1.00
- (13) drizzle probability weighting = 1.00
- (14) freezing drizzle probability weighting = 1.00
- (15) rain probability weighting = 1.00
- (16) freezing rain probability weighting = 1.00
- (17) snow grain probability weighting = 1.00
- (18) snow flake probability weighting = 1.00
- (19) ice pellet probability weighting = 1.00
- (20) hail probability weighting = 1.00
- (21) graupel probability weighting = 1.00

Make a selection: 4

enter snow water content (0 to 9999) 1.00 : 0.9

Figure 4-25. Snow water content adjustment

The mixed precipitation threshold value can be adjusted by choosing options 5-8 on the WEATHER PARAMETERS menu. This will bring up a line asking for a value between 0 to 1. A value of 0 means there is no threshold for mixed precipitation – a single other type of particle in a specific event will give rise to a mixed event, therefore mixed events are highly likely; and may easily be caused by the occasional erroneous particle classification. A value of 1 means an equal number of two types will have to be observed to trigger a mixed event, therefore mixed events are highly unlikely. A setting of 0.5 means that a second precipitation type needs to be 50% or more of the most common type to be distinguished as a mixed event.

Four thresholds are given to allow maximum flexibility and to allow the sensor to be setup to match local observer practise (which varies).

Option 5 controls the threshold for mixed events between two types of liquid precipitation, e.g. rain and drizzle.

Option 6 controls the threshold for mixed events when a liquid type is the dominant particle type and a solid is the next most prevalent particle type, e.g. when it is raining and snowflakes are detected. Observers are typically more

sensitive to reporting this as a mixed event than for rain/drizzle as occasional snowflakes are easy to see.

Option 7 controls the threshold for mixed events when a solid type is the dominant particle type and a liquid is the next most prevalent particle type, e.g. when it is snowing but changing to rain.

Option 8 controls the threshold for mixed events between two types of solid precipitation, e.g. snow and snow pellets.

WEATHER PARAMETERS

- (1) visibility range alarm 1 = 5000
- (2) visibility range alarm 2 = 1500
- (3) visibility range alarm 3 = 500
- (4) snow water content = 1.00
- (5) mixed liquid & liquid precipitation threshold = 0.5
- (6) mixed liquid & solid precipitation threshold = 0.1
- (7) mixed solid & liquid precipitation threshold = 0.9
- (8) mixed solid & solid precipitation threshold = 0.5
- (9) visibility SYNOP mist RH% threshold = 95.0
- (10) visibility METAR mist/haze RH% threshold = 80.0
- (11) visibility METAR fog/haze RH% threshold = 95.0
- (12) SYNOP snow_flake to snow_grain weighting = 1.00
- (13) drizzle probability weighting = 1.00
- (14) freezing drizzle probability weighting = 1.00
- (15) rain probability weighting = 1.00
- (16) freezing rain probability weighting = 1.00
- (17) snow grain probability weighting = 1.00
- (18) snow flake probability weighting = 1.00
- (19) ice pellet probability weighting = 1.00
- (20) hail probability weighting = 1.00
- (21) graupel probability weighting = 1.00

Make a selection: 8

enter solid & solid mixed precipitation threshold (0 to 1)
0.5 :

Figure 4-26. Mixed precipitation threshold adjustment

Option 9 sets the RH threshold for mist or fog to be reported instead of haze in SYNOP messages. The default is 95%.

Option 10 sets the RH threshold for mist to be reported instead of haze in METAR messages. The default is 80%.

Option 11 sets the RH threshold for fog to be reported instead of haze if visibility is less than 1000 m in METAR messages. The default is 95%.

Option 12 sets a weighting factor for deciding whether a mixture of snow grains and snowflakes should be reported as a SYNOP code for snow or snow grains. The range is 0 to 10. If it is 0 then if any snow grains are present SYNOP code 77 will be reported. If it is set to 10 then snow will be reported unless there are an overwhelming number of snow grains. The default is 1.0. Changing this parameter

has no effect on reported particle type distribution or calculated accumulations or intensities.

Options 13 to 21 set a probability weighting for each type of particle the PWS100 will use in conjunction with other parameters in its fuzzy logic to determine particle type. This will affect the particle type distribution and calculations of accumulation or intensity. The range is 0.0 – 1.0. If a probability weighting is set to 0.0 then that particle type will never be reported and instead be allocated to another possible particle or as an unknown. Calculations of accumulation, intensity and SYNOP, METAR and NWS codes will all be affected.

NOTE

Setting the probability weighting to other than defaults can have a major effect on the performance of the PWS100. If in any doubt, please contact Campbell Scientific.

4.4.6 Top Menu Option 7 (Terminal)

Choosing option 7 from the SETUP menu brings up the TERMINAL screen, Figure 4-27. Pressing any key brings up the terminal as described in Section 4.3.

```

TERMINAL ACTIVE

Type 'menu' or 'close' when done.
For help on terminal commands see user manual

Any key to continue....

```

Figure 4-27. Terminal active screen

4.4.7 Top Menu Option 8 (Info)

Choosing option 8 from the SETUP menu brings up the INFORMATION menu, Figure 4-28. This shows various parameters for the PWS100 system. The software version shows the current operating system number which may be required in communications with Campbell Scientific about the PWS100. The watchdog shows errors that have occurred since the installation of the operating system or a hardware reset. The SDI-12 values of temperature and relative humidity will be -999.00 if no such information is available such as when no probe is connected to the SDI-12 port. The diagnostic mode shows two values. The first value is the flag for the fuzzy diagnostic mode (0 or 1) (see '4.6.2 Retrieving Historical Data' for more information). The second value indicates the connection status of the calibration unit, 0 shows that the unit is not connected and 1 shows that it is connected.

```
INFORMATION SN 1069

Hardware ver          4
DSP ver              6
Software ver         007628-06d
Watchdog             0
Battery V, SHDN V    13.0 0.0
Pws Fault            0
TRH probe type       1
Temperature           23.23
RH%                  49.91
Hood temp            25.0
Upper led temp       37.7
Lower led temp       38.0
Laser temp           25.3
Upper detector temp  29.2
Lower detector temp  28.8
Laser current        53.6
Visibility (not corrected) 12
Diagnostic mode      0 0
Output, Terminal mode 1 0
Alarms               1110000000000000 0

Any key to continue....
```

Figure 4-28. Information menu

4.4.8 Top Menu Option 9 (Done)

Choosing option 9 from the SETUP menu brings up the DONE menu, Figure 4-29. Here changes made can be saved before quitting (option 1) or lost before quitting (option 2). Alternatively option 0 returns to the main menu.

```
DONE

(1) save changes & quit
(2) quit & lose changes
(0) main menu

Make a selection:
```

Figure 4-29. Done menu

4.5 Message Related Commands

Messages can be set for a variety of output types, including fixed standard types and user defined types. The system can be set up to send automated messages at user defined intervals, or can be used as a user polled system.

4.5.1 Automatic and Polled Message Sending

Whilst the command mode is closed, the PWS100 will operate by sending data output as set by the user in either automatic or polled modes (see '4.3.3 Message Polling' for a description of the manual data polling command).

To define the output parameters and fields, use the MSET command with the *Message_ID*, *Message_Interval*, *Message_Mode* and *Message_Fields* parameters as follows:

```
MSET Message_ID Message_Interval Message_Mode Message_Fields
↵
```

e.g. MSET 0 3600 0 105 106↵

In order to ensure that output is as required, the *Message_ID*, *Message_Interval*, *Message_Mode* and *Message_Fields* parameters must be defined.

Three *Message_IDs* 0, 1 and 2 can be defined to provide the scope for different output types to be given at different time intervals, e.g. *Message_ID* 0 can be defined with a 15 second interval, whereas *Message_ID* 1 can have a 60 second interval. Then every 15 seconds the message defined by *Message_ID* 0 will be output, additionally every 60 seconds the message defined by *Message_ID* 1 will be output. Each *Message_ID* should be defined as a separate command.

The *Message_Interval* parameter must also be defined from 0 second to 32767 seconds which is the rate at which the system will display the output message and the period which statistics are calculated over (the factory and reset default for ID 0 is 60 seconds). If the *Message_Interval* is 0 then it will set the message polling mode (see '4.3.3 Message Polling' for a description of the manual data polling command). Setting the *Message_interval* to less than 10 seconds will result in repeated data due to the ten seconds measurement cycle in the sensor (see Section 5.5).

The *Message_Mode* defines special functions and can be set to either 0 or 1. Setting *Message_Mode* to 0 allows output to the serial port and stores the 'MSET' data history. Setting the *Message_Mode* to 1 prevents the output to the serial port but stores the 'MSET' data. For message polling mode the *Message_Mode* should be set to 0.

By default (factory set and after reset of the system) the *Message_Field* parameter for *message_ID* 0 is set up as described in Section 4.4.1.1 which is a combination of message types. If no message field parameters are set, then no output will be given, thus a particular ID can be cleared by using the above method.

There are many fixed message types which are detailed elsewhere in Sections 4.4.1.1 to 4.4.1.36. Table 4-2 defines the possible message field parameters.

To view all current user messages set then leave all parameters blank as below:

```
MSET↵
```

The system will then output the current message in the form:

```
Message_ID Message_Interval Message_Mode Message_Fields
....
....
```

To view only the *Message_ID* of interest then leave all parameters blank apart from *Message_ID* as follows:

MSET *Message_ID* ↵

The system will then output the current message for that *Message_ID* in the form:

Message_ID Message_Interval Message_Mode Message_Fields

e.g. for ID 0 set with a 10 second interval, serial port output and parameters 105 and 106 the output will be: 0 10 0 105 106

Note that the MSET command will output the parameters for all of the *message_IDs* set. e.g if additional to ID 0 set above, ID 1 is set with a time interval of 30 seconds, serial port output and with parameter 104 set the output will be:

0 10 0 105 106
1 30 0 104

To set manual polling mode the MSET command should be of the form:

MSET *Message_ID* 0 0 *Message_Fields* ↵

e.g. MSET 0 0 0 105 106 ↵

NOTE

A minimum message interval of 10 seconds can be set for all types of message field output. If a time is set less than 10 seconds data values will be repeated (see Section 5.5)

4.5.2 Retrieving Historical Data

Historical data can be output by using the HDATA command. This has a parameter, *period* which is the number of seconds to output going back in history. The most recent message will be output first going back *period* seconds into history. The command is:

HDATA *period* ↵

If *period* is larger than the number of seconds stored, then only the messages stored will be output. If no value is provided for *period* then all of the stored historical data will be output. Note that this command outputs particle by particle data (size, velocity, volume).

This function is provided for initial setup and diagnosis. It is not intended for long term use as it has several limitations, which include the amount of data that can be stored is limited by the system memory (see specifications) and no data is stored whilst the system is in the terminal or system menu.

The HDATA command outputs this format:

Timestamp (seconds), datatype, value a, value b, value c

The datatype can range from 0 to 1015 currently. Low value numbers, ranging from 0 to 99, indicate it is particle data with the coding:

- 0 Drizzle
- 1 Freezing drizzle
- 2 Rain
- 3 Freezing rain
- 4 Snow grain

5	Snowflake
6	Ice pellets
7	Hail
8	Graupel
90	Error
99	Unknown particle type

For the above value a, value b and value c relate to size (diameter in mm), velocity (ms^{-1}) and volume (m^3).

Higher codes indicate this is another type of data (stored every 10 seconds) where values a, b, and c have different meanings as indicated below:

1000	Time stamp (in seconds from 1/1/2007)
1001	Temperature, RH and wetbulb temperature
1002	Visibility data (upper, lower and calibrated mV sample)
1010	Wetness grid value
1011	Error codes (temperature / RH error code, wetness error code)
1012	Aux sensor value

Extra information about each particle can be given from the sensor if the sensor is set up to store such extra information. The command to enable the storage of this extra information is:

FUZZYDIAG 1.␣

Once this command is given then the following information will also be stored for each particle observed:

1013 Minimum signal peak, pedestal height and signal to pedestal ratio for detector 1

1014 Minimum signal peak, pedestal height and signal to pedestal ratio for detector 2

1015 Polycrystalline flag (1 for polycrystalline, 0 for not polycrystalline)

To disable the storage of the above extra information (which if not required frees up more memory to store more history of particles) use the command:

FUZZYDIAG 0.␣

This data is part of the logical processing of each particle as the signal to pedestal ratio value is used in one of the fuzzy logic tables to help determine particle type. It has been shown from studies of the PWS100 signal output that snow grains and snowflakes exhibit much smaller ratios than for drizzle and rain. This is only possible due to the structured nature of the detection volume and the fact that polycrystalline particles such as snow exhibit refraction and reflection of light from multiple scattering sites as opposed to mainly refraction from what is effectively one scattering site for liquid particles.

In terms of data storage with FUZZYDIAG enabled 5 records are used every 10 seconds (1001, 1002, 1010, 1011 and 1012) plus 4 records for every processed particle that passes through the volume (0-99, 1013, 1014 and 1015). For example if 20 particles per second are processed then 80.5 records are used per second. Since 1000000 records can be stored in the LPA only 1242 seconds worth of data can be stored as opposed to 4878 seconds with FUZZYDIAG disabled. FUZZYDIAG will be disabled by default.

NOTE Three values are always given in the HDATA output however if the particular coded output has less than three parameters the remaining values will be zero, 1010 and 1012 are examples of this.

4.5.3 Viewing Data Output on the Command Line

A number of records (defined by the number n) of uncollected historic m data (message data) can be output to the command line in ASCII text format in exactly the same format as defined in the messages. To do this type:

```
HMDATA n ↵
```

If the parameter n is omitted then all uncollected data is output. Any output message of either interval or polled are stored in a large final output buffer and any uncollected data can be collected using this command. See Section 4.5.4 for the preferred method of collecting this data.

4.5.4 Collection of Data in Text File Format

A number of records (defined by the number n) of uncollected historic m data (message data) can be collected using Xmodem 1K protocol. To do this type the following on the command line:

```
XHMDATA n ↵
```

If the parameter n is omitted then all uncollected data is collected. Any output message of either interval or polled are stored in a large final output buffer and any uncollected data can be collected using this command. This command would normally be used for scheduled collection using a computer. The file downloaded is a text file with messages in exactly the same format as defined in the messages.

4.6 Weather Related Commands

4.6.1 Setting and Viewing Weather Parameters

Visibility alarm limit parameters, a snow water content parameter and a mixed precipitation threshold parameter can be viewed using the SETPARAM command. To view these parameters, type:

```
SETPARAM ↵
```

The PWS100 will then display three visibility alarm limit parameters, the snow water content parameter and the mixed precipitation threshold parameters (4 in total) on screen in the following format:

```
vislim1 vislim2 vislim3 snowwater mixthreshold
```

```
vislim1 = visibility limit alarm 1 limit (Default 5Km)
```

```
vislim2 = visibility limit alarm 2 limit (Default 1.5Km)
```

```
vislim3 = visibility limit alarm 3 limit (Default 0.5Km)
```

```
snowwater = snow water content (Default 1.0)
```

```
mixthresholds 1..4 = mixed precipitation thresholds (4 values)
```

To set the adjustable visibility limit parameters, type:

```
SETPARAM vislim1 vislim2 vislim3 snowwater mixthreshold 1..4↵
```

The system will respond by displaying the new settings as described above with SETPARAM↵ command. Please see Section 4.4.5 for a description of the mixthresholds and the default values.

4.6.2 Receiving data from remote sensors

Instead of using data from sensors directly connected to the PWS100, it can be sent data from remote sources, e.g. a different temperature and humidity sensor connected to the controlling system/datalogger. To do this the TRH sensor type needs to be changed to the remote sensor option and the data sent to the PWS100 by the controlling system at regular intervals, e.g every minute. The RSENSOR command is used as follows:

```
RSENSOR Pws_Id Temperature Humidity ↵
```

Temperature should be in degrees Celsius and humidity as a percent (0-100). The PWS100 will use the last values sent to it for its particle discrimination decisions.

4.7 System Configuration Commands

4.7.1 Setting System Parameters

The system configuration parameters can be viewed using the CONFIG command and those capable of being set by the user are set using the SETCONFIG command. To view the system configuration parameters, type:

```
CONFIG ↵
```

The PWS100 will then display the configuration parameters on screen in the following format:

```
Date and Time
PWS100 product identification
Serial Number
Hardware Version
Software Version
PWS100 ID
Serial Baud Rate
Interface type [RS232 / RS485] and duplex [FULL / HALF]
Auxiliary Sensor ID 1, 2...
Hood and Dew heater settings
Overrun error count
Output mode Terminal mode
Diagnostic mode
Watchdog error count
```

Some of these parameters are set using other commands, such as the time and date being set using the TIME command and the various message output parameters set using the MSET command. Other configuration parameters will only be updated with an OS change.

An example of the output given from the CONFIG command is given below:

```
23/2/2007 16:30:01
```

```

PWS100
SN-9999
HW4
OS 007628-02c
PWS_ID 0
Baud 115200
RS232 Full Duplex
TRH 1 Wetness 0 Aux 0
Hood 10 Dew 2
OR_ERR 0
Output_Mode 1 Terminal Mode 0
Diag 0 0
WD 0
    
```

Using the SETCONFIG command will adjust system configuration parameters. SETCONFIG allows you to change the PWS100 ID and the sensor types.

To view the current SETCONFIG parameters without changing them use SETCONFIG.J.

To change the parameters use the following command:

```

SETCONFIG pws100_ID TRH_Sensor Reserved Reserved Hood_Set Dew_Set
Output_Mode Terminal_mode Psu_shutdown_voltage
    
```

The *pws100_ID* is a number from 0 to 99. This is the effectively the station address and is required on any communication with the PWS100. On a network with more than one PWS100 the ID must be set different for each station. The default factory *pws100_ID* is zero (0).

Currently three other sensors types can be connected to the PWS100. The sensor configured is changed by parameters *TRH_Sensor* (Temperature and RH%), *Wetness_Sensor* & *Aux_Sensor*. The Wetness and Aux sensors currently should always set to zero. Section 5 gives further details of how to connect optional sensors. Table 4-5 gives the IDs of TRH_ sensor types. To add these to the system put the appropriate sensor ID to the appropriate sensor parameter.

Table 4-5. TRH sensor types.

ID	Sensor Type
0	No Sensor
1	CS-215 Temperature RH%
2	Remote Temperature and RH
3-99	Reserved for future use

The *Hood_Set* value sets the temperature at which the hood heaters are set to function at and can be set to 0 (off) or a temperature between 10 and 50°C. The *Dew_Set* value sets the temperature at which the internal dew heaters are set to function at and can be 0 (off), 1 (on) or 2 (auto).

The *Output_Mode* value relates to the use of packetized output. The message framing is done by STX and ETX (start and end) delimiters. The *Output_Mode*

values available are 0 = No STX / ETX or 1 = STX / ETX. The default is 1 = Send STX / ETX. The use of STX and ETX is mainly used in multidrop systems with many sensors on one RS-485 bus or to aid software development.

4.8 Maintenance Commands

4.8.1 Loading a New OS

A new OS can be loaded into the PWS100. A new OS may be developed and provided by Campbell Scientific to improve the functionality of the system. The system will check that the OS loaded is valid, however the user should ensure that the OS is the latest OS provided by Campbell Scientific.

Save the relevant new OS file provided by Campbell Scientific in a known directory on the PC used for communications to the PWS100.

A new operating system can be loaded with the Present Weather Viewer program, using the option in the tools menu (see the help system for this) or it can be loaded using a terminal program as described below.

With the PWS100 then connected to the PC use the following command to load a new OS:

```
LOADOS ↵
```

The system will now respond by attempting to upload the new OS using Xmodem. Select 'Transfer' on the pull down menu and then select 'Send File'. Select the Xmodem 1k protocol and select the OS file using the 'Browse' button. Once selected press the 'Send' button. The Xmodem file send dialogue box then opens displaying download progress and will close automatically once the download has completed. The OS can be seen to be being installed by a series of memory block erasures, followed by writing of the OS and verification of the OS. The user is then prompted to wait for 5 seconds for the OS to restart. The new OS is now installed.

WARNING

Do not remove power to the unit whilst the OS is being installed as this will cause the unit to malfunction.

NOTE

Terminal PWS100 OS upload and data collection will not work when an NL100 is used in the communications link.

4.8.2 Running a Diagnostic Test

To run a DIAG test first the fields need to be set by using the DIAGSET command as below:

```
DIAGSET Stats_Period Diagnostic_Fields ↵
```

The *Stats_Period* parameter is the period in seconds that statistics are calculated over ranging from 0 to 32767.

The *Diagnostic_Fields* parameter is a list of fields required as listed in Table 4-2. There is no restriction on the type or combination of fields that can be output.

If DIAGSET is executed with *Stats_Period* & *Diagnostic_Fields* blank then the diagnostic field parameters will be output without changes.

Note: the diagnostic message type is 9000 and this is can be seen with both the outputs of DIAGSET and DIAG commands.

To run diagnostic tests use the DIAG command as below:

DIAG *Output_Rate* ↵

Output_Rate is the rate in seconds ranging from 0 to 32767. If *Output_Rate* is not entered then the *Output_Rate* will be set the same as the *Stats_Period*.

e.g. DIAG 10 ↵

In the example above the PWS100 will output the diagnostic information with statistics calculated over a period defined by the DIAGSET command at an output rate of 10 seconds. This information will continue to be displayed until the key combination 'Ctrl + C' is pressed, or after 10 minutes has passed.

4.8.3 Running the Calibration

The PWS100 calibration can be checked and adjusted using the optional PWC100 PWS Calibrator. Please refer to the PWC100 manual for further details of operation of the PWC100 and mounting of the calibrator on the sensor body.

It is possible to carry out a simple visibility only calibration using the PVISC100 visibility calibrator, part number 010443 (included in the PWC100 or purchased separately. This is described in Section 4.4.3.

4.8.4 Rotating the Calibration Disc

The command RUNDISC *n* will start the disc of the PWS Calibrator (if connected) rotating at a speed $n = \text{ms}^{-1}$. To start the disc spinning type the following:

RUNDISC *n* ↵

The user can then use this to test or demonstrate the PWS functions. Using the command RUNDISC without any parameter, or $n = 0.0$ will stop the disc. *n* can be anything between 0.0 and 7.0.

4.9 Other Commands

4.9.1 Setting the Time and Date

The time and date of the system can be observed by using the TIME command as follows, note the set time could drift up to +/- 14 seconds a day:

TIME ↵
yyyy/mm/dd hh:mm:ss

To change the system time and date then the command requires the time and date in the correct format as follows:

TIME *yyyy/mm/dd hh:mm:ss* ↵

Where, in the order shown in the command above, *yyyy* is the year, *mm* is the month of the year, *dd* is the day of the month, *hh* are the hours (24 hour clock), *mm* are the minutes, *ss* are the seconds. Leading zeros on the values are not

necessary however the colons (:) and forward slashes (/) are required and a space is required between the day and the hour.

It is possible to set just the date or the time independently of the other. To set just the date without altering the time the following should be used:

```
TIME yyyy/mm/dd↵
```

To set the time without the date being altered the following should be used:

```
TIME hh:mm:ss↵
```

4.9.2 Resetting the System

A “soft” system reset can be done by using the RESET command as follows:

```
RESET↵
```

This will terminate all current measurements and reset the system. The time, date and calibration values will be maintained, but all other user enterable data are lost and will need to be input again as required.

If a problem is found with the sensor first try power cycling the sensor. A soft reset is the next level of debugging and should be tried before using a hardware reset (see switch settings).

4.9.3 Status

The command STATUS↵ displays system status information similar to that in Figure 4-30 below.

```
PWS>status
INFORMATION  SN 1069

Hardware ver           4
DSP ver                6
Software ver          007628-07
Watchdog               0
Battery V, SHDN V     15.2 0.0
Pws Fault              0
TRH probe type        1
Temperature            -999.00
RH%                   -999.00
Hood temp              24.2
Upper led temp         39.2
Lower led temp         39.6
Laser temp             24.6
Upper detector temp    28.6
Lower detector temp    28.3
Laser current          57.5
Visibility (not corrected) 15798
Diagnostic mode        0 0
Output, Terminal mode 1 0
Alarms                 0000000000000000 0
```

Figure 4-30. System status information

In this example temperature and RH% are -999 because no external t/RH sensor is attached and no T/RH data is available to the PWS100.

The alarm characters are interpreted as follows:

The first 16 characters are the same as the message field 24, alarms, (see 4.4.1.8). The last character is a fault code as follows: 0 = No Fault, 1 = laser hood thermistor, 2 = laser thermistor, 3 = lower led thermistor, 4 = lower detector thermistor, 5 = upper led thermistor, 6 = upper detector thermistor, 7 = laser dirty window, 8 = battery voltage, 9 = upper detector DC, 10 = lower detector DC, 11 = auto calibration secondary offset, 12 = auto calibration primary offset, 13 = battery voltage, 14 = upper dirty window, 15 = lower dirty window, 16 = laser dirty window, 17 and 18 = laser current.

4.10 Connecting the PWS100 to a Datalogger

4.10.1 Connections

The PWS100 can be connected to a datalogger's RS232 port using the supplied RS-232 cable with a null modem between the PWS100 and the datalogger. The connections should adhere to the EIA232F standard for RS-232 communications. If the supplied 9 pin D-connector is removed to connect to a device without a suitable socket for the D-connector, e.g. to COM1..4 on the terminal blocks of the datalogger, then connect using the information supplied in Table 3-1. Please make sure that the RTS/CTS lines are connected correctly when making up this cable as no data will be transmitted otherwise. Normally these lines should be connected together in the PWS enclosure or joined at the end of the cable, as it is not necessary to use handshaking with a Campbell Scientific datalogger.

4.10.2 Example Logger Programs

Prior to writing a data logging program whether it be for a Campbell logger or another system it is important to consider the issue of whether the sensor is to be set to automatically transmit the data at a given interval and the logger capture it OR the logging system poll the sensor based upon the loggers time base.

The automatic transmission system appears to be easier and may be the only way to work where several systems need to listen in and pick up data from one sensor. However, there will always be issues with synchronising the data transmitted by the sensor and that stored alongside it in the logging system. The main cause of these problems is the relative time drift between the sensor and logging system. The simplest issue this causes is the timestamp from the sensor will drift away from the logger, unless regularly corrected and also the data output from the sensor will relate to different times in the logger, e.g. the sensor may output anywhere within the loggers' minute interval if set to one minute output interval. More noticeable issues are that, depending on the relative gains or losses of the two clocks that the logger will over time either receive an extra transmission from the sensor or not get a transmission from the sensor in a given period. Apart from accepting this as being inevitable the only solution to this is to get the sensor to output more frequently than you need the logger to receive data and have the logging system work with the latest transmission, but this is not always ideal or possible.

Polling the sensor for data gives full control of the timing of measurements to the logging system, as with the PWS100 it can be asked to output a message for a given time up until the instant the poll command is issued. The PWS100 processes the data in its buffer for that period and generates the message "on the fly". Apart

from needing both transmit and receive connections to the logger the only disadvantage of this technique is there may be a slight delay (typically less than one second) whilst the PWS100 prepares the message in response to the poll command.

Two simple example programs for a CR1000 Campbell Scientific datalogger are given below. A more powerful, documented program that includes advanced setup, CRC checks, etc, can be downloaded from:

<http://www.campbellsci.co.uk/downloads>

The following is an example program for the Campbell Scientific CR1000 datalogger using automated output settings (see Section 4.6.1). Note that the aliases are set for the output as defined in the program, these should be altered to suit the individual outputs selected. The PWS100 outputs can be set manually or by the command line from the logger – “MSET 0 60 0 49 21 24 40 41 151”.

```
'CR1000 Series Datalogger
'Campbell Scientific Ltd. PWS100 Present Weather Sensor
'Example of data capture in a single message output
'automatically by a sensor connected to COM1 on the logger

'Declare General Variables
Public Temp, PWS_Bytes

'Incoming PWS100 Data buffer
Public InString As String * 500

'Final PWS100 Data - define the array large enough to match the
'number of fields in the message
Public PWS100data(11)
'Define aliases so the results are easier to identify
'Need to match the fields selected in the message
Alias PWS100data(1) = MessageID
Alias PWS100data(2) = PWSID
Alias PWS100data(3) = Visibility
Alias PWS100data(4) = PWS
Alias PWS100data(5) = NWS
Alias PWS100data(6) = Intensity
Alias PWS100data(7) = Accumulation
Alias PWS100data(8)= DayCount
Alias PWS100data(9) = Hour
Alias PWS100data(10) = Minute
Alias PWS100data(11) = Second

'Declare Constants
Const STX = &H02
Const ETX = &H03

DataTable (PWS100,True,-1)
    Sample (11,PWS100data(),IEEE4)
EndTable

'Main Program
BeginProg

'Open Serial Port to the PWS100
SerialOpen (Com1,115200,3,0,10000)
```

```

'Commands can be included here to setup the
'sensor if it has not been preconfigured

Scan (60,Sec,0,0)

'Read the data using the STX and ETX characters as delimiters
'If a whole message is not in the serial buffer this will
'store "NAN" in the string
SerialInRecord(COM1,InString,STX,0,ETX,PWS_Bytes,01)
'If a full string has been read then parse the data and store it
If PWS_Bytes>0 Then
    SplitStr (PWS100data(),InString," ",11,0)
    CallTable PWS100
EndIf
NextScan

EndProg

```

The following is an example program for the Campbell Scientific CR1000 datalogger using polled output settings (see Section 4.6.1). The PWS100 outputs can be set manually or by the command line from the logger – “MSET 0 0 0 49 21 24 40 41 151”.

```

'CR1000 Series Datalogger
'Campbell Scientific Ltd. PWS100 Present Weather Sensor
'Example of data capture in a single message that is polled
'for by the logger. The sensor is connected to COM1

'Declare variables
'Incoming PWS100 Data buffer
Public InString As String * 500

'Final PWS100 Data - define the array large enough to match the
'number of fields in the message
Public PWS100data(11)
'Define aliases so the results are easier to identify
'Need to match the fields selected in the message
Alias PWS100data(1) = MessageID
Alias PWS100data(2) = PWSID
Alias PWS100data(3) = Visibility
Alias PWS100data(4) = PWS
Alias PWS100data(5) = NWS
Alias PWS100data(6) = Intensity
Alias PWS100data(7) = Accumulation
Alias PWS100data(8)= DayCount
Alias PWS100data(9) = Hour
Alias PWS100data(10) = Minute
Alias PWS100data(11) = Second

'Declare Constants
Const CR = CHR(13)
Const LF = CHR(10)

```

```
DataTable (PWS100,True,-1)
  Sample (11,PWS100data(),IEEE4)
EndTable

'Main Program
BeginProg

'Open Serial Port to the PWS100
SerialOpen (Com1,115200,3,0,10000)

'Commands can be included here to setup the sensor
'if it has not been preconfigured
Scan (60,Sec,0,0)
  'Poll for message 0 from the PWS100 using msend
  'In this case getting a message for the last 60 s of data
  'First flush the buffer
  SerialFlush (Com1)
  SerialOut (Com1,"msend 0 60 0" & CR,"",0,0)

  'Read in the data waiting for up to two seconds
  'for the response
  SerialIn (InString,Com1,200,LF,2000)
  'If we received something parse the data and store
  If Len(InString) >0 Then
    SplitStr (PWS100data(),InString," ",11,0)
    CallTable PWS100
  EndIf
NextScan
EndProg
```


Section 5. Functional Description

5.1 General

The PWS100 Present Weather Sensor is an optical sensor using the best of scatter meter and disdrometer techniques to give accurate analysis of weather conditions including precipitation classification, precipitation intensity, drop size distributions and visibility range.

Visibility is measured using the forward scatter technique, which gives an estimation of the meteorological optical range (MOR). The amount of scatter detected at the sensor heads is proportional to the visibility for small fog particles. For larger particles, which are detected as various forms of precipitation, the PWS100 is able to give estimates of visibility using its particle discrimination as a calibration factor.

Precipitation is detected using an optical technique, originally developed as a method for the measurement of the size and velocity of fine particles in sprays, which has been modified to make it applicable to the analysis of precipitation. Individual precipitation particles are analysed using the optical arrangement described in Section 5.2 'Optical Measurement'. As well as the size and velocity measurements, the instrument also looks at the structure of the signal to provide further parameters for particle classification. From the measurements, the volume of particles (or water equivalent volume in the case of snow) is calculated which gives a measurement of precipitation intensity. Drop size distributions can be determined from data collected over set periods.

5.2 Optical Measurement

5.2.1 Optical Arrangement

The optical design is such that the system outputs a number of evenly spaced horizontal light sheets that are parallel to each other in order to define a structured volume that is consistent. The two sensors are at angles of 20° to the optic axis of the light sheet generator (laser unit), one deviated through 20° in the horizontal plane, the other 20° in the vertical plane. This defines a good-sized volume in which to detect particles of all sizes and provide accurate statistical analysis of events. With the PWS100 optical arrangement good signal strength from all types of particle (drizzle, rain, snow, sleet, hail etc...) is observed.

The laser unit, as shown in Figure 5-1, comprises a laser diode and a number of optical elements to produce the light sheet pattern as shown in Figure 5-2, which extends some distance whilst maintaining a parallel sheet distribution. Over the volume length there is negligible distortion to the light sheets.

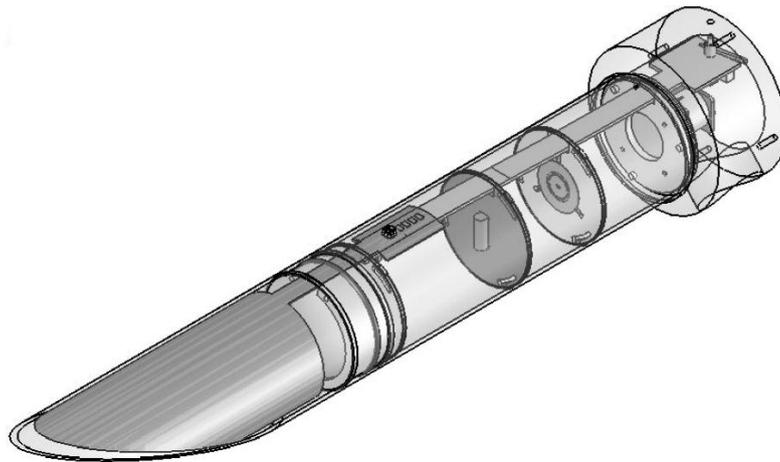


Figure 5-1. Laser unit

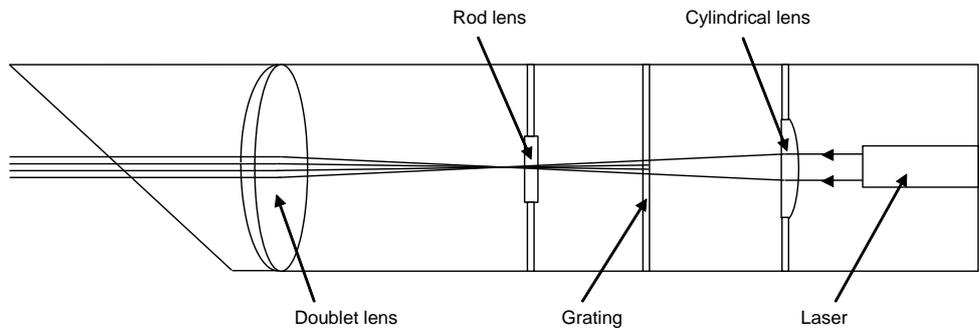


Figure 5-2. Laser unit showing light sheet production (not to scale).

The sensor units as shown in Figure 5-3, comprise a lens, a filter tuned to the wavelength of the laser output and a photodiode placed at the back focal length of the lens with suitable amplification electronics. This photodiode then accepts light from the detection volume over a finite range of angles as shown in Figure 5-4.

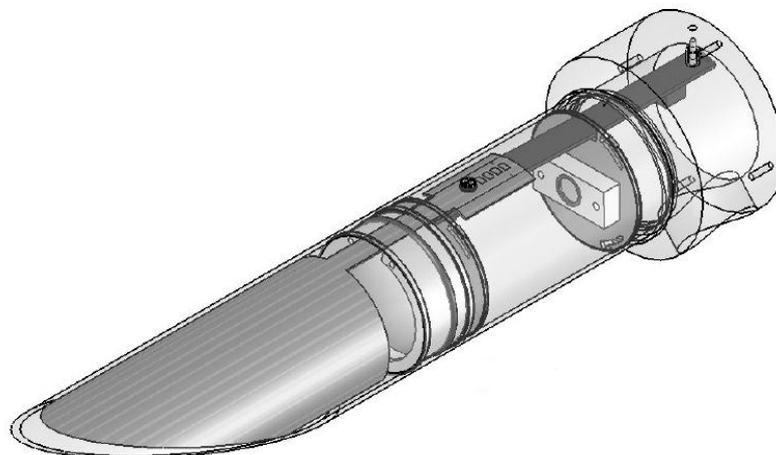


Figure 5-3. Sensor unit

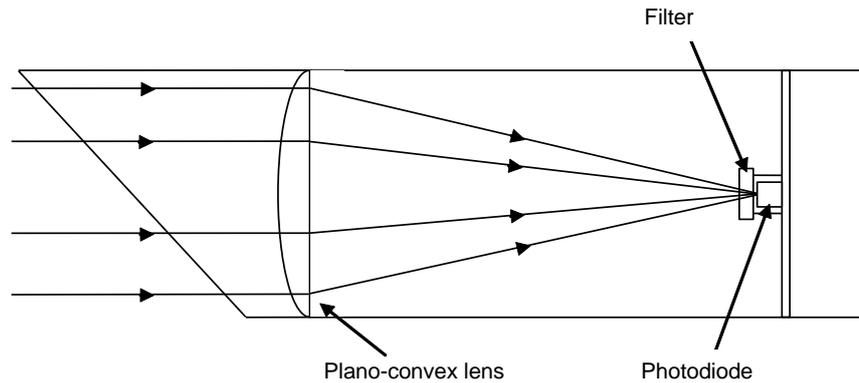


Figure 5-4. Sensor unit showing light path extents (not to scale)

5.3 Additional Sensor Connections

Although it is possible to use the PWS100 as a standalone present weather sensor, its ability to distinguish particle types is improved when certain other sensors are connected to the unit. In particular a temperature and RH probe provides the system with more discriminating parameters, ensuring that solid and liquid precipitation are more clearly identified. Though general statistics would be enough on most occasions to determine particle types over minute or hour long averaging periods, individual particle analysis will benefit from these extra temperature, humidity and corresponding wet bulb temperature parameters being incorporated into the classification algorithms. The standard PWS100 can be ordered with a CS215 temperature and relative humidity probe, complete with 0.5 m lead terminating in a LEMO connector, or temperature and RH values can be sent to the PWS100 from the controlling system/datalogger.

5.3.1 Using a CS215 on the PWS100

The CS215 temperature and RH probe should be connected directly to one of the free SDI-12 connectors at the base of the DSP enclosure as shown in Figure 3-8. The CS215 is mounted inside a radiation shield and needs to be mounted away from the actual detection volume of the PWS100 in order to avoid any turbulence effects in the volume that could give rise to inaccuracies in the measurement of speed and size of particles. The bracket for the CS215 should therefore point in the opposite direction to the mounted PWS100. Adding a CS215 improves the precipitation type algorithm by adding three further parameters, temperature, relative humidity and wet bulb temperature. Though wetbulb temperature is derived from other parameters, there is plenty of evidence showing its relationship with the precipitation type and thus it becomes a useful parameter within itself. If no CS215 is connected then an internal, less accurate temperature measurement is used and the sensor assumes the relative humidity is 100%. The removal of the CS215 does not prevent the unit from working, but can lead to less accurate particle classifications.

Note the CS215 should be “recalibrated” at the recommended interval, normally every year, to ensure accurate measurements from it and the PWS100. In the case of the CS215 this is most easily achieved by replacing the sensor element in situ with a new one.

5.3.2 Using Other Sensors on the PWS100

Starting from operating system version 4, the PWS100 can accept temperature and humidity values sent from the controlling system, which might have access to data from another T and RH sensor. This is enabled by selected the remote TRH sensor type in the configuration menu and the remote system sending the data (space separated) using the RSENSOR terminal command.

5.4 PWS100 Control Unit

The PWS100 control unit, shown in Figure 5-5 as a block diagram, is a custom designed DSP board comprising a DSP, memory, timing circuits and analogue to digital converter.

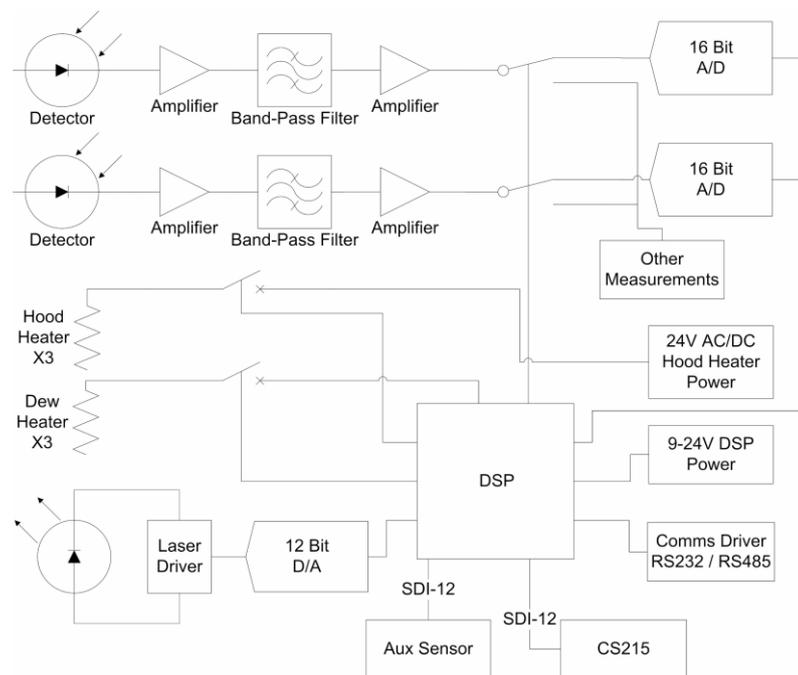


Figure 5-5. Block diagram of PWS100 Control Unit

The DSP board controls all of the functions of the system, including switching of heaters when the temperature sensors in each head pass certain thresholds, laser modulation, signal analysis and communications. The on board memory holds the program code, data tables and data for statistical manipulation.

5.5 Measurement Signal Processing

The PWS100 has two phases of operation based around a ten second cycle. The main phase is run for nine seconds out of every ten during which it continuously captures data from the optical detectors and processes the data to analyse for particles. The second phase, which runs in the remaining second is used for making measurements from other sensors both within the sensor itself and from the external sensors. Precipitation amounts and rates are corrected for the 90% particle duty cycle, whilst counts of particles are not. As a result of this ten second cycle statistical data are only updated every ten seconds.

The algorithm descriptions in this user guide give details as to how particles are detected and used to give the outputs relevant to present weather monitoring.

5.6 Algorithm Description

5.6.1 Detecting and Classifying Precipitation

The PWS100 comprises one laser head and two detector heads. Each of the detector heads is 20° off axis to the laser unit axis, one in the horizontal plane, the other in the vertical plane. It has a structured detection volume consisting of four sheets of light each 0.4 mm in depth with 0.4 mm spacing. The area of detection is approximately 40 cm² as defined by the overlap of the two detectors.

When a particle passes through the four light sheets it provides a signal characteristic of the particle type and provides information on the velocity of the particle.

Water particles give well defined signal peaks as they pass through the detection layers. The time between these peaks gives the fall speed of the particle. Because the dominant scattering mechanism for water is refraction there is a delay between the peaks detected by the vertical and horizontal detectors. This offset represents the time taken for a drop to fall a known fraction of its diameter and hence, combined with the fall speed, gives its diameter. As a particle falls through the detection volume the signal peaks are superimposed on a signal 'pedestal' as scattering will not be totally due to the above mechanism.

The structure of the particle is to some degree given by analysis of the signal peak to signal pedestal ratio. The signal pedestal is higher for particles with higher crystallinity and therefore more scattering sites. Particles of water have almost no pedestal compared to the peak signal value whereas snow can have large pedestals compared to the peak signal value.

Particles for which the pedestal is very large (e.g. snow) may have their size measured by the analysis of particle transit time or signal amplitude (in the same way that present weather sensors without structured detection volumes measure particle size).

Analysis of separate snow and rain/drizzle events has shown that there is very little overlap in the signal peak to pedestal peak ratio for the solid and liquid particles, though drizzle values extend further towards the snow values and snow grains extend further towards the liquid precipitation values, whilst the larger rain and snowflakes remain almost entirely separate. This is shown graphically in Figure 5-6 which represents two separate events one comprising snowflakes and snow grains (particle count on the left vertical axis) and one representing a mixed drizzle and rain event (particle count on the right vertical axis). This particular differentiator, only obtainable because the PWS100 has a structured detection volume, is extremely useful in the fuzzy logic processing as described below and further in Section 5.6.4.1.

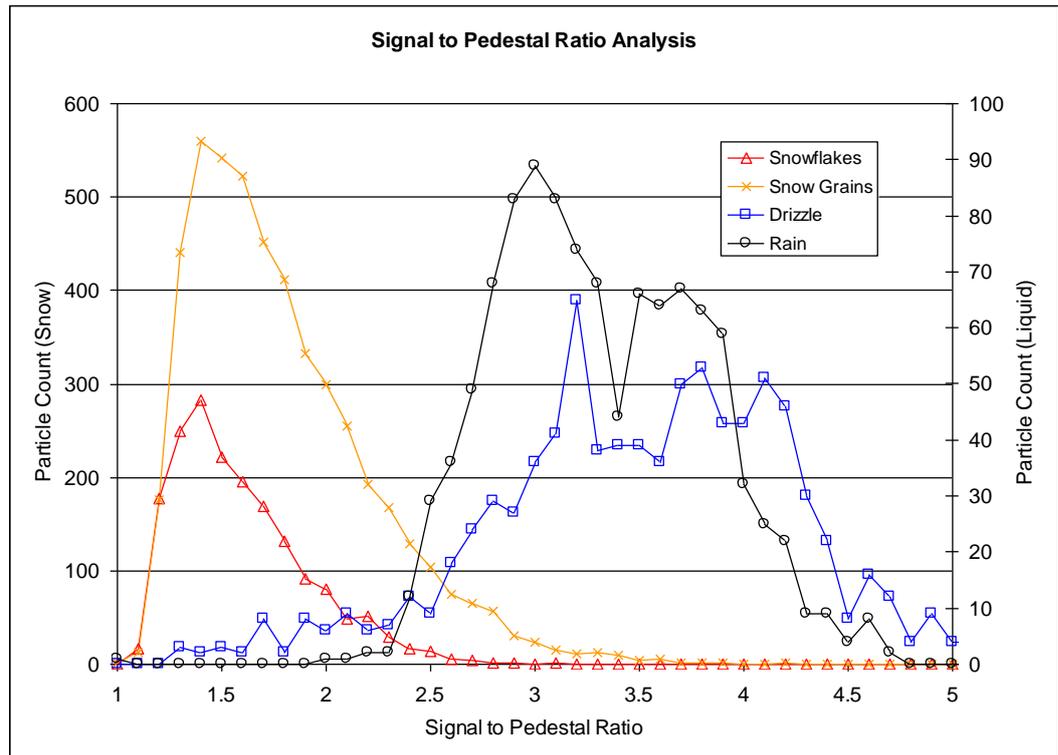


Figure 5-6. Signal to pedestal ratio values for different precipitation types

N.B.: The above data were collected during the sensor development. Results from production instruments will differ. In particular the optics do not allow accurate measurement of the pedestal ratio for true drizzle (particles <0.5 mm diameter)

Auxiliary data including values of temperature, relative humidity and derived wet bulb temperature are used in the analysis of particles if a CS215 is connected to the PWS100 or the data are transmitted to it. There is a complex relationship between these parameters and the types of particles that are formed, however since the PWS100 only measures point values, and the evolution of particle formation is not known, the true nature of the particle type can only be estimated from such parameters.

Processing of these data values is done by a series of fuzzy logic tables, some of which provide certain pure logical differentiators such as the size bounds for drizzle and rain, snow grains and snowflakes and ice pellets and hail. Through the use of the parameters determined from the PWS100 and CS215 the fuzzy logic tables provide a means of determining particle type. The general parameters thus analysed in this fuzzy logic processing are size versus velocity, signal peak to signal pedestal ratio, temperature, relative humidity and wet bulb temperature.

Each particle type from drizzle, freezing drizzle, rain, freezing rain, snow grains, snowflakes, ice pellets, hail and graupel have a set of fuzzy logic tables covering the above parameters. The size versus velocity tables are based on values derived from previous studies either by Campbell Scientific Ltd. or other research institutes and organisations (see Ellis R A et al, 2006, New Laser Technology to Determine Present Weather Parameters, Meas. Sci. Technol., 17 1715-1722). The fuzzy part of these tables gives a reduced fuzzy logic score off of the defined size versus velocity curve. These values then overlap on the various tables such that a particle could be assigned a size/velocity value of 0 for drizzle, 0.4 for rain, 0.3 for snowflakes, 0.4 for graupel, 0.1 for ice pellet etc... The fuzzy value assigned is always between 0 and 1. Since certain particle types are mutually exclusive then some types will be assigned 0 based on pure logic, e.g. a particle > 0.5 mm

diameter will have a rain value which can be >0 whereas the drizzle value for this type will always be 0.

Once each possible particle type has been assigned a fuzzy logic value for all of the parameters the values are multiplied for each particle to give 9 particle type scores between 0 and 1. The highest value is more likely to be the correct particle and so this type is assigned to the individual particle. If two values are exactly the same then the particle is of unknown type and is assigned a type as such.

Over the measurement period there are likely to be a number of particles falling through the detection volume. To define a precipitation type the individual particles are binned into 11 classes. 9 specific types, 1 unknown and 1 error.

The unknown classification is used for particles which appeared to have been measured correctly but either have fuzzy logic classifications that are not unique OR fall outside the realms of possibility for natural particles, e.g. they are measuring as travelling too fast for their size, or perhaps a particle appears to be classified as a snow flake at very high temperatures. Measurements where two particles have overlapped in the optical path are also classified as unknown. Unknown particles' size and speeds measurements are excluded from statistical calculations, but as at least one particle has definitely been detected the rainfall intensity and total measurements are corrected by adding one extra particle with the characteristics of the average of the good particles falling at that time.

The error classification is used for particles where various quality checks determine the measurement to be suspect, e.g. a particle is moving upwards, the signal to noise ratio is too small, the particle has fallen through the edge of the measurement zone or the measurements are off scale in some way. In general particles with the erroneous classification are not likely to be real or should not be counted (upwards moving for instance) so these are not included in any statistics nor is any correction made to rainfall rates or totals.

During normal measurements a small fraction of unknown or error particles will be recorded. This is because there will always be a small fraction of the particles which fall through the edge of the sampling volume. The proportions of these particles can increase with the type of precipitation and weather conditions, e.g. under heavy rainfall conditions both more unknown and error particles will be counted. This is due to a larger proportion of particles clipping the edge of the optical path (as they are larger) and an increased risk that two particles will pass through the optical path at the same time. Similarly where there are very windy conditions more particles will not fall through all four light sheets so cannot be properly measured.

5.6.2 Precipitation Intensity

Precipitation intensity calculations are possible because of the instruments accurate analysis of particle size. Over the defined period of time, the volume of all particles is summed and precipitation rate output is then given as an equivalent mmh^{-1} measurement. The PWS100 has exceptional sensitivity to the start and end of precipitation events. Note though, that to avoid falsely reporting precipitation due to insects etc, the sensor will not report the detection of particles at the start of an event until a threshold of ~ 3 particles per minute is exceeded.

Measurements of both intensity and accumulation are however subject to some assumptions as is common with most optical rain detectors. These are that all rain particles are distorted in a similar way as they fall and also that there is a defined cut-off area for the optical sampling volume. Those assumptions break down in windy conditions, when accuracy can be increasingly degraded. During high winds from critical directions the optical housing or mounting poles may also create shadows causing under-reading.

In terms of an intensity output through the SYNOP and METAR and NWS codes the intensity is calculated from the precipitation rate over the measurement period. As heavy drizzle can give less precipitation accumulation (and thus precipitation rate) than moderate rain for example, it is necessary to observe the precipitation rate and also take into consideration the particle type distribution of those particles. The following WMO standard table of intensity definitions is used to define the intensity class of different types of precipitation.

Table 5-1. Precipitation intensities

Variable	Range	Intensity Class
Drizzle	$i < 0.1 \text{ mmh}^{-1}$	Light
	$0.1 \text{ mmh}^{-1} < i < 0.5 \text{ mmh}^{-1}$	Moderate
	$i > 0.5 \text{ mmh}^{-1}$	Heavy
Rain	$i < 2.5 \text{ mmh}^{-1}$	Light
	$2.5 \text{ mmh}^{-1} < i < 10.0 \text{ mmh}^{-1}$	Moderate
	$i > 10.0 \text{ mmh}^{-1}$	Heavy
Snow	$i < 1.0 \text{ mmh}^{-1}$	Light
	$1.0 \text{ mmh}^{-1} < i < 5.0 \text{ mmh}^{-1}$	Moderate
	$i > 5.0 \text{ mmh}^{-1}$	Heavy

The PWS100 defines various intensity classes for all types and combination of types of precipitation and these are shown fully in Appendix A. Although the WMO guidelines have been followed as far as possible with these intensity ranges some have been added since the WMO guidelines do not cover all possible eventualities

5.6.3 Precipitation Accumulation

Precipitation accumulation is calculated in mm over a specified time period by summing the volume of all precipitation particles falling through the defined volume. As mentioned above, as with most other similar optical detectors the PWS100 will be subject to increased error and bias in windy conditions.

Accumulations of snow are based on the water content of those particles. The snow water content scaling factor is a user definable parameter in the instrument, see Section 4.4.5. The accumulation given will be the water equivalent depth and not the snow depth which requires further knowledge of packing structures, wind effects, ground temperature, ground type and a myriad of other parameters related to snow depth. The ratio of water accumulation to snow depth will be lower than the snow water content figure and is typically in the order of 0.1 (i.e. the snow pack is 10 times deeper than the water accumulation of the melted snow pack). Local conditions will dictate the values to use and since these will be different for every location it is not possible to give accurate snow depth figures with the PWS100. Thus only accurate snow water content values for the particles falling through the detection volume are given.

5.6.4 Present Weather

Present weather covers precipitation type analysis and visibility in the PWS100 algorithms. The PWS has separate routines for these two functions along with various housekeeping tasks to ensure that the output is as accurate as possible.

5.6.4.1 Precipitation Types

The precipitation types identified are drizzle, freezing drizzle, rain, freezing rain, snow grains, snowflakes, ice pellets, hail and graupel. A mixture of these types and intensity of these types gives an array of outputs that have been assigned codes by the WMO. These are defined as the WMO SYNOP codes (4680, W_aW_a). See Appendix A for the code table. Each particle is assigned a type from analysis of particle size, velocity, signal structure and inclusion of any other weather parameters from auxiliary instruments connected to the PWS100. The CS215 provides three additional parameters, temperature, relative humidity and wetbulb temperature. Fuzzy logic is used to define particle type from these values as this provides the best estimate of a particle type, allowing for grey boundaries in terms of size and velocity measurements for example, which may help to determine particle types during windy conditions. Standard logic can be flawed when incorporating a number of different parameters from the signal and auxiliary instruments as the boundaries have to be effectively black and white allowing for no margin of error, this is highlighted by the use of temperature matrices on certain instruments which have fixed boundaries between snow and rain. With such non-fuzzy logic instruments all particles above a set temperature are classified as rain, drizzle or unknown and below that temperature have to be snow or unknown.

5.6.4.2 Visibility Types

Also by using the WMO SYNOP code table (4680) a visibility type can be defined. These types cover mist, fog, haze and smoke. See Appendix A for details.

5.6.4.3 Weather Classes

Since the PWS100 stores historical data it can give codes relating to the conditions during the previous hour if no event is currently taking place. Again these events have specific WMO 4680 codes.

5.6.4.4 Weather Code Selection

Weather code selection is based on a history of particle types determined for each particle falling through the detection volume and classified by the instrument. A table of particle types can be called from the history over a user specified period of time (or after a specific amount of time if the instrument runs in an automated mode). This table will consist of 11 numbers, one for each particle type as defined above, one for unknown type and one for errors observed from the signal (e.g. a size out of the range specified for the instrument). Logical processing is then used to determine the most prevalent particle type or to classify mixed types if present. No precipitation and unknown precipitation outputs are also possible. Unknown precipitation is classified if a certain number of the detected particles are individually classified as unknown types.

Precipitation intensity is also given for the period specified. Output can then be given as ascii (e.g. Heavy snow) or as any of the set output standard codes, such as WMO SYNOP (WW73), METAR (+SN) and NWS (S+). Note that for some output types, certain particle types are not given an individual code. In these cases the most appropriate classification is given. METAR can support 3 or more types in one output, NWS output is normally only reported as a single code and the

WMO code has mixed types incorporated into its 80 specific codes (00 to 99 available but 20 codes reserved for future allocation).

Although the PWS100 detects and classifies graupel (heavily rimed precipitation particles), for the purposes of WMO 4680 coding graupel is classed as snow as there is no classification codes for this type of particle. The type classification output will still reflect the number of particles identified as snow grains, snowflakes and graupel. The PWS100 will output snow grains and snowflakes (snow) as separate outputs as per the WMO 4680 code tables if these are dominant.

5.6.5 Visibility

Visibility as defined in the British Standard 'BS 185-15:1972 Glossary of Aeronautical and Astronautical Terms – Section 15 : Meteorology' is "the greatest distance at which an object of specified characteristics can be seen and identified. At night, lights are observed and an equivalent day-light visibility is deduced". Because of the human perception of the environment, visibility is a subjective measurement dependant on the contrast response of the individual human eye. Therefore no instrument can truly measure visibility. It is only possible to measure the immediate surroundings, selecting appropriate parameters, which can be related to the environmental air quality and human visual perception.

The PWS100 has the ability to define an obscurant type and determine a visibility value based on the amount of particle scatter calibrated against the type of particles in the detection volume. The size distribution can also be used to calibrate the visibility value if such a distribution exists in the present weather event – i.e. available when the obscurant is drizzle, snow or some other large particle but not when fog or mist as particle sizes are too small to enable the distribution to be determined. When the obscurant consists of fog, mist or some other sub-drizzle sized particles then no visibility range correction is required.

The $\pm 10\%$ accuracy range of the visibility output from the PWS100 is from 0 to 10,000 m with a 20,000 m cap on the total range. These accuracy figures are quoted for fog/rain conditions in typical UK conditions with clean optics. Accuracy will be lower in conditions of freezing precipitation and less common conditions, e.g. dust.

As with any instrument sampling obscurants over a small portion of the range given (including transmissometers, forward scatter meters and backscatter meters) the output is only accurate if the scattering medium is uniformly dense over that given range. Some time averaging may lead to better agreement with a human observer during inconsistent events and may avoid highly variable output not consistent with overall events. In order to reduce noise levels the visibility measurements (raw voltage readings) are taken for 9 out of 10 seconds of time measurement interval and then averaged. Visibility range (in metres) is then processed in the statistical output over the required period.

Any accuracy figures quoted by any manufacturer of automated visibility sensors will consider only uniform events over the range given, even then differences in obscurant particle observed (including but not limited to particle density, surface roughness and optical scatter mechanism) can lead to $\pm 20\%$ errors (UK Met. Office studies). Only by determining particle type accurately and having the added information of particle size distribution can these errors during uniform events be minimised. The PWS100 is capable of determining this extra information and therefore giving the most accurate visibility estimates in uniform events.

Currently the PWS100 implements two separate calibrations for fog and rain events and interpolates between them depending on the rainfall intensity. In the future other calibrations will be added to give increase accuracy in other types of events.

5.7 Applications

Because of the amount of information available from the sensor it is capable of giving detailed analysis of weather conditions suitable for meteorological, aeronautical, agricultural and transportation applications. Measurements of visibility are applicable for aviation or roadside weather monitoring. Drop size and velocity distributions can be used in the analysis of soil erosion, flood prediction or as a calibration for radar instruments in meteorological studies.

5.8 Internal Monitoring

The PWS100 has a number of internal checks including temperature analysis inside each head unit of the sensor, temperature check at the laser, dirty window contamination checks and voltage monitoring (particularly for the laser source). These can be select for output with the weather data, see Section 4.4 for more details.

Section 6. Maintenance

6.1 General

The PWS100 Present Weather Sensor is a robust instrument that will provide years of uninterrupted weather monitoring. Calibration of the instrument is carried out at the factory and can be redone easily on site with the optional calibration kit or carried out by Campbell Scientific if required. Only general cleaning of the lenses is required to keep the sensor working efficiently. There are no user serviceable parts in the optical heads. The plates at the back of the optical heads are held in place with machine screws that should be torqued to 1 nm and should not be disturbed.

6.2 Cleaning

Cleaning of the PWS100 will be required from time to time to ensure that the lenses are free from contaminants. The frequency of required cleaning depends on the exposure of the instrument to such contaminants. This will vary depending on the site location. The PWS100 is capable of self-diagnosing dirty lenses and will indicate in its output when the lenses are contaminated to such a degree that its particle measurements may be affected.

We suggest 6 monthly intervals for locations not prone to contaminants and monthly intervals for those prone to contamination (roadside or airport use). In some cases more frequent cleaning may be required where there are high levels of contaminants and high dependency on the instrument output.

CAUTION

If the lenses require cleaning, it is very important that only a proper lens cloth or lens tissue be used. The use of inappropriate materials to clean the lenses can permanently damage or reduce the effectiveness of the lenses leading to errors in measurement of precipitation and visibility.

The baffles in the front of the laser head and lower head housing are easily removed by unscrewing the retaining screw and carefully removing it, ensuring that the nylon washer remains with the screw, as shown in Figure 6-1.

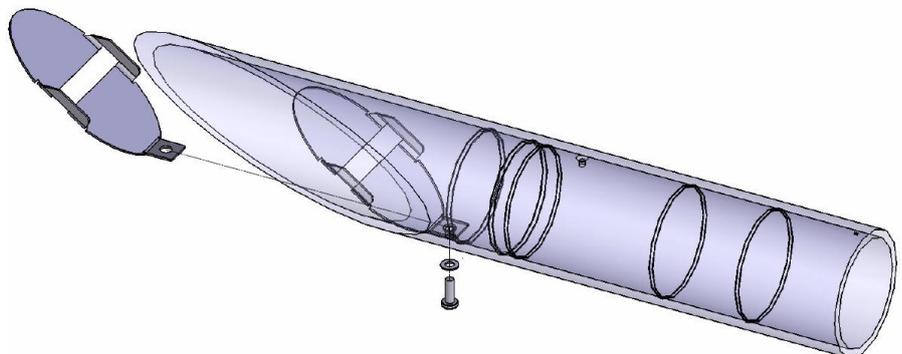


Figure 6-1. Baffle removal and fitting

It is advisable to use air duster to blow any loose dust and dirt from the lenses as a first step. Using a lint free lens cloth or lens tissue impregnated with a small amount of isopropyl alcohol solvent clean the lens surface by dragging the cloth across the lens surface being careful not to apply excessive pressure. Excessive pressure may lead to some types of contaminant scratching the lens surface. Over time such scratches can lead to reduced sensor accuracy.

Once clean, replace the baffle by carefully slotting it into position, being careful not to scratch the paint coating or damage any heater element. Lock the baffle into place using the retaining screw, ensuring that the nylon washer is in place.

6.3 Calibration

The PWS100 is fully calibrated before leaving the factory. This calibration covers the mechanical arrangement of the system (including detection volume) as well as setting laser power and other electronic settings. The system is self-regulating, however it is recommended that the PWS100 is calibrated every two years.

The detection volume is calibrated using the optional PWS Calibrator PWC100 part no 010441. The particle analysis is done using the unit with a rotating disc which has an embedded high precision ball lens. The refractive index of this ball lens is taken into consideration when calibrating the unit. The disc is rotated at a known speed which provides a known velocity component to the calibration and the refraction from the known diameter ball lens to the two detectors provides a size calibration. Visibility calibration is carried out using the second fixture which comprises a material with known scatter parameters. Light impenetrable sensor blocks are used to determine sensor offset and will need to be placed in the sensor heads when required. The unit will then determine the calibration factors and indicate if there is any problem with the optical or mechanical arrangement of the present weather sensor. Laser power can be monitored using a commercial laser power meter.

It is possible to carry out a simple visibility only calibration using the PVISC100 visibility calibrator, part number 010443 (included in the PWC100 or purchased separately). This is described in Section 4.4.3.

Please refer to the PWS Calibrator manual for further details of its operation. Section 4.4.3 on the menu structure also gives details of how to view and set various calibration factors.

Section 7. Troubleshooting

7.1 Introduction

If your PWS100 seems to be operating incorrectly, there are a number of checks you can make to isolate the problem. These checks may enable you to solve the problem or at least provide vital basic information for one of our engineers should you need to contact Campbell Scientific.

7.2 Possible Problems

The following problems can be encountered. Following the steps laid out should enable you to resolve these problems quickly and easily.

7.2.1 No response from PWS100

The following steps should be carried out to try to diagnose the problem:

Check the physical power connection. Attempt to connect again.

Check the communication cable. If the cables are secure but there is still no response, remove and refit the cables. Attempt to connect again.

Check the baud rate settings on the DSP board. If the baud rate setting is incorrect or mismatched from the terminal used to connect to the PWS adjust settings accordingly. Attempt to connect again.

Ensure that the correct *Pws_Id* value is being used. Also ensure that if a password is set then the correct password is being entered for the OPEN command e.g.

```
OPEN Pws_Id Password↵
```

Attempt to connect again.

If the previous steps have failed then a hardware reset can be carried out (see '3.5.10 Load Factory Defaults'). This will wipe the password and user defined messages. Attempt to connect again.

If the sensor still does not respond contact Campbell Scientific.

7.2.2 PWS100 responds but no data output given

Check the PWS100 settings by entering the command mode and using the MSET function. Ensure that at least one message is set and that the interval is appropriate.

If viewing the data using Hyperterminal or similar, ensure that the message mode is set to 'Store & Output'.

7.2.3 Ice has formed in the end of the hoods

The heaters may not be working. Enter the command mode of the sensor, run DIAGSET with the following command:

```
DIAGSET 10 102
```

Ensure that the laser hood temperature (first value following the 9000 and 0 output) is above zero. If it is not then it is possible that the heaters may not be active or may need servicing.

To check the settings of the hood heaters use the SETCONFIG command. Ensure that the fifth value is between 10 and 50 (temperature setting). If this is set to 0 then the hood heaters are off and should be set between 10 and 50. If the hood heaters are on but ice is still present set the hood heaters to a higher temperature. If this does not clear the ice then the hood heaters may have failed. Contact Campbell Scientific in this instance.

If the heater settings are correct and only some of the hoods are clear and others not then it is possible that a single heater may have failed. Contact Campbell Scientific if the problem persists.

7.2.4 The visibility output is clearly in error

Ensure that the sensor is placed in a location free from obstructions which may cause erroneous scatter into the sensors. Following the installation instructions in this manual is sufficient.

If the sensor still gives erroneous output then it is possible that the lenses have become contaminated. Refer to Section 6.2 for cleaning the lenses.

Also check there is no sign of condensation inside the sensor which might occur if the desiccant is not replaced at the required interval.

7.2.5 The sensor does not detect particles during a precipitation event

It is possible that the lenses have become overly contaminated. Refer to Section 6.2 for cleaning the lenses. If there is no contamination, the laser may have failed. Holding a diffuser, e.g. the visibility calibration disk or even some tissue paper in the sample volume should result in a reduction in visibility readings if the laser is functioning. If there is no contamination and the laser output is within accepted limits, then hardware reset the sensor (see '3.5.10 Load Factory Defaults').

Remember that the PWS100 samples only a small area and in events where precipitation is falling but with high spatial separation then there may be periods where no particles fall through the volume but an observer looking at a larger area observes some particles.

7.2.6 The sensor detects particles when there are none present

Although the sensor uses sophisticated processing routines to determine particle types and eliminate false alarms, under certain conditions the sensor may report the incidence of particles in the detection volume when an observer does not. There are possibly several reasons for this. Firstly it should be checked that there are no spider's webs on the instrument, especially in and around the detection volume and hoods of the unit. If spider's webs are present they should be removed as they can collect condensed water vapour to form droplets on the strands which may give rise to spurious signals. Secondly flying insects may cause spurious signals, however these are likely to be disregarded by the instrument and are unlikely to lead to classification of precipitation. If insects become a problem then it may be necessary to use insect deterrents or re-site the instrument away from any areas where insects gather.

If insects are a persistent problem two other techniques can be used to dissuade them from living on or near the sensor. One is to spray the baffle plates and end of the sensor with a water proof insecticide, taking great care not to spray the lenses. The insecticide may need to be reapplied on a regular basis. The other technique is to turn on the hood heaters and adjust the temperature to a high level which can deter some species. If doing this in summer months it is advisable to turn off the dew heaters to prevent excess heat building up inside the sensor housings.

7.2.7 The OS update did not work

Ensure that the upload is not being carried out with an NL100 network link interface in the communications pathway as this will prevent the OS update from working due to the NL100 being incompatible with the Xmodem protocol for the OS download. In such an instance it will be necessary to connect directly to the PWS100 with, for example, a laptop computer.

If the OS update fails and there is no physical barrier for the upload then check the speed of the communications link. With slow links the system may drop the connection causing the upload to fail. In this instance try the upload again, possibly at a time when the communications link may run faster.

If the OS update still fails after checking the above then the OS file may be corrupt and a new file may be required. Contact Campbell Scientific if this is the case.

7.3 Contact Details for Help

In the unlikely event that you have any problems with the PWS100, first check out the possible problems section in Section 7. Further help and advice is available from Campbell Scientific. Our contact details are as follows:

Campbell Scientific Ltd,
Campbell Park,
80 Hathern Road,
Shepshed,
Leicestershire,
LE12 9GX,
UK.

Tel: +44 (0) 1509 601141
Fax: +44 (0) 1509 601091

Email: support@campbellsci.co.uk for European support
World Wide Web: <http://www.campbellsci.co.uk>

Appendix A. PWS100 Output Codes

The codes that are used in the PWS100 are taken from WMO Manual on Codes 1995 edition, Suppl. No. 5 (VIII.2005), Rec. 5 (CBS-XIII). Table A-1 shows the weather types output from the PWS100.

The table is based on intensity limits for mixed events which are explained subsequent to Table A-1 and shown in Tables A-3 to A-8.

WMO codes 20 to 25 are used to report precipitation, fog or thunderstorms observed during the preceding hour but not at the time of observation (the time of observation) in the case of the automated PWS100 is the latest set message period and so could be 1 minute, 1 hour or any user defined interval, the preceding hour being the hour before this period. Hence if 1 hour message intervals are set the preceding hour is from 2 hours ago to 1 hour ago. If 1 minute message intervals are set then the preceding hour is from 1 hour 1 minute ago to 1 minute ago. All other codes are for weather observed during the latest observation period.

NWS codes shown are used with an intensity indicator '+' for heavy, '-' for light and no indicator for moderate. For example 'R+' means heavy rain and 'S' means moderate snow.

WMO METAR codes (Code Table 4678) include a code for the weather at or near the station of significance to the aeronautical operations. The PWS100 being a sample based instrument cannot detect precipitation not at the site and so such codes cannot be given by the instrument. Some other codes such as those for dust devils and volcanic ash are not covered by the PWS100 METAR output. The METAR codes shown are used with an intensity indicator '+' for heavy, '-' for light and no indicator for moderate. For example '+RA' means heavy rain and 'RASN' means moderate mixed rain and snow. Where there are mixed events the order of the codes output indicate the more prevalent components first. When no precipitation is detected a code of 'NSW' is output for the METAR code.

Table A-1. PWS100 SYNOP 4680 output codes

58 codes can be reported.

Weather Type	4680 Code
No significant weather observed	00
Haze or smoke, or dust in suspension in the air, visibility ≥ 1 km*	04
Haze or smoke, or dust in suspension in the air, visibility < 1 km*	05
Mist	10
Fog (in the preceding hour)	20
Precipitation (in the preceding hour)	21
Drizzle (not freezing) or snow grains (in the preceding hour)	22
Rain (not freezing), (in the preceding hour)	23
Snow (in the preceding hour)	24
Freezing rain or freezing drizzle (in the preceding hour)	25
FOG	30
Fog or ice fog in patches	31
Fog or ice fog, has become thinner during the past hour	32
Fog or ice fog, no appreciable change during the past hour	33
Fog or ice fog has begun or become thicker during the past hour	34
Fog, depositing rime	35
PRECIPITATION	40
Precipitation, slight or moderate	41
Precipitation, heavy	42
Solid precipitation, slight or moderate**	45
Freezing precipitation, slight or moderate**	47
Freezing precipitation, heavy**	48
DRIZZLE**	50
Drizzle, not freezing, slight	51
Drizzle, not freezing, moderate	52
Drizzle, not freezing, heavy	53
Drizzle, freezing, slight	54
Drizzle, freezing, moderate	55
Drizzle, freezing, heavy	56
Drizzle and rain, slight	57
Drizzle and rain, moderate or heavy	58

RAIN**	60
Rain, slight	61
Rain, moderate	62
Rain, heavy	63
Rain, freezing, slight	64
Rain, freezing, moderate	65
Rain, freezing, heavy	66
Rain (or drizzle) and snow, slight	67
Rain (or drizzle) and snow, moderate or heavy	68
SNOW**	70
Snow, slight (snow includes graupel)	71
Snow, moderate (snow includes graupel)	72
Snow, heavy (snow includes graupel)	73
Ice pellets, slight	74
Ice pellets, moderate	75
Ice pellets, heavy	76
Snow grains	77
Ice crystals	78
SHOWER(S) OR INTERMITTENT PRECIPITATION	80
Rain shower(s) or intermittent rain, slight	81
Rain shower(s) or intermittent rain, moderate	82
Rain shower(s) or intermittent rain, heavy	83
Rain shower(s) or intermittent rain, violent	84
Snow shower(s) or intermittent snow, slight	85
Snow shower(s) or intermittent snow, moderate	86
Snow shower(s) or intermittent snow, heavy	87
Hail	89

*Only reported if a CS215 is connected to provide relative humidity, otherwise they will default to mist (10) or fog (20, 30, 31, 32, 33, 34 or 35).

**Only reported in the generic message field.

Table A-2. PWS100 NWS output codes

No precipitation	C
Precipitation	P
Drizzle	L
Freezing drizzle	ZL
Rain	R
Freezing rain	ZR
Snow	S
Ice pellets (sleet in US)	IP
Snow grains	SG
Ice crystals	IC
Hail	A

Table A-3. PWS100 METAR codes

Qualifier		Weather phenomena	
Intensity	Descriptor	Precipitation	Obscuration
- Light	SH Shower ¹	DZ Drizzle	BR Mist
No qualifier Moderate	FZ Freezing	RA Rain	FG Fog
+ Heavy	BC Patches	SN Snow	HZ Haze
		SG Snow grains	
		IC Ice crystals	
		PL Ice pellets	
		GR Hail ¹	
		GS Graupel	
		UP Unknown precipitation	

¹Used only in the combination SHGR

NOTE Many combinations of METAR codes are possible, for example +FZRASN meaning heavy freezing rain and snow.

The WMO Guide to Meteorological Instruments and Methods of Observation (WMO No. 8, 7th Edition) gives the following information in the Annex to Chapter 14 – ‘Present and Past Weather; State of the Ground’ regarding the criteria for light, moderate and heavy precipitation intensity which was recommended by the WMO Expert Meeting on Automation of Visual and Subjective Observations (Trappes, Paris, France, 14-16 May 1997) and the Working Group on Surface Measurements (Geneva, Switzerland, 27-31 August 2001).

Table A-4. Light, moderate and heavy precipitation defined with respect to type of Precipitation and to intensity, i , with intensity values based on a three-minute measurement period

Variable	Range	Intensity class
Drizzle	$i < 0.1 \text{ mm h}^{-1}$ $0.1 \leq i < 0.5 \text{ mm h}^{-1}$ $i \geq 0.5 \text{ mm h}^{-1}$	Light Moderate Heavy
Rain (also showers)	$i < 2.5 \text{ mm h}^{-1}$ $2.5 \leq i < 10.0 \text{ mm h}^{-1}$ $10.0 \leq i < 50.0 \text{ mm h}^{-1}$ $\geq 50.0 \text{ mm h}^{-1}$	Light Moderate Heavy Violent
Snow (also showers)	$i < 1.0 \text{ mm h}^{-1}$ (water equivalent) $1.0 \leq i < 5.0 \text{ mm h}^{-1}$ (water equivalent) $i \geq 5.0 \text{ mm h}^{-1}$ (water equivalent)	Light Moderate Heavy

Additionally the following points are given in the WMO No. 8 document:

Mixed precipitation of rain and snow: The same as for snow (since the ratio rain/snow is not subject to any measurement, a simple choice should be made). Note that this is altered in the PWS100 processing and additional mixed output intensity modifiers have been developed – see further discussion below.

Hail: The same as for rain.

Ice-pellets: The same as for snow.

Freezing phenomena: The same as for the non-freezing phenomena.

The implementation here for the PWS100 uses a proportional mix of the intensity values for the mixed types, i.e. if an event is of mixed rain and snow then the rain and snow modifiers for light, moderate and heavy events are added and divided by two, thus giving some mean value for the intensity modifiers. There are some meteorological services which suggest using the intensity value of the highest type (i.e. using the largest values of intensity so for a mixed rain and drizzle event the intensity values for rain would be used); though this is scientifically inaccurate but does follow the above WMO guideline for mixed rain and snow. The implementation in the PWS100 as outlined here serves as a reasonable compromise between altering intensity ranges on particle distributions and choosing the largest intensity ranges.

However it is also noted that non-mixed reports such as rain or snow may also contain a proportion of other types of particle such as drizzle which is not included in any intensity range modification for non-mixed reports. Without modifying on the proportion of identified particle types this is an inaccuracy that will be inherent in some data though statistically should not be extremely significant and certainly less so than choosing the largest range of the mixed types observed.

Table A-5 gives mixed intensity ranges for rain and drizzle, Table A-6 gives mixed intensity ranges for rain and snow (WMO 68), Table A-7 gives mixed intensity ranges for drizzle and snow (WMO 68), Table A-8 gives mixed intensity ranges for rain, drizzle and snow (WMO 68), Table A-9 gives mixed intensity ranges for rain, drizzle, ice pellets, hail and snow, Table A-10 gives mixed intensity ranges for ice pellets, hail and snow.

Table A-5. Intensity bounds for rain and drizzle

	Rain	Drizzle	Rain and Drizzle (same for freezing)
Light	$i < 2.5$	$i < 0.1$	$i < 1/2 \times 2.5 + 1/2 \times 0.1$ $i < 1.3 \text{ mmh}^{-1}$
Moderate	$2.5 \leq i < 10.0$	$0.1 \leq i < 0.5$	$1/2 \times 2.5 + 1/2 \times 0.1 \leq i < 1/2 \times 10 + 1/2 \times 0.5$ $1.3 \text{ mmh}^{-1} \leq i < 5.25 \text{ mmh}^{-1}$
Heavy	$i \geq 10.0$	$i \geq 0.5$	$i \geq 1/2 \times 10 + 1/2 \times 0.5$ $i \geq 5.25 \text{ mmh}^{-1}$

Table A-6. Intensity bounds for rain and snow

	Rain	Snow	Rain and Snow
Light	$i < 2.5$	$i < 1.0$	$i < 1/2 \times 2.5 + 1/2 \times 1.0$ $i < 1.75 \text{ mmh}^{-1}$
Moderate	$2.5 \leq i < 10.0$	$1.0 \leq i < 5.0$	$1/2 \times 2.5 + 1/2 \times 1.0 \leq i < 1/2 \times 10 + 1/2 \times 5.0$ $1.75 \text{ mmh}^{-1} \leq i < 7.5 \text{ mmh}^{-1}$
Heavy	$i \geq 10.0$	$i \geq 5.0$	$i \geq 1/2 \times 10 + 1/2 \times 5.0$ $i \geq 7.5 \text{ mmh}^{-1}$

Table A-7. Intensity bounds for drizzle and snow

	Drizzle	Snow	Drizzle and Snow
Light	$i < 0.1$	$i < 1.0$	$i < 1/2 \times 0.1 + 1/2 \times 1.0$ $i < 0.55 \text{ mmh}^{-1}$
Moderate	$0.1 \leq i < 0.5$	$1.0 \leq i < 5.0$	$1/2 \times 0.1 + 1/2 \times 1.0 \leq i < 1/2 \times 0.5 + 1/2 \times 5.0$ $0.55 \text{ mmh}^{-1} \leq i < 2.75 \text{ mmh}^{-1}$
Heavy	$i \geq 0.5$	$i \geq 5.0$	$i \geq 1/2 \times 0.5 + 1/2 \times 5.0$ $i \geq 2.75 \text{ mmh}^{-1}$

Table A-8. Intensity bounds for rain, drizzle and snow

	Rain	Drizzle	Snow	Rain, Drizzle and Snow
Light	$i < 2.5$	$i < 0.1$	$i < 1.0$	$i < 1/3 \times 2.5 + 1/3 \times 0.1 + 1/3 \times 1.0$ $i < 1.2 \text{ mmh}^{-1}$
Moderate	$2.5 \leq i < 10.0$	$0.1 \leq i < 0.5$	$1.0 \leq i < 5.0$	$1/3 \times 2.5 + 1/3 \times 0.1 + 1/3 \times 1.0 \leq i < 1/3 \times 10 + 1/3 \times 0.5 + 1/3 \times 5.0$ $1.2 \text{ mmh}^{-1} \leq i < 5.17 \text{ mmh}^{-1}$
Heavy	$i \geq 10.0$	$i \geq 0.5$	$i \geq 5.0$	$i \geq 1/3 \times 10 + 1/3 \times 0.5 + 1/3 \times 5.0$ $i \geq 5.17 \text{ mmh}^{-1}$

Table A-9. Intensity bounds for rain, drizzle, ice pellets, hail and snow

	Rain	Drizzle	Ice Pellets	Hail	Snow	Rain, Drizzle, Ice Pellets, Hail and Snow
Light	$i < 2.5$	$i < 0.1$	$i < 1.0$	$i < 2.5$	$i < 1.0$	$i < 1/5 \times 2.5 + 1/5 \times 0.1 + 1/5 \times 1.0 + 1/5 \times 2.5 + 1/5 \times 1.0$ $i < 0.97 \text{ mmh}^{-1}$
Moderate	$2.5 \leq i < 10.0$	$0.1 \leq i < 0.5$	$1.0 \leq i < 5.0$	$2.5 \leq i < 10.0$	$1.0 \leq i < 5.0$	$1/5 \times 2.5 + 1/5 \times 0.1 + 1/5 \times 1.0 + 1/5 \times 2.5 + 1/5 \times 1.0 \leq i < 1/5 \times 10.0 + 1/5 \times 0.5 + 1/5 \times 5.0 + 1/5 \times 10.0 + 1/5 \times 5.0$ $0.97 \text{ mmh}^{-1} \leq i < 6.1 \text{ mmh}^{-1}$
Heavy	$i \geq 10.0$	$i \geq 0.5$	$i \geq 5.0$	$i \geq 10.0$	$i \geq 5.0$	$i \geq 1/5 \times 10.0 + 1/5 \times 0.5 + 1/5 \times 5.0 + 1/5 \times 10.0 + 1/5 \times 5.0$ $i \geq 6.1 \text{ mmh}^{-1}$

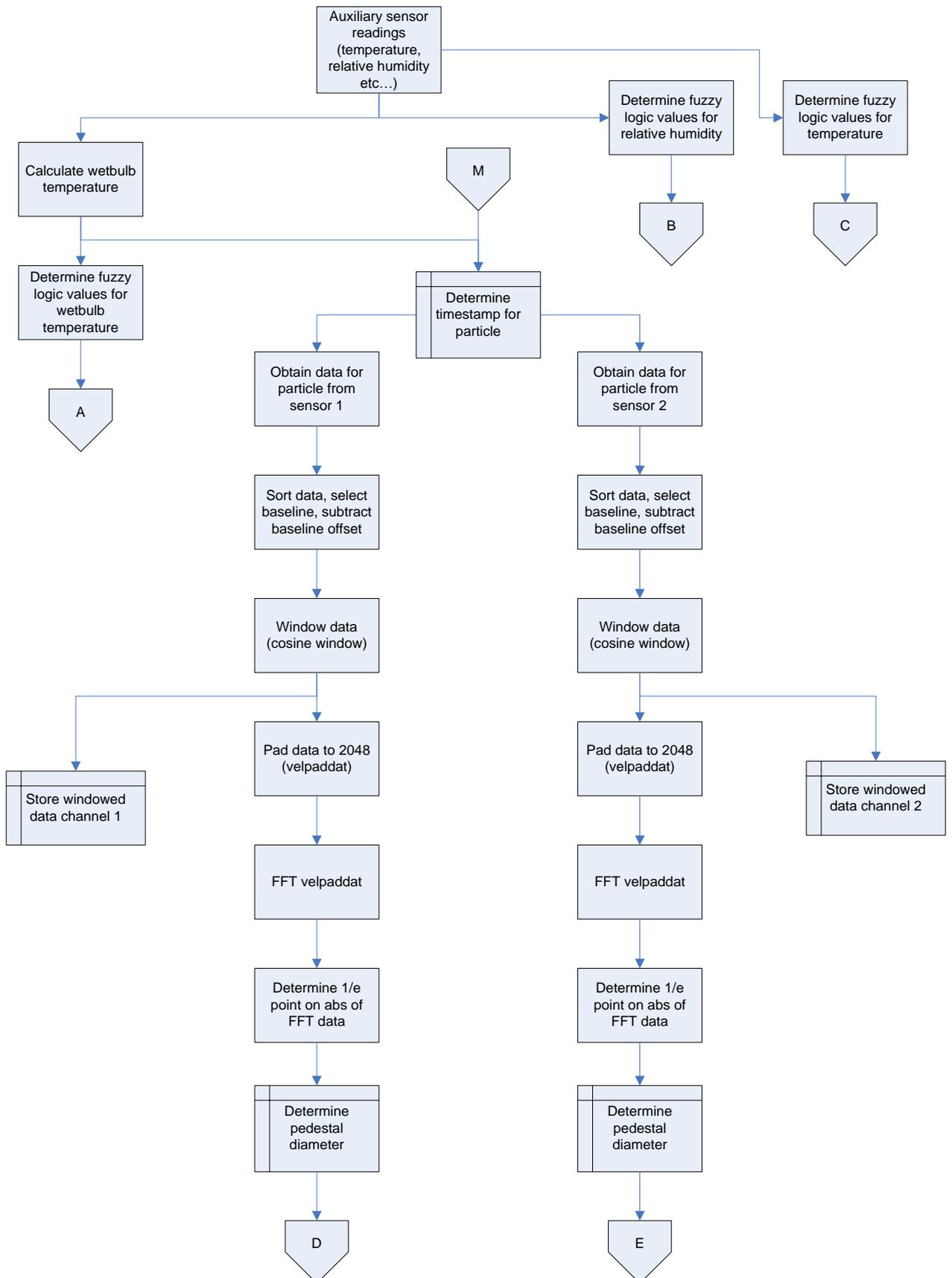
Table A-10. Intensity bounds for ice pellets, hail and snow

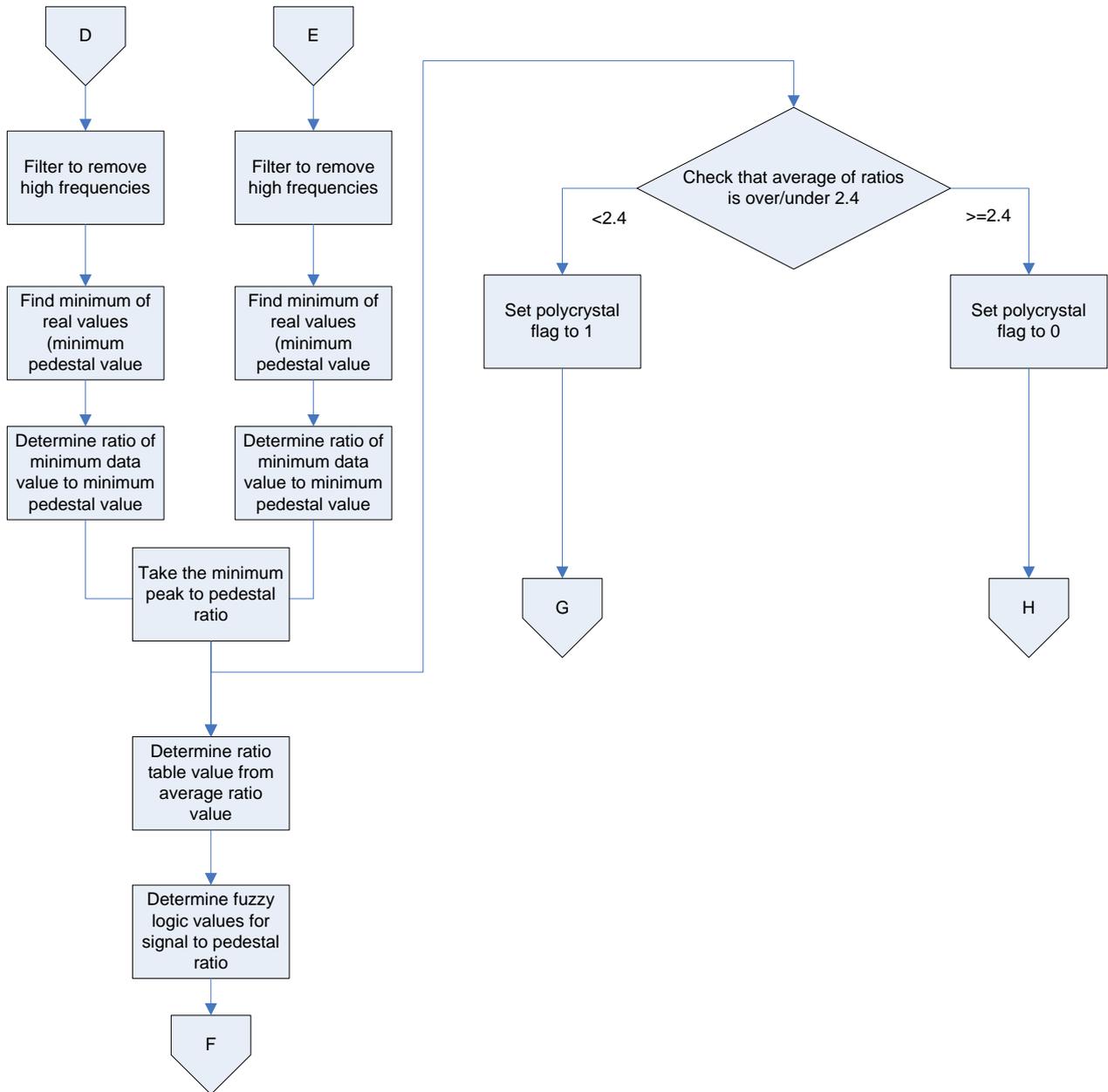
	Ice Pellets	Hail	Snow	Ice Pellets, Hail and Snow
Light	$i < 1.0$	$i < 2.5$	$i < 1.0$	$i < 1/3 \times 1.0 + 1/3 \times 2.5 + 1/3 \times 1.0$ $i < 1.5 \text{ mmh}^{-1}$
Moderate	$1.0 \leq i < 5.0$	$2.5 \leq i < 10.0$	$1.0 \leq i < 5.0$	$1/3 \times 1.0 + 1/3 \times 2.5 + 1/3 \times 1.0 \leq i < 1/3 \times 5.0 + 1/3 \times 10 + 1/3 \times 5.0$ $1.5 \text{ mmh}^{-1} \leq i < 6.67 \text{ mmh}^{-1}$
Heavy	$i \geq 5.0$	$i \geq 10.0$	$i \geq 5.0$	$i \geq 1/3 \times 5.0 + 1/3 \times 10 + 1/3 \times 5.0$ $i \geq 6.67 \text{ mmh}^{-1}$

Table A-11. PWS100 Precipitation size criteria

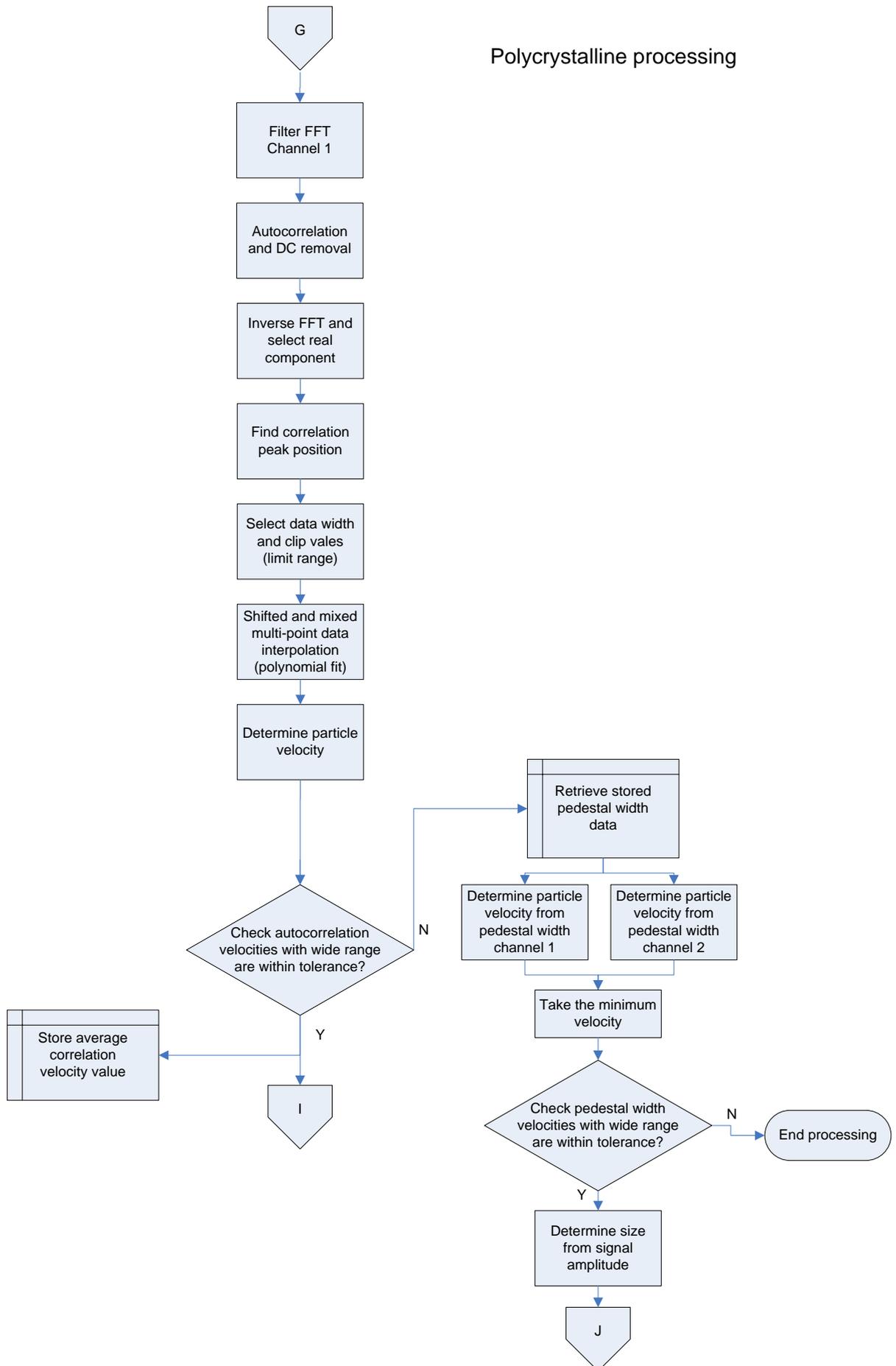
Precipitation type	Diameter
Drizzle	< 0.5 mm
Rain	> 0.5 mm
Snow	> 1 mm
Ice pellets	< 5 mm
Snow grains	< 1 mm
Hail	> 5 mm

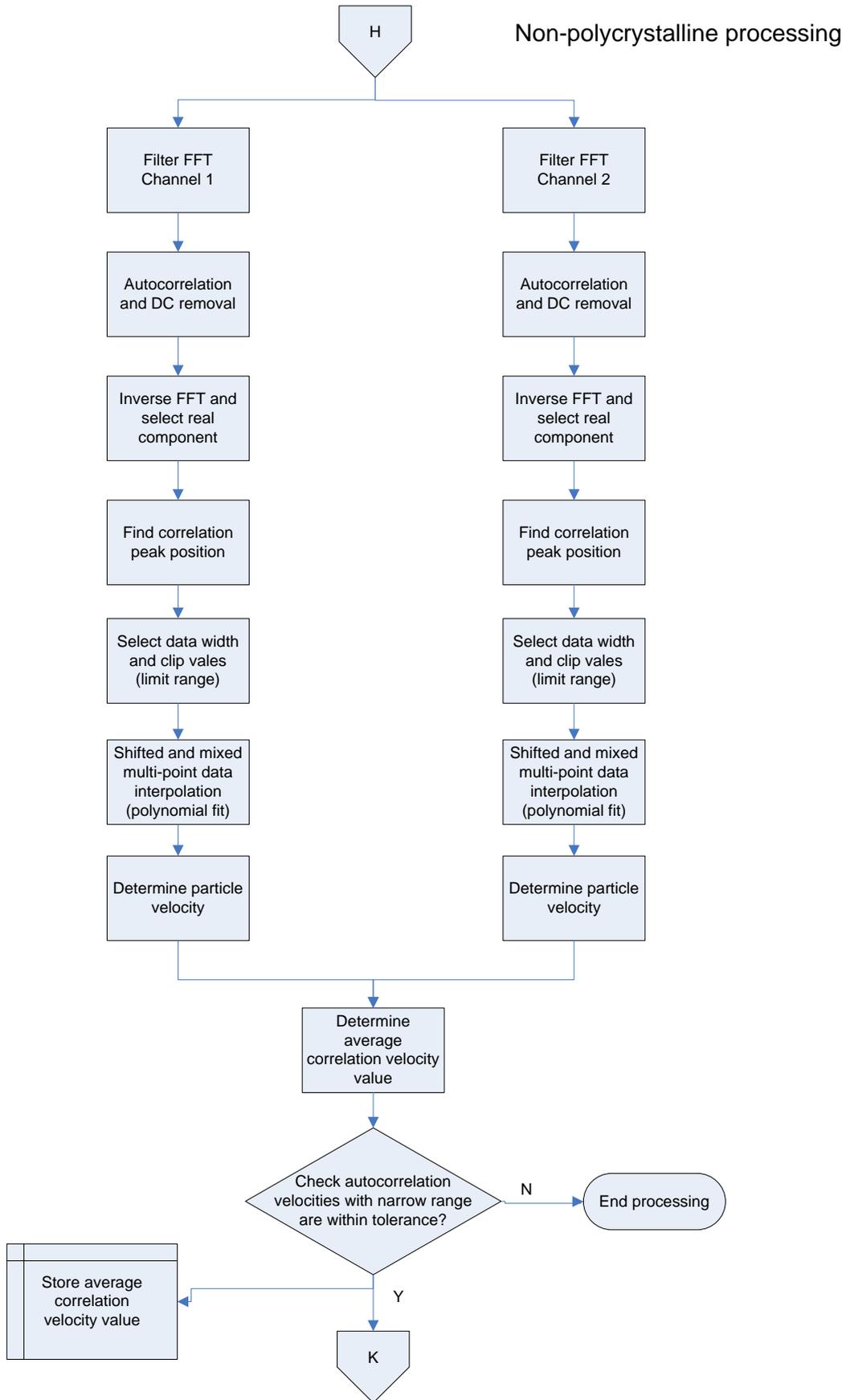
Appendix B. Software Flowchart

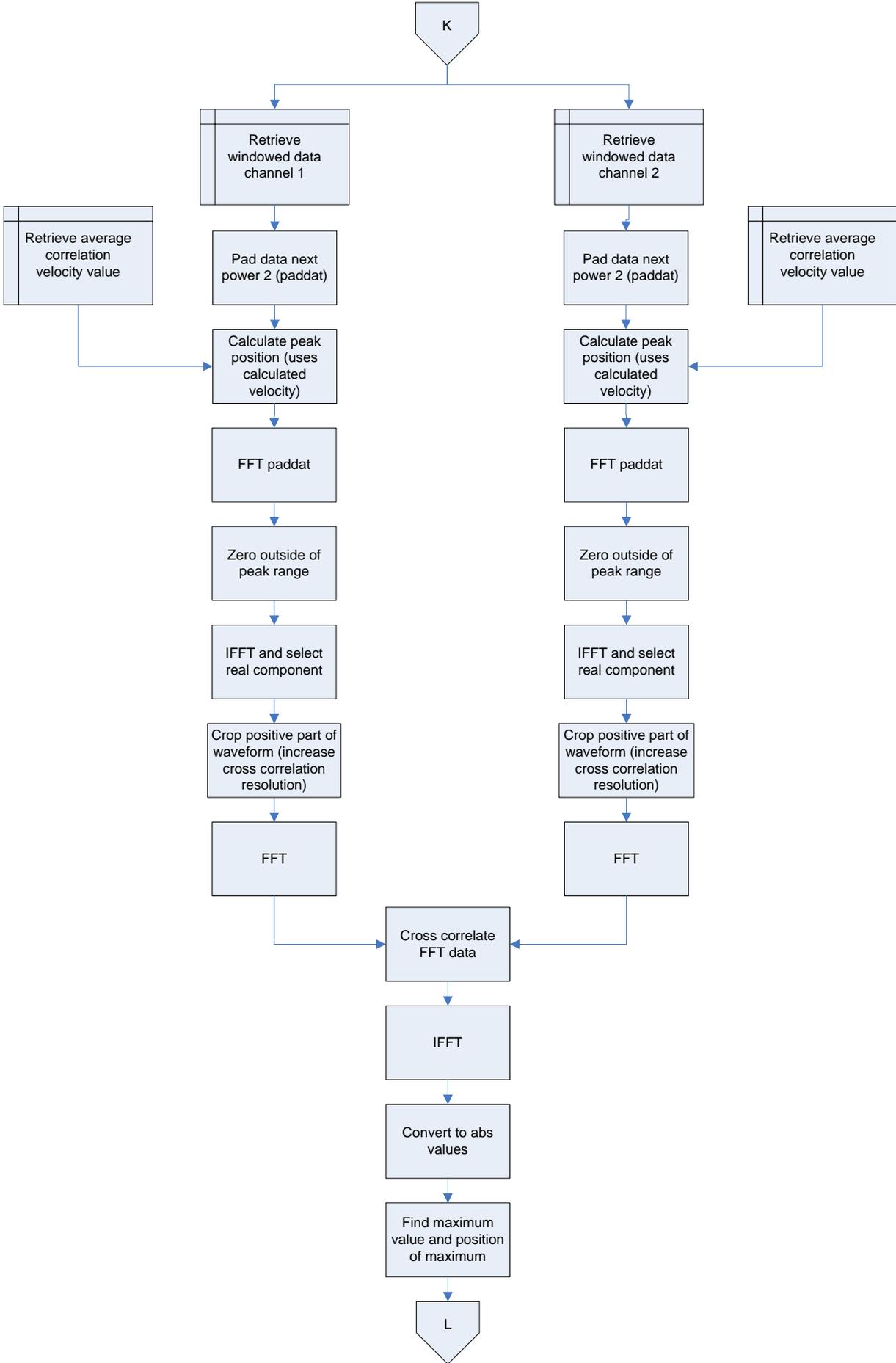


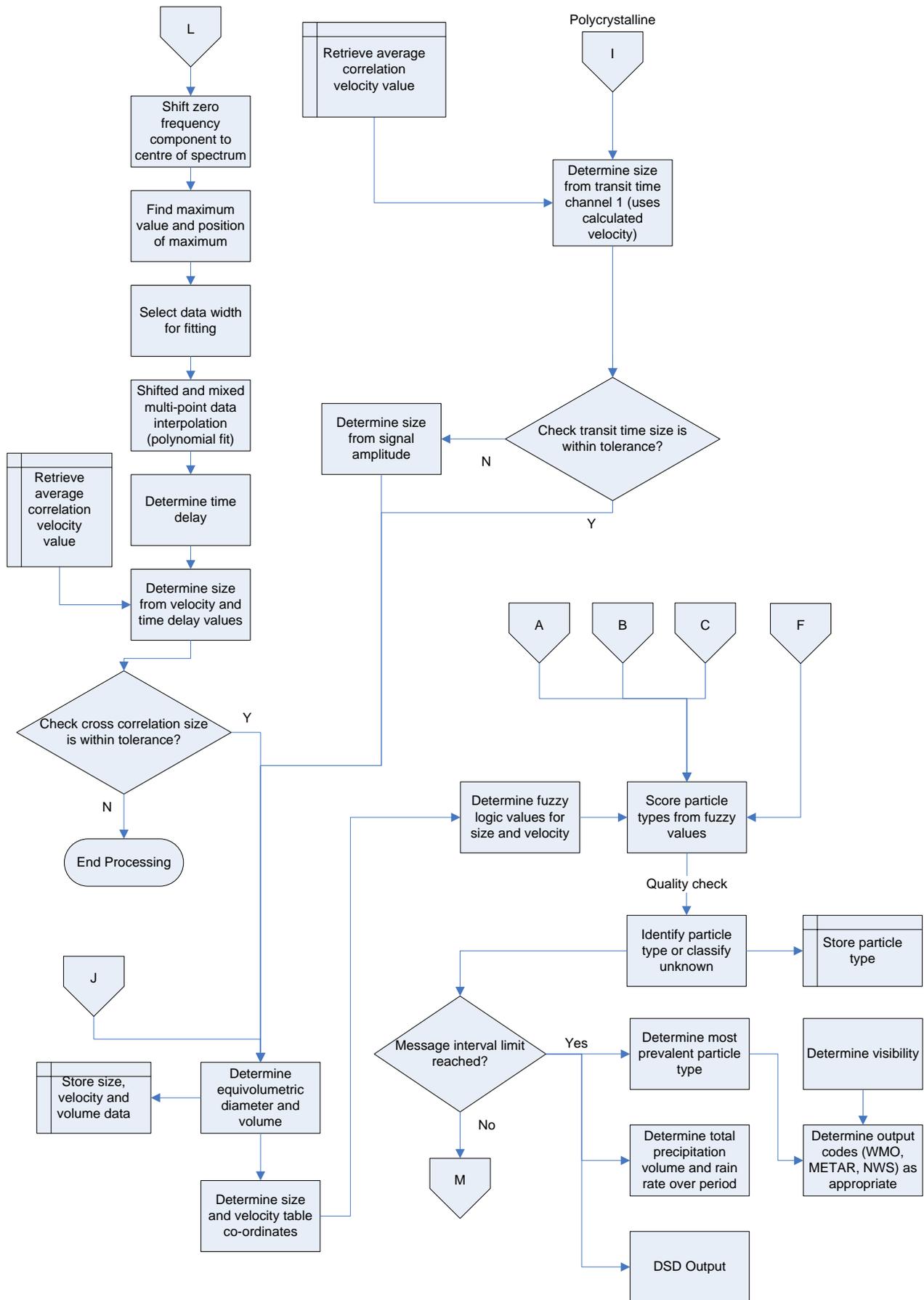


Polycrystalline processing





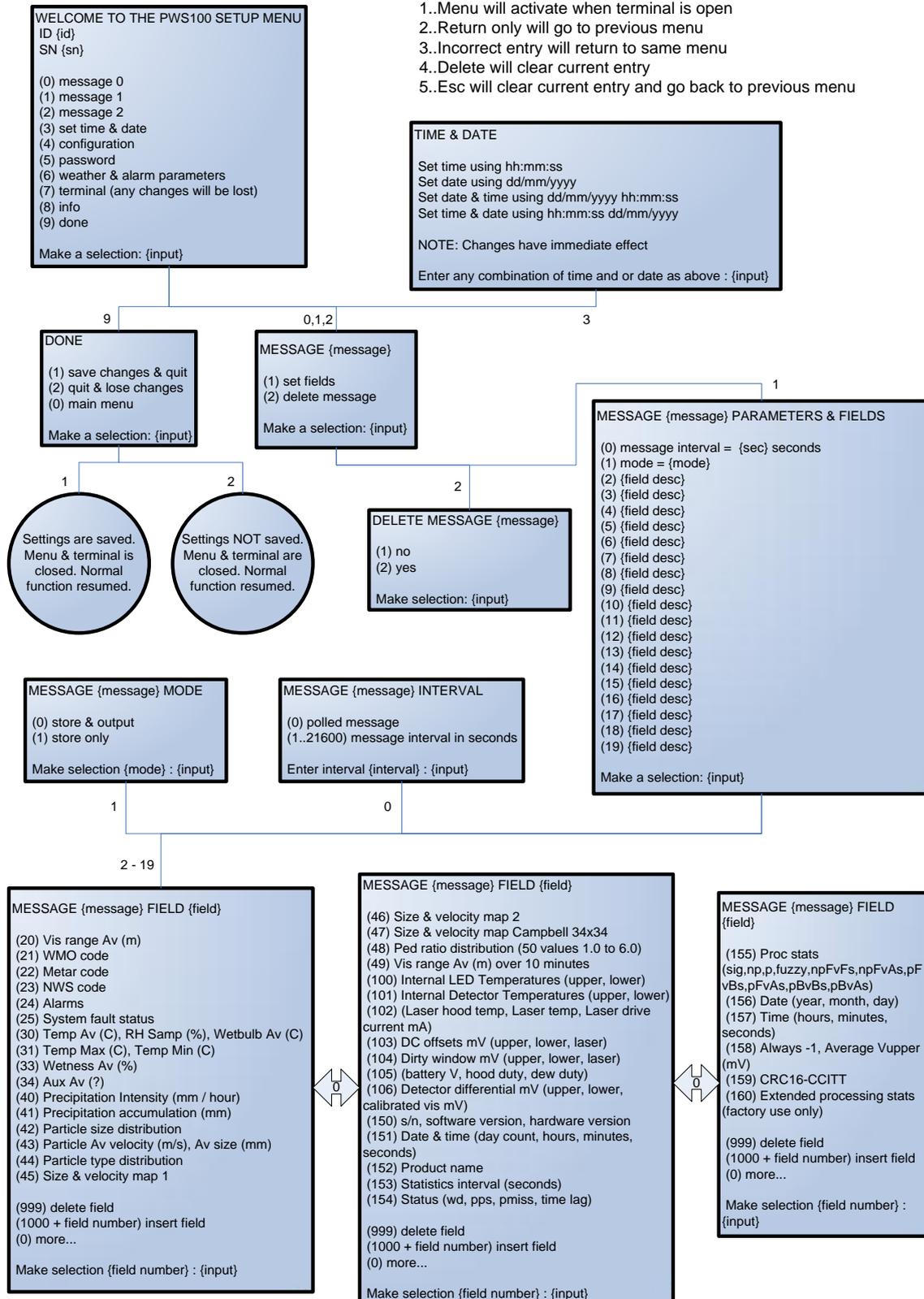




Appendix C. Menu System Map

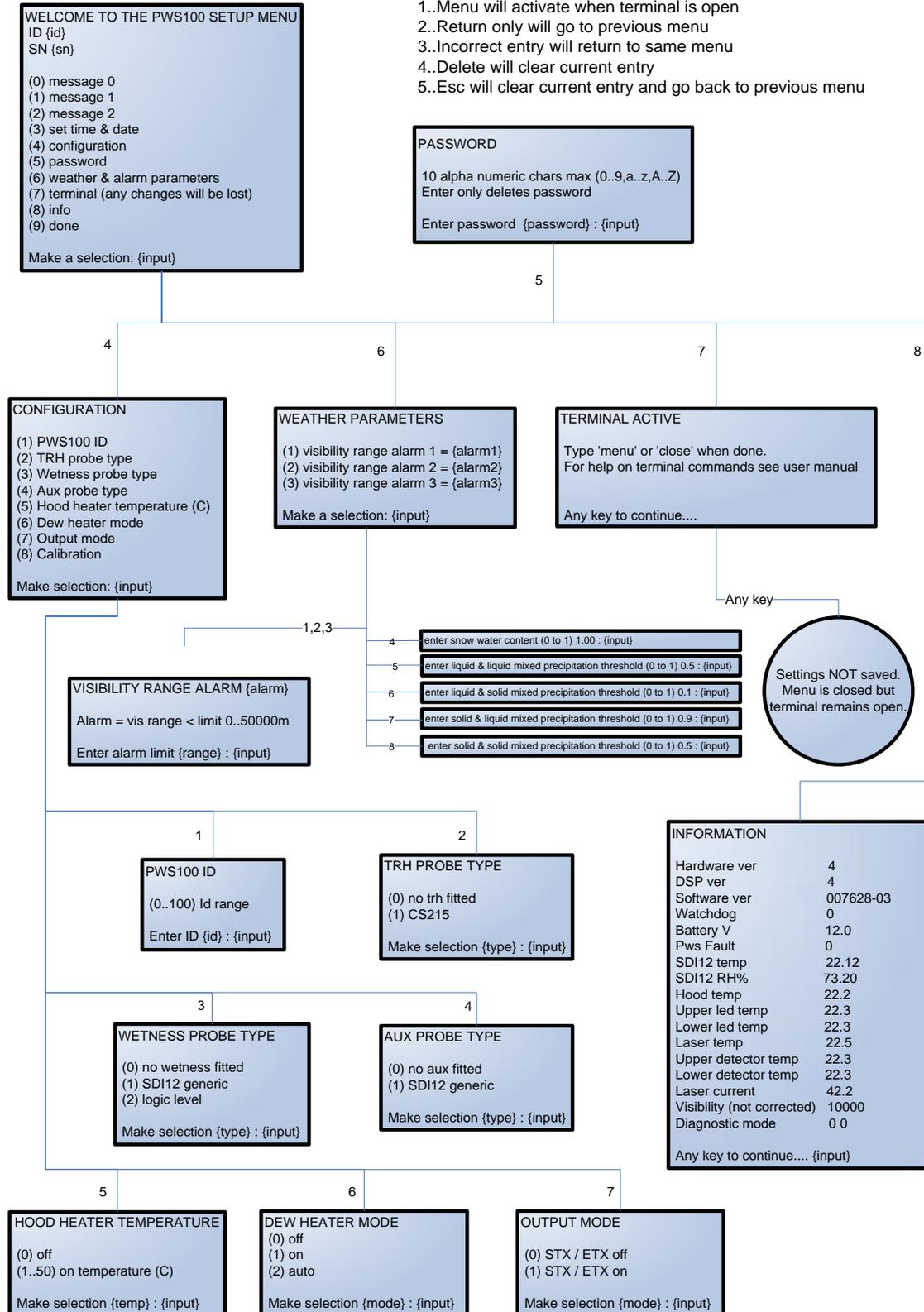
Menu operation

- 1..Menu will activate when terminal is open
- 2..Return only will go to previous menu
- 3..Incorrect entry will return to same menu
- 4..Delete will clear current entry
- 5..Esc will clear current entry and go back to previous menu



Menu operation

- 1..Menu will activate when terminal is open
- 2..Return only will go to previous menu
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Menu operation

- 1..Menu will activate when terminal is open
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- 4..Delete will clear current entry
- 5..Esc will clear current entry and go back to previous menu

```

WELCOME TO THE PWS100 SETUP MENU
ID {id}
SN {sn}

(0) message 0
(1) message 1
(2) message 2
(3) set time & date
(4) configuration
(5) password
(6) weather & alarm parameters
(7) terminal (any changes will be lost)
(8) info
(9) done

Make a selection: {input}
    
```

4

```

CONFIGURATION

(1) PWS100 ID
(2) TRH probe type
(3) Wetness probe type
(4) Aux probe type
(5) Hood heater temperature (C)
(6) Dew heater mode
(7) Output mode
(8) Calibration

Make selection: {input}
    
```

8

```

PWS100 Calibration

CAUTION! INCORRECT ENTRIES CAN SERIOUSLY DEGRADE ACCURACY

to edit or view instrument calibration, type 'confirm' : {input}
    
```

0

1

```

PWS100 View / Enter calibration disc constants

s/n          1234
velocity (m/sec) 5.000
size (mm)    2.386
visibility (mV) 0.318

enter s/n 1234 : {input}
enter size constant (mm) 2.386 : {input}
enter visibility constant (mV) 0.318 : {input}
    
```

```

PWS100 View / Adjust calibration

Latest results from calibrator date 21:05:08

          latest target--range calibration date
Velocity_Centre 5.000 4.900 5.100 21:05:08
Velocity_Left   5.000 n/a   n/a   n/a
Velocity_Right  5.000 n/a   n/a   n/a
Size_Centre     2.350 2.311 2.461 21:05:08
Visibility (mV) 0.300 0.286 0.350 21:05:08
Visibility Offset (uV) 0.000 -2.000 2.000 n/a

(0) no change
(1) adjust calibration (THIS WILL TAKE IMMEDIATE EFFECT)

Make selection : {input}

Update velocity calibration y/n : {input} saved
Update size calibration y/n : {input} saved
Update visibility calibration y/n : {input} saved
    
```

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