Manual

Installation, Operation and Maintenance of Automatic Meteorological Stations Established in The Nile Basin

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Information Products for Nile Basin Water Resources Management
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List of Acronyms

AH	Ampere Hour
AWS	Automatic Weather Station
CHG	Charge
CSi	Campbell Scientific
DoD	Depth of Discharge
DSP	Data Storage Pointer
FAO	Food an Agriculture Organization of the United Nations
FSA	Final Storage Area
G	Ground Terminal
HADA	High Aswan Dam Authority
ID	Identification Code
LVBD	Lake Victoria Basin Database
METSTAT	Meteorological Station Datalogger Programme
NBD	Nile Basin Database
OCV	Open circuit Voltage
P	Pulse
PV	Photovoltaic
RAM	Random Access Memory/Readily Available Memory
RH	Relative Humidity
SM4M	Storage Module of 4 Megabytes
SoC	State of Charge
SPTR	Storage Module Reference Pointer
SVP	Saturated Vapor Pressure
VP	Vapor Pressure
VPD	Vapor Pressure Deficit

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Introduction

1.1 General

This manual presents detailed instructions for the installation, operation, and maintenance of the Automatic Weather Stations (AWS) installed in the Nile Basin by the FAO Nile Basin Water Resources Project. The monitoring equipment was procured from Campbell Scientific, USA. This company has a proven track record in Africa, and a number of Campbell Scientific AWS have been operational in the basin for several years.

The reader is advised to study this manual carefully before starting to work with the monitoring equipment. We have worked hard to present the user instructions as concise as possible, although we have not compromised on the necessary detail. Background information on the functioning of the various instruments is presented at appropriate occasions. We hope this will provide the user with a clear overview of the role of each AWS element in the data acquisition process.

In the remainder of this text, Automatic Meteorological Station is referred to as Met Station.

Main purpose of the Met Stations is to collect continuous high quality climatological data. Such information is used for many purposes, including:

- Climate change assessment;
- Hydrological analysis;
- Calibration of METEOSAT rainfall estimation algorithm;
- Evaporation estimation of large water bodies (Lake Victoria, Lake Nasser);
- Agricultural planning, etc.

The Met Stations are equipped with sensors for (1) rainfall, (2) air temperature, (3) relative humidity, (4) wind speed, (5) wind direction, and (6) incoming short wave solar radiation. These parameters facilitate estimating potential (open water) evaporation using the Penman-Monteith or Priestley-Taylor approach.

The project has advocated the introduction of electronic monitoring equipment in the Nile basin. The use of electronic sensors connected to a datalogger is now well established in the world, and carries many advantages. For example, it facilitates automation of data processing. It is the experience of the authors that processing of the observations often forms the main obstacle in the data collection process, not so much the actual measurement. Another major benefit of electronic monitoring is the acquisition of a continuous set of sub daily data values. This provides important additional information on the behavior of the often highly variable climatological parameters.

The project operated an AWS at its compound for testing and manual preparation purposes for several months. This station worked impeccable and did not show any technical problem in the testing period. Based on this experience, and the fact that other Campbell Scientific AWS' are satisfactorily operational in the basin for several years now, the project believes that automatic monitoring of meteorological parameters is feasible within the Nile basin. However, this under the provision that the user follows the operation and maintenance instructions presented in this manual.

1.2 Individual Components of the Met Station

Figure 1 shows a Met Station with a similar sensor configuration as selected for the Nile basin. Obviously, this figure only shows the external hardware components. A number of essential elements (datalogger and power supply) are placed within the protective enclosure and therefore not visible on this picture.
tions will be issued in the future.

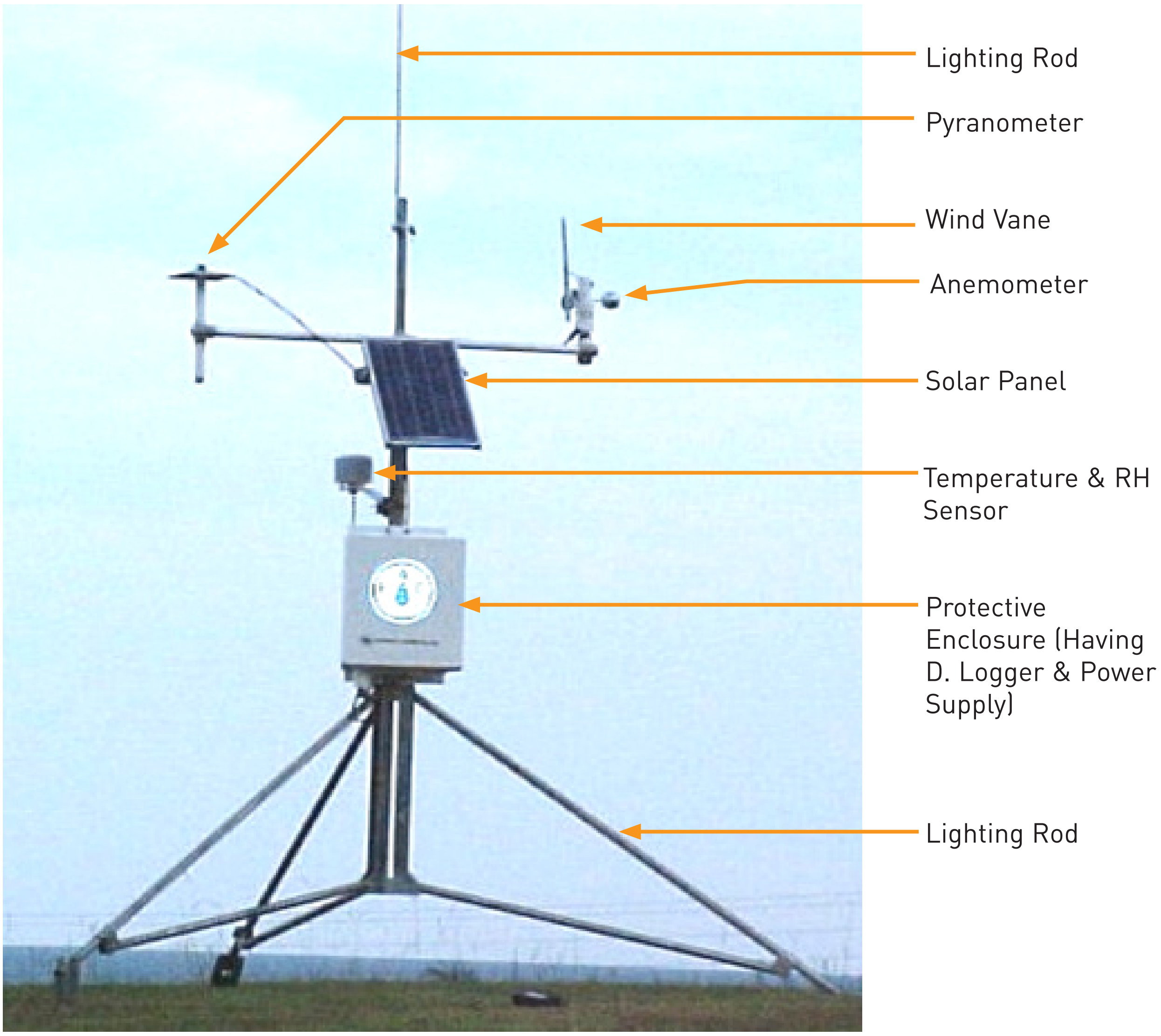


Figure 1: Met Station

The main components of the Met Station are:

- Tripod (partly manufactured locally)
- Protective enclosure ENC12/14
- CR10X storage and control module (inside the protective enclosure)
- PS12LA power supply (including rechargeable battery; inside the protective enclosure)
- MSX10R Solar panel
- Sensors
- SM4M storage module (a single unit used for multiple stations)
- CR10KD keyboard display (a single unit used for multiple stations)

Figure 2 displays the CR10X storage and control module, which is the actual data logger. The various sensors will be connected to the green terminal strip, following a wiring schedule presented later in this manual.

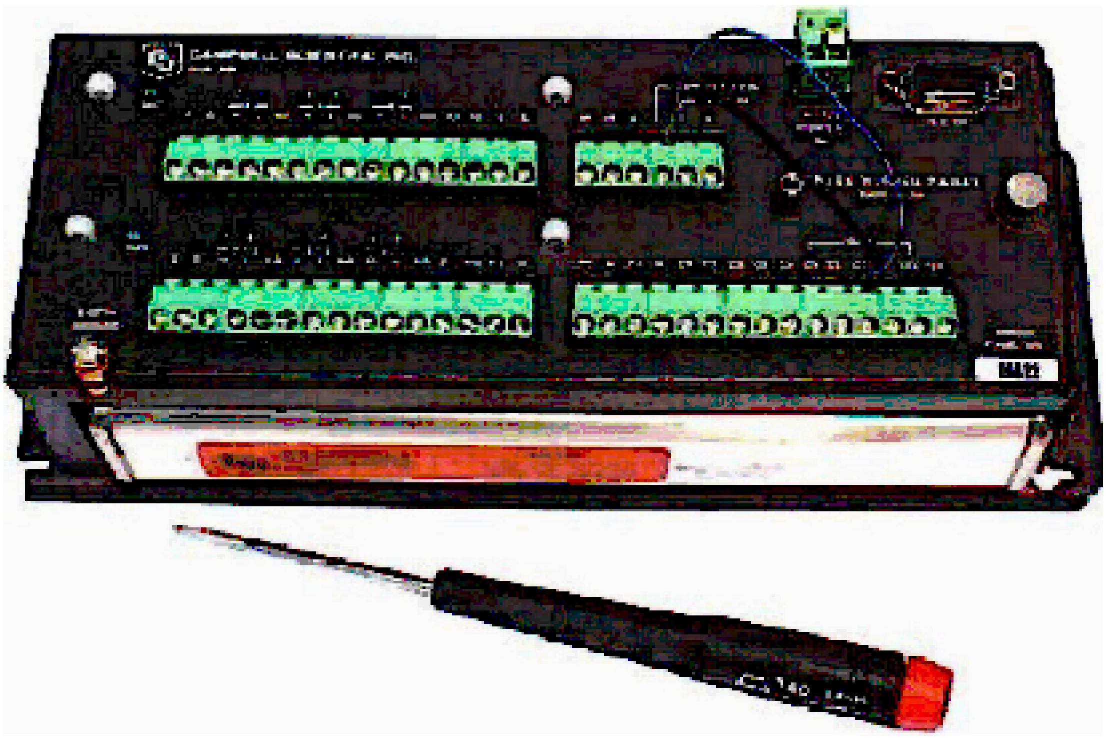


Figure 2: CR10X Data logger

Figure 3 presents the PS12LA Power Supply. It consists of a rechargeable battery, and an integrated regulator and charging unit.

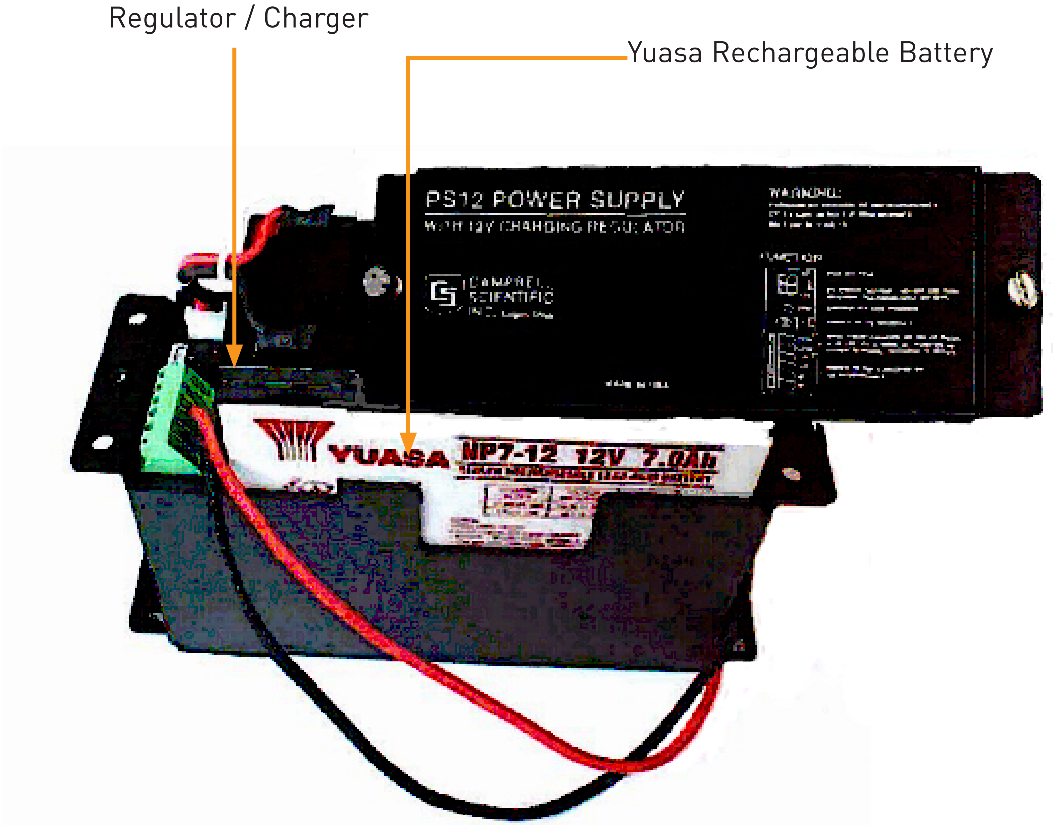


Figure 4 presents the portable keyboard display and the data storage module, which are used together to communicate with the data logger while in the field. One set can serve several stations, as these items are only used during the periodic inspection visits. The storage module is a solid, rugged instrument, and is used to transfer the measurement values from the datalogger in the field to a PC in the office.

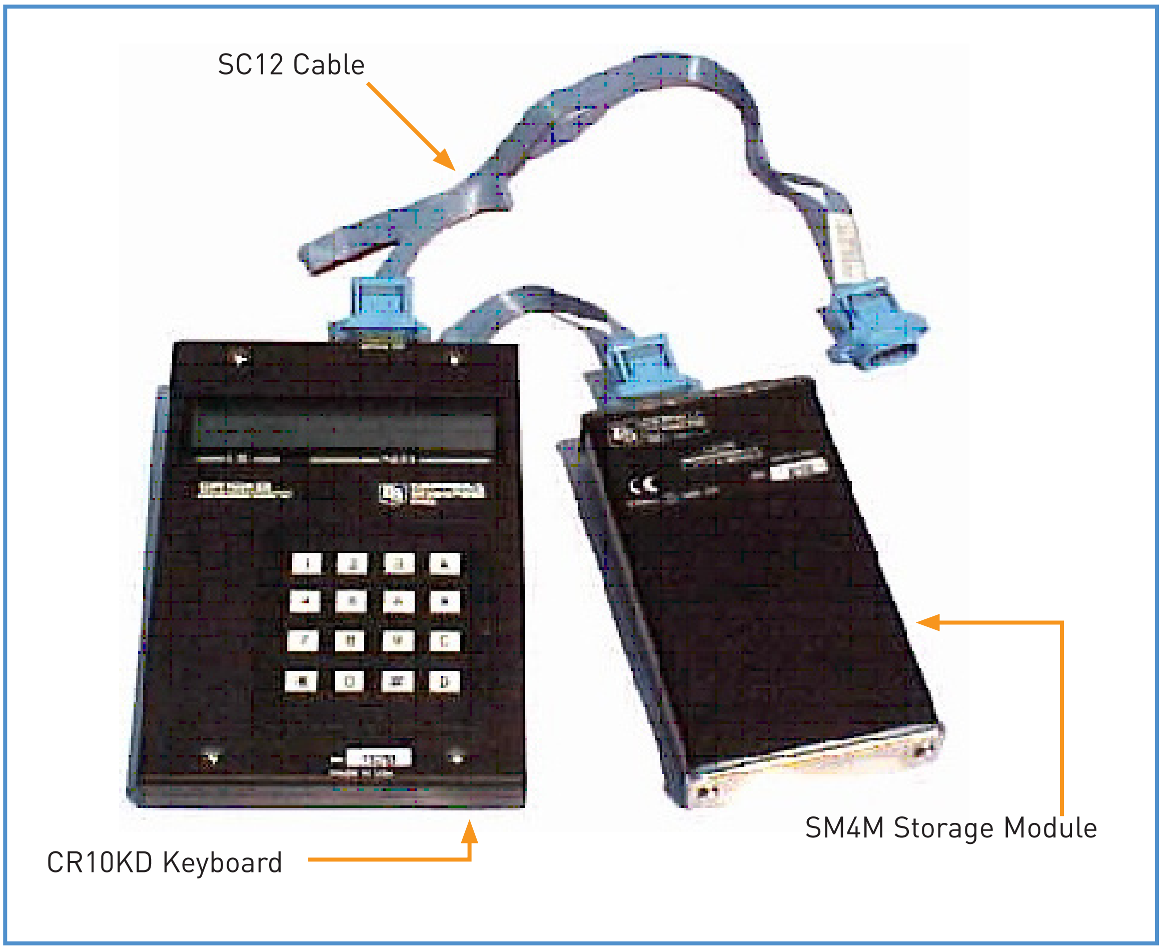


Figure 4: Portable Keyboard Display (CR10KD) with Portable Data Storage Module (SM4M).

1.3 Overview of the Contents of the Manual

This manual presents all the information needed to install, operate, and maintain all components of the Met Station.

Chapter 2 covers the storage and control module CR10X, including its interactions with the SM4M storage module and CR10KD keyboard display. Chapter 3 describes the functioning of all six sensors, while chapter 4 discusses the power supply, including solar panel, charger/regulator, and rechargeable battery. Chapter 5 presents the tripod, while detailed information on the protective enclosure ENC12/14 is discussed in chapter 6. Guidelines on how to maintain the Met Station compound are covered in chapter 7.

The following text refers at several places to Campbell Scientific Operation Manuals, which should have been provided with the equipment. These operation manuals should be considered as background information. They could be useful if the reader wants to know in detail how the equipment works, or would like to modify the data logger program when a new sensor has been added. We do not advise to study these operation manuals. All relevant information needed for the installation, use, and maintenance of the Met Station are covered in this document.

However, this document does not include the complete data trajectory. Retrieval of the data values from the SM4M storage module to PC is dealt with in a separate manual called "Manual on Data Retrieval, Processing, and Final Storage in the Database".

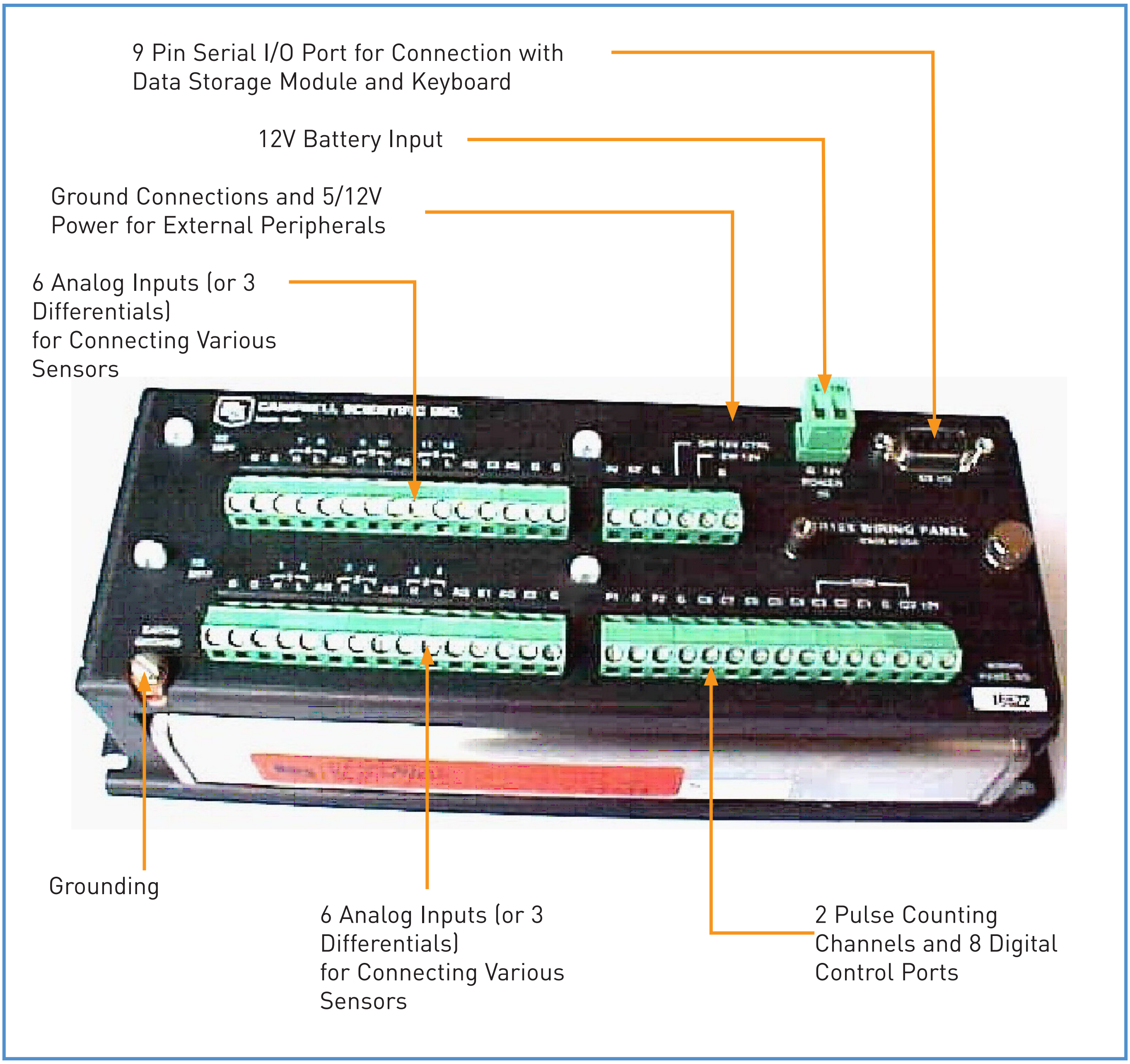
CR10X Storage and Control Module

2.1 General

The CR10X is the actual datalogger. It is an electronic storage and control system that manages the data acquisition, processing, storage, and retrieval within the Met Station. The CR10X hardware consists of (a) a measurement and control module, and (b) a detachable wiring panel. The CR10X datalogger program is specifically created by the project for the selected sensor configuration, and written in a proprietary Campbell Scientific programming language.

The wiring panel can accommodate 12 single ended analogue inputs, as well as two digital ones. The required number of input channels differs per sensor. For example, a pyranometer is an analogue sensor occupying two input slots, while the tipping bucket rain gage is a pulse sensor that needs to be connected to a digital channel.

Figure 5 shows the wiring panel and the functions of the various terminals.



The datalogger has two separate memories, i.e.: (1) a Flash ROM of 128 Kb for storing the operating system and various datalogger programs, and (2) a RAM of 128 Kb for data processing and storage, with a capacity of 96,000 readings.

The CR10X datalogger has no internal power supply, apart from a small lithium battery for back-up purposes. Instead, the logger draws its electricity from the external PS12-LA power unit, connected to a solar panel. This unit is discussed in detail in chapter 4.

The user can program the datalogger, or communicate with system using the "PC208W" datalogger support software supplied by Campbell Scientific. This package contains: (a) a program editor (EDLOG), (b) several datalogger communication routines, and (c) options for data retrieval using either a storage module or telecommunication.

The CR10KD keyboard display is used for communicating with the datalogger when in the field, while the SM4M storage module serves to load a datalogger program, or to transfer the measurements from station to office PC. These two items are only used during an actual field visit, and one set can therefore serve several stations.

Detailed information on operating and programming the CR10X datalogger is presented in the Operator's Manual supplied by the supplier. However, the reader is advised to consider this document only as a reference. The single sections of immediate interest are (a) the Overview (OV) Chapter, and (b) the Operating Details and Cautionary Notes. These paragraphs present some basic information on how the instrument works, and what peripherals are involved.

Campbell Scientific has prepared tutorial software called PCTour. This auxiliary package offers a computer-guided tour on the operating principles of the CR10X and the associated support software. Instructions on how to install and operate PCTour are provided in Annex 1.

2.2 Installation

Mount the CR10X on the back plate in the ENC12/14 protective enclosure as indicated in figure 6. Grommets with screws have already been put in the square holes at the appropriate locations. Firmly attach the CR10X by tightening the screws.

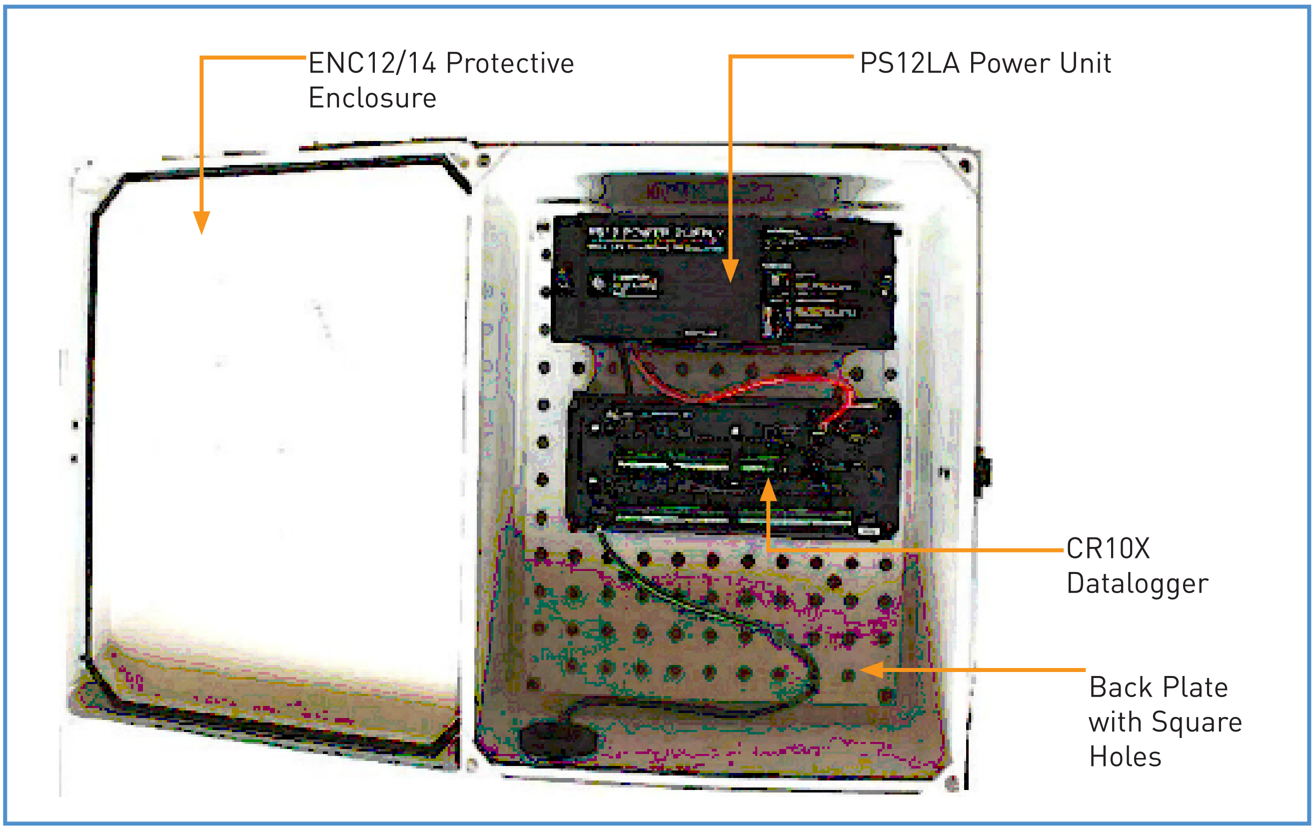


Figure 6: PS12-LA and CR10X in ENC12/14 Protective Enclosure

Fix the central grounding cable of the protective enclosure to the ground terminal on the CR10X wiring panel. This is essential for protecting the instrument against lightning strikes. It is also crucial for obtaining precise measurements, as sensors and datalogger need the same ground reference.

Before connecting the CR10X to the external power supply, toggle the switch on the PS12-LA charger/regulator to 'OFF', to make sure that power is disconnected.

Connect the red wire attached to the 12V terminal of the PS12-LA power supply to its 12V counterpart on the wiring panel. In the same manner, connect the black wire attach to the ground terminal on the PS12-LA to the 'power in' G terminal on the wiring panel. The above sequence is important to avoid creating a short circuit. DO NOT supply power to the logger until all sensors are properly connected, and all other hardware installation activities are completed.

Connect the various sensor cables to the CR10X wiring panel according to the wiring schedule in Annex 2 and the below presented table 1. All wires are pre-stripped and pre-tinned, and there is no need for removing more wire isolation. Do not cut any wire since the complete length may be useful in future applications. Instead, attach all sensor cables properly to the datalogger and ENC12/14 enclosure with the supplied strain relief flanges and cable ties.

Table 1: Wiring Schedule

Sensor	Color	Terminal
CS500 (Temp & RH)	Green	AG
	Clear	G
	Black	1H
	Brown	1L
	Red	SW12V
	jumper from C1 to SW12 CTRL	from C1 to SW12 CTRL
L!200 (Pyranometer)	White	G
	Clear	G
	Red	2H
	Black	2L
034A (Mod. Met One)	Red	P1
	Clear	G
	Black	G
	White	AG
	Green	3H
	Blue	E1
TE525 (Rain Gage)	Clear	G
	White	AG
	Black	P2

After connecting all sensors to the wiring panel, the user should load an appropriate datalogger program into the CR10X. To this end, store the METSTAT datalogger program in Program Location 8 of the SM4M storage module (see Annex 8 for the complete instructions for this activity), and then connect the SM4M storage module and CR10KD keyboard display to the logger using the SC12 cable.

Box 1: Permanent Storage of METSTAT in Program Location 8 of the SM4M

It is advised to leave an uncorrupted version of METSTAT at all times in program location 8 of the SM4M storage module. As discussed later in the "trouble shooting' chapter, a wide range of possible operation problems can be solved by reloading METSTAT into the datalogger.

Upon toggling the PS12-LA Power Supply switch to "ON", the program stored in location 8 of the SM4M storage module (in this case METSTAT) is automatically loaded into the CR10X, and subsequently made the active program.

Make sure that the installation of all hardware components is completed before powering on the datalogger.

Box 2: Loading METSTAT into CR10X Storage and Control Module

(it is assumed that METSTAT is stored in program location 8 of the SM4M)

Option 1: Automatically
-1: connect SM4M to CR10X;
-2: switch power Off/On by toggling the switch on the PS12-LA Power Supply;
-3: METSTAT is now automatically loaded and made the active program.

Option 2: Manually Using the CR10KD Keyboard Display
Connect the CR10KD and SM4M to the CR10X and type in the following keyboard instructions (for presentation purposes given between double quotes):

"*D" (to activate Star D Mode; the display shows 13:00)
"71" (code for SM4M)
"A" (keyboard equivalent for ENTER; the display shows 71:00)
"28" ("2" stands for loading a program, "8" stands for program location 8)
"A" (keyboard equivalent to ENTER; METSTAT is now loaded and activated)

METSTAT is a datalogger program specifically created by the Project for the selected sensor configuration, and adapted to the required measurement schedule in the Nile Basin. It is written in the proprietary Campbell Scientific programming language. The reader is referred to Annex 3 for more information on the METSTAT program.

To set the CR10X system clock, type in the following keyboard commands (given between double quotes for presentation purposes):
"*5" (to activate Star Five Mode; the display shows the current time in HH:MM:SS)
"A" (keyboard equivalent to ENTER)
"YYYY" (enter Year)
"A" (keyboard equivalent to ENTER)
"DDDD" (enter Julian Day; See Prompt Sheet to transfer calendar days to Julian days)
"A" (keyboard equivalent to ENTER)
"HHMM" (hour and minute)
"A" (keyboard equivalent to ENTER)

The next step in the installation process is assigning a datalogger-ID to the station. This ID obviously serves to separate data from different sources. This is needed when a single storage module is used for transferring measurements from several stations to one office PC. METSTAT does not contain an automatic routine for this purpose. Instead, the user has to define the ID manually during installation.

To assign the ID, type in the following keyboard commands (given between double quotes for presentation purposes):
"*D" (activates D mode)
"8" (to go to command option 8)
"A" (keyboard equivalent of ENTER)
"xxx" (enter datalogger ID, this should be an integer between 1 and 12 or 14 and 254)
"A" (keyboard equivalent to ENTER)
"*0" (to activate the program, begin logging and re-enable security)

The last step in the installation process is protecting the system against unauthorized user interventions. For this purpose a password is introduced, which blocks access to (a) modifying the active datalogger program, (b) loading new programs, and (c) changing the memory allocations.

To enter a password, type in the following commands (given between double quotes for presentation purposes):
"*C" (activates C mode)
"2000" (the proposed default password for all dataloggers)
"A" (keyboard equivalent of ENTER)

Box 3: Temporarily De-activate Security

Security needs to be temporarily disabled when the user wants to reload METSTAT. To this end, type the following commands on the CR10KD (for presentation purposes given between double quotes):

"*C" (activates C mode)
"2000" (the proposed default password for all dataloggers)
"A" (keyboard equivalent of ENTER)

On entering "*0" security is automatically re-enabled.

This completes the installation process, and the datalogger should now be operational and executing the periodic measurements according to the instructions encoded in METSTAT.

The user can check the initial performance of the system by entering 'star-six' mode. This mode displays the input storage values, which represent the 'fresh' measurements. Annex 4 presents the respective input locations per variable used by METSTAT. The user can check if these values are within the expected range, and corresponding to the present weather conditions. Use "A" to advance to the next input location, and "B" to return to the previous one. Please note that METSTAT has an execution interval of 300 seconds. Hence the values shown in star-six mode do not represent the instant weather conditions.

If all values are within a satisfactory range, disconnect keyboard display and storage module. Installation of the CR10X is now completed.

Paragraph 2.6 presents a Prompt Sheet, which serves as a memory aid while in the field. It contains a comprehensive overview of relevant keyboard commands.

2.3 Use

The operation of the CR10X does not require any additional actions of the user once successfully installed. Sensor activation, measurements, initial data processing, and data storage are all fully automatic, according to the instructions given in METSTAT.

METSTAT includes a routine called 'instruction 96'. This instruction checks every 5 minutes if the SM4M storage module is connected to the system. If this is the case, METSTAT automatically initiates data transfer from the logger's Final Storage Areas to the SM4M. No further user interactions are needed. If the SM4M is not connected to the datalogger, which is of course the dominant situation, METSTAT simply aborts instruction 96 and continues with the next line in the program.

Hence downloading data from the CR10X datalogger to the SM4m storage module is accomplished by simply connecting the SM4M to the logger for minimal five minutes. However, to be positively sure that all data have been transferred, it is advised to keep the storage module connected for at least 15 minutes.

Experienced users can manually invoke data transfer by using the star-eight mode on the keyboard display. To this

end, type in the following CR10KD keyboard instructions (for presentation purposes given between double quotes):
"*8" (to activate Manual Data Dump using the star-eight mode)

METSTAT only uses Final Storage Area 1, and star-eight mode therefore automatically continues with the selection of the output device. The display will show "01". Type the following command:
"71" (this is the code for the SM4M storage module)
"A" (keyboard equivalent for ENTER)

The display shows a number. This is the Storage Module Pointer (SPTR), which represents the location up to which data have been downloaded in previous dump sessions. As a default, this is the starting point for the next data transfer exercise. To continue, type:
"A" (keyboard equivalent for ENTER)

The display shows a number; which is the address of the last occupied slot in the Final Storage Location, containing the most recent measurement value. As above, it concerns a pointer and is called the Data Storage Pointer (DSP). To continue, type:
"A" (keyboard equivalent for ENTER)

The display shows "04". To start data transfer, type:
"1" (in fact, any number would do)
"A" (keyboard equivalent to ENTER)

After finalizing the data dump, the keyboard displays the number of the last occupied Final Storage Location.

"Instruction 96", as well as the above-presented "star-eight" mode, only transfers 'fresh' data from the logger to the storage module, i.e. data that have not been down loaded before. In the majority of cases this is the appropriate procedure. The trouble shooting section in this paragraph presents the instructions for transferring 'old' data to the SM4M, i.e. data that have already been down loaded in a previous dump session.

2.4 Maintenance

The CR10X requires minimal maintenance. During the periodic inspection visits, the user should check that:

- all sensor cables are connected to the wiring panel according to the wiring schedule presented in Annex 2 and Table 1;
- the wiring panel is free of corrosion or other alien substances;
- the grounding cable between ENC12/14 central grounding point and wiring panel is firmly connected;
- the CR10X is firmly attached to the back plate in the protective enclosure ENC12/14.

The CR10X contains an internal lithium coil cell battery that operates the internal clock and SRAM when the datalogger is not connected to an external power source. This lithium battery should last for at least 4 years when no external power is available. However, in the default situation the datalogger is connected to the PS12LA power supply, and the expected lifetime of the lithium battery is therefore around 10 years. Consequently, battery replacement will not be needed in the mid term future.

The voltage of this internal Lithium battery can be measured using "star-B" mode, operation 8. The user is referred to the Campbell Scientific CR10X Operator's Manual for the exact instructions. If the voltage drops below 2.4 V the battery needs to be replaced. In this unlikely event, the user is advised to contact Campbell Scientific. Relevant addresses are presented in Annex 9.

2.5 Signature

METSTAT contains an instruction to calculate a program signature on a daily basis. This signature is a function of the exact text of the METSTAT program in the logger's memory. The signature therefore changes if the program is modified of corrupted. Thus, a daily calculation of the program signature represents a good test for checking the state of the datalogger program.

The reader is referred to Annex 5, for detailed instructions on how to check the daily program signature,. A change in program signature requires that METSTAT needs to be reloaded (for the appropriate instructions to this end see paragraph 2.2).

2.6 Prompt Sheet

The project has prepared a Prompt Sheet, which is intended as memory aid when going into the field to visit the Automatic Meteorological Stations. This sheet contains: (a) all relevant keyboard commands, (b) the wiring diagram, (c) an overview of the addresses used by METSTAT, (d) a table with Julian days, as well as other useful information while checking and operating the station.

The Prompt Sheet is included at the back of this manual. An additional laminated copy is provided, and can be left on site in the ENC12/14 protective enclosure.

2.7 Trouble Shooting

Problem 1: Logger is not recording/general failure.

Cause: The majority of general operation failures is due to a corrupted data logger program.

Remedy 1.1: Place a secure version of METSTAT in program location 8 of the Storage Module SM4M. De-activate security by following the instructions in Box 2. Connect the SM4M to the data logger with the SC12 cable. Switch power Off/On. The secure version of METSTAT is now automatically loaded into the logger's system memory, compiled, and made the active program. Re-activate security by following the instruction given in paragraph 2.2.

If the problems persist, all indicators are pointing towards a hardware problem.

Remedy 1.2: check if all cables are properly connected; check if wiring is according to the wiring schedule presented in Annex 2; check if power is connected (please note that the keyboard display CR10KD is powered by the logger, hence, if it works properly the problem is not related to power).

Remedy 1.3: check the grounding. The reader is referred to paragraph 4.5 for detailed instructions on how to ground the Met Station.

A series of test in the Project office has shown that inadequate grounding can have significant influence on the measurement values.

Box 4: Transfer Data Prior to Re-loading METSTAT into CR10X

Although re-installing METSTAT does not erase information stored in the logger's Final Storage Areas, it is advised to transfer all data to the storage module prior to (re-) loading METSTAT into the CR10X. To this effect, follow the instructions given in paragraph 2.3.

Problem 2: Data have been lost somewhere in the trajectory between logger and computer, or, have accidentally been deleted from the database.

Remedy 2: Due to the applied ring configuration of the logger's RAM, data are not erased from Final Storage after data dump. Only when the memory is full, old information is written over by new one. Given the expected data output of METSTAT and the size of the logger's RAM, data are preserved for about 5 months in Final Storage before being written over. Consequently, in the unlikely case that data are lost somewhere in the trajectory between Met Station and computer, or, if data are accidentally deleted from a database, it may still be recovered from the logger's RAM.

To down load "old" data from CR10X to SM4M, type in the following CR10KD keyboard instructions (for presentation purposes given between double quotes):

"*8" (to activate Manual Data Dump using the star-eight mode)

Since METSTAT only uses Final Storage Area 1, star-eight mode automatically continues with the selection of the output device. The display will show "01". Type the following command:
"71" (this is the code for the SM4M storage module)
"A" (keyboard equivalent for ENTER)

The display shows a number. This is the Storage Module Pointer (SPTR), which represents the location up to which data have been downloaded in previous dump sessions. As a default, this is the starting point for the next data transfer exercise. However, in this case the user must manually change the SPTR. To transfer the complete Final Storage to the storage module, type in:
"A" (keyboard equivalent for ENTER)

The display shows a number; which is the address of the last occupied slot in the Final Storage Location, containing the most recent measurement value. As above, it concerns a pointer and is called the Data Storage Pointer (DSP). Write down this number. Type in:
"B" (to go back to the previous step in the "star-eight" mode)

As before, the display shows a number, now representing the SPTR. To change the location from where data transfer will start, type in the DSP added with one. In this way the full Final Storage will be transferred to the SM4M. Continue by typing in:
"A" (keyboard equivalent for ENTER)

The display shows "04". To start data transfer, type:
"1" (in fact, any number would do)
"A" (keyboard equivalent to ENTER)

The actual search for the lost information should be done using the SPLIT module of the PC208W Data Logger Software. The user is referred to the separate SPLIT manual, included in Campbell Scientific' Instruction Manual for the PC208W Datalogger Support Software.

Problem 3: Although data transfer from logger to SM4M has been concluded successfully, the downloaded data does not cover the whole period between present and previous data dump. Instead, the available data only seems to come from the most recent period.

Cause: The SM4M automatically retrieves all data between Storage Module Pointer (SPTR) and Data Storage Pointer (DSP). In this particular case, the period between the two last data retrieval events has generated more data than the capacity of the logger's RAM. Consequently, given the logger's ring mode, new data have been written over not yet retrieved locations. The location of the SPTR has remained unchanged while the DSP, because of the circular configuration, has come back to its original position at a certain stage, and once again moved in front of the SPTR.

Remedy 3: Increase the frequency of inspection and data retrieval visits to the station. Part of the lost information can be recovered by manually down loading data using the "star-eight" mode. To this end follow the instructions given under "Remedy 2".

Sensors

3.1 Tipping Bucket Rain Gauge

3.1.1 General

The Met Station includes a TE525 tipping bucket rain gauge made by Texas Electronics, USA. It is a smaller adaptation of the standard US Weather Bureau tipping bucket rain gauge. The instrument is equipped with two buckets, with a known volume, connected to each other by a horizontal axis balanced on a fulcrum. Rain is collected with a conventional funnel of standard diameter and directed to one of the buckets. Once this bucket is full, it becomes unstable and tips, herewith emptying the full bucket and bringing the other bucket into filling position. Each tip generates an electric pulse, which is recorded by the data logger. A pulse represents 0.1 mm of rainfall, and the total rain volume is thus obtained by summing the pulses and subsequent multiplying with 0.1. The user can measure the temporal distribution of a rainfall event by defining short time intervals in which the pulses are aggregated and recorded.

For detailed technical specifications of the TE525 Tipping Bucket Rain Gauge, the reader is referred to the corresponding Campbell Scientific' Instruction Manual.

Figure 7 shows the TE525.

Figure 7: Tipping Bucket Rain Gauge TE525

3.1.2 Installation

The rainfall recordings should be representative for the surrounding area. Towards this end, the user is advised to observe the following guidelines when selecting the rain gauge location:

- Select a site for the Met Station that it is representative for the area. Wind speed at gauge level should be uniform, and preferably as small as possible;
- Remove all obstacles in the vicinity of the gauge that could create wind effects, as these may influence the rain catch; the distance of the gauge to obstructing objects should be at least 4 times the height of the obstruction;
- No objects should intercept precipitation that should reach the gauge;
- The area surrounding the gauge should be relatively level, and the gage orifice should be horizontal; the lip of the funnel should be at 50 cm above the ground.
- The ground surrounding the gage should be covered with short grass, equivalent natural vegetation, or gravel to avoid splashing of rainfall into the gage; the ground surface around the gage should not be paved.

The TE525 Rain Gauge mounts to a 2-inch pipe. Drive the pipe into the ground to acquire a firm vertical post, and use the enclosed hose clamps to mount the gauge to this post. The lip of the funnel should be 50 cm above ground level and at least 5 cm above the post. Level the gauge after mounting it.

Note: before final leveling, press one of the buckets down against its stop to make sure that the buckets are NOT hung up in the center.

The TE525 includes a 25 feet electrical cable. To protect this cable from accidental cutting, it should be placed in a 1-inch underground PVC tube from rain gauge to tripod. Next, lead the cable through the opening in bottom of the ENC12/14 protective enclosure to the datalogger. Tie up carefully any excess cable, and do not cut it off, as it may be useful in other occasions. Connect the stripped black wire to terminal P2 of the wiring panel, and the stripped clear wire to terminal G next to P2. See table 1 in paragraph 2.2, and Annex 2 for the detailed wiring schedule of the CR10X data logger.

3.1.3 Operation

Operation of the TE525 Tipping Bucket Rain Gauge is fully automatic and does not require any user intervention. The appropriate instruction for this purpose is included in the datalogger program METSTAT. The reader is referred to paragraph 2.2 and Annex 3 in case of need of more information on this subject.

3.1.4 Maintenance

Maintenance is limited to the following. At every visit to the Met station:

- Check if the TE525 is securely attached to the post, and that the post is firmly implanted in the ground;
- Check if the cable from TE525 to tripod is completely underground;
- Check if all excess cable is carefully tied up, and that the wires are soundly connected to the wiring panel. If necessary clean contacts;
- Check if the funnel and bucket mechanism are clean; remove any leaves, dust, insects, or other foreign material.

Perform a field calibration check every 12 months, as follows:

- Secure a metal or plastic can that can hold at least one liter of water;
- Punch a very small hole in the bottom of the can;
- Place the can on top of the funnel of the rain gage, and pour 0.5 liter of water into the can;
- The hole is too large if it takes less than 40 minutes to empty the can;
- This should result in 91 tips, plus or minus three;
- If necessary correct the tipping mechanism. Adjusting screws are located on the bottom next to the large center drain hole. One half-turn of both screws causes 2% to 3% change. Adjust both screws the same number of turns. A rotation clockwise increases the number of tips per 0.5 liter, while a rotation counter-clockwise decreases the number of tips.

- Check and re-level the rain gage lid.

In principle no factory calibration is needed. In the unlikely event that such calibration would be required, the reader is referred to the corresponding Campbell Scientific Instruction Manual for the TE525 Tipping Bucket Rain Gauge for further instructions.

3.1.5 Trouble Shooting

Problem 1: No rainfall is recorded in spite of clear evidence of a recent rain event.

Remedy 1.1: Check if all wires are properly connected, both to the rain gauge and to the CR10X wiring panel. The reader is referred to table 1 in paragraph 2.2, and Annex 2 for the correct wiring of the CR10X. Check if the cable from gage to logger has not been cut (for example during slashing).

Remedy 1.2: Check if the tipping mechanism in the rain gage is not blocked.

Remedy 1.3: Re-load METSTAT following the instructions given in paragraph 2.5.

3.2 Met One 034A-L Windset

3.2.1 General

The Met Station includes the Met One 034A-L integrated cup anemometer and wind vane for monitoring wind speed and direction. Wind observations are mainly used for determining potential evaporation. However, these measurements can also be useful for hydraulic design, selecting locations for wind mills, positioning air strips, etc..

Figure 8 shows the Met One 034A-L Wind Set.

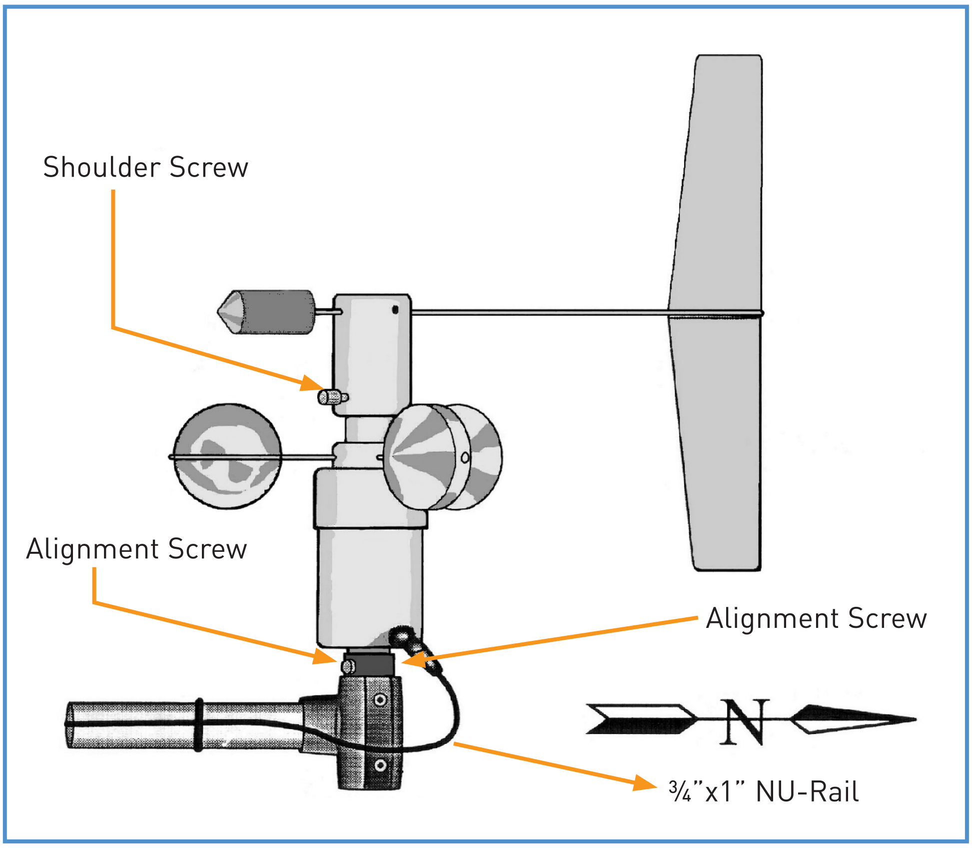


Figure 8: Met One 034A-L Wind Set

Wind speed is measured by the anemometer, which consists of three cups in a horizontal plane that rotate on a vertical shaft. This rotation activates a sealed reed switch. Each open-closure event of this switch generates an electric pulse, which is recorded by the datalogger. The rate of pulses is proportional to the wind speed.

Wind direction is also sensed electronically. The wind vane drives a 10-kilo ohm potentiometer connected to the logger. The recorded voltage is a function of the declination of the vane, and thus of the wind direction.

For detailed technical specifications, the reader is referred to the corresponding Campbell Scientific Instruction Manual for the Met One 034A-L Wind Set.

3.2.2 Installation

The wind sensors should be located away from wind obstructing obstacles like trees and buildings. As a general rule, the horizontal distance between wind set and obstruction should measure at least ten times the height of the obstruction.

Follow the below instructions to install the Wind Set. Figure 8 presents a graphic explanation of some of the terminology used.

- Attach the 019ALU cross arm to the top of the tripod;
- Orient this cross arm in the east-west direction, with ¾" x 1" Nu-rail facing West on the Southern hemisphere, and East on the Northern hemisphere, and tighten the set screws;
- Remove the alignment screw at the base of the 034A-L (wind set) and insert 034A-L into the aluminum bushing (black) provided with the sensor;
- Align the hole in the bushing with that in the 034A-L base and replace the screw
- Place the Wind Set with bushing into ¾" x 1" NU-rail and tighten the alignment screw firmly;
- Align the sensors so that the counter weight points to the true south and tighten the set screws on the NU-rail;
- Remove the shoulder screw to allow the vane to rotate;
- Attach the sensor cable, properly keyed, to the six pin male connector on the Wind Set;
- Finger tighten the knurled ring;
- Route the sensor cable along the underside of the cross arm to the tripod and down to the ENC12/14 protective enclosure;
- Lead the cable through the bottom of the enclosure to the datalogger; do not cut any excess cable since this may be useful at other occasions, instead tie it up carefully;
- Connect the cable to the wiring panel according to table 1 in paragraph 2.2, and Annex 2, as follows:
  - green wire to terminal H3:
  - blue wire to terminal E1;
  - white wire to the AG terminal next to E1;
  - clear wire to the last G terminal of the connector block;
  - red wire to terminal P1:
  - black wire to the G terminal next to P1;

Box 5: Determining the Geographic North

A compass is the appropriate instrument for locating the North. However, a compass determines the magnetic north, which differs from the geographic one. Though the location of the magnetic north is subject to constant change, it can be considered stable for time spans in the order of magnitude of 100 years.

The magnetic declination is defined as the angle between magnetic and geographic north. It has been determined for each spot on earth and is exactly THREE DEGREES and ZERO MINUTES West in the Lake Victoria region.

To determine the geographic north, measure the magnetic north with a compass and adjust for the existing magnetic declination by adding THREE DEGREES and ZERO MINUTES in a clock- wise direction.

While orienting the cross arm and Nu-rail using a compass, please note that there is a difference between geographic and magnetic north. Figure 9 presents the current declination angle for the Lake Victoria region.

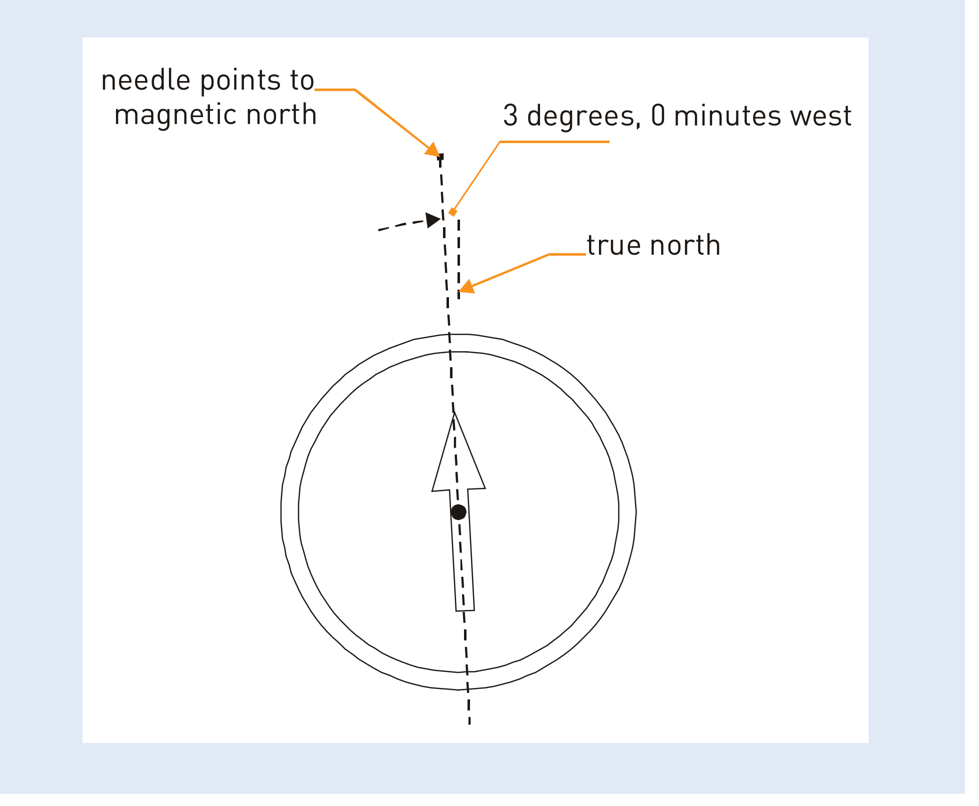


Figure 9: Declination Angle in the Lake Victoria Region

3.2.3 Operation

Operation of the Met One 034A-L Wind Set is fully automatic and does not require any user intervention. The appropriate instructions for this purpose are included in the datalogger program METSTAT. The reader is referred to paragraph 2.2 and Annex 3 in case of need of more information on METSTAT.

3.2.4 Maintenance

The Met One 034A-L Windset requires the following maintenance:

- During each visit to the Met Station, visually inspect the anemometer at low wind speeds; verify that the cup assembly and wind vane rotate freely; check if all connections are tight; check if the rotating elements do not generate unusual sounds; remove all foreign material (spider webs, etc.) from both anemometer and vane;
- Each two years, replace the anemometer bearings (contact Campbell Scientific);
- Each two years, replace the wind vane potentiometer and bearings (contact Campbell Scientific).

3.2.5 Trouble Shooting

Problem 1: Both wind speed and wind direction values are zero.
Remedy 1.1: Check if all wires are properly connected, both to the Met One 034A-L and to the CR10X wiring panel. The reader is referred to table 1 in paragraph 2.2, and Annex 2, for the correct wiring of the 034A-L to the CR10X.
Remedy 1.2: Re-load METSTAT following the instructions given in paragraph 2.5.

Problem 2: Unusual and/or unexpected recordings for either wind speed or direction.
Remedy 2: Re-load METSTAT following the instructions given in paragraph 2.5.

Problem 3: Recorded wind directions exceed 360 degrees.
Remedy 3.1: Connect the CR10KD keyboard and use "star-six" mode to monitor the input locations. Check in Annex 4 which one is used for Wind Direction and use the "A" key to advance to this location.

Manually rotate the wind vane to its maximum location; this is where the value on the keyboard jumps back to zero. Write down the maximum wind direction (e.g. 367 degrees). Adjust the multiplier in the Wind Direction Instruction in METSTAT by multiplying this value with 360 divided by the maximum wind direction. For this necessary modification of METSTAT, the reader is referred to the Campbell Scientific Operators Manual for the CR10X Storage and Control Module.

3.3 LI200X Pyranometer

3.3.1 General

Short wave solar radiation is an important parameter for determining potential and actual evaporation. It is used both in the Penman-Monteith and Priestley-Taylor approach. The LI200X pyranometer measures both sun and sky radiation on a horizontal surface. It uses a silicon photovoltaic cell mounted in a cosine-corrected head. The initial current output of this sensor is transferred to voltage, which facilitates direct connection to the datalogger.

The technical specifications of this sensor are discussed in detail in the corresponding Campbell Scientific Instruction Manual for the LI200X pyranometer. The reader is referred to this text in case of need of more information.

3.3.2 Installation

Attach the 025 Pyranometer Cross Arm Stand to the 019 ALU Cross Arm. Figure 10 presents a graphical sketch of the set-up, as well as some of the used terminology.

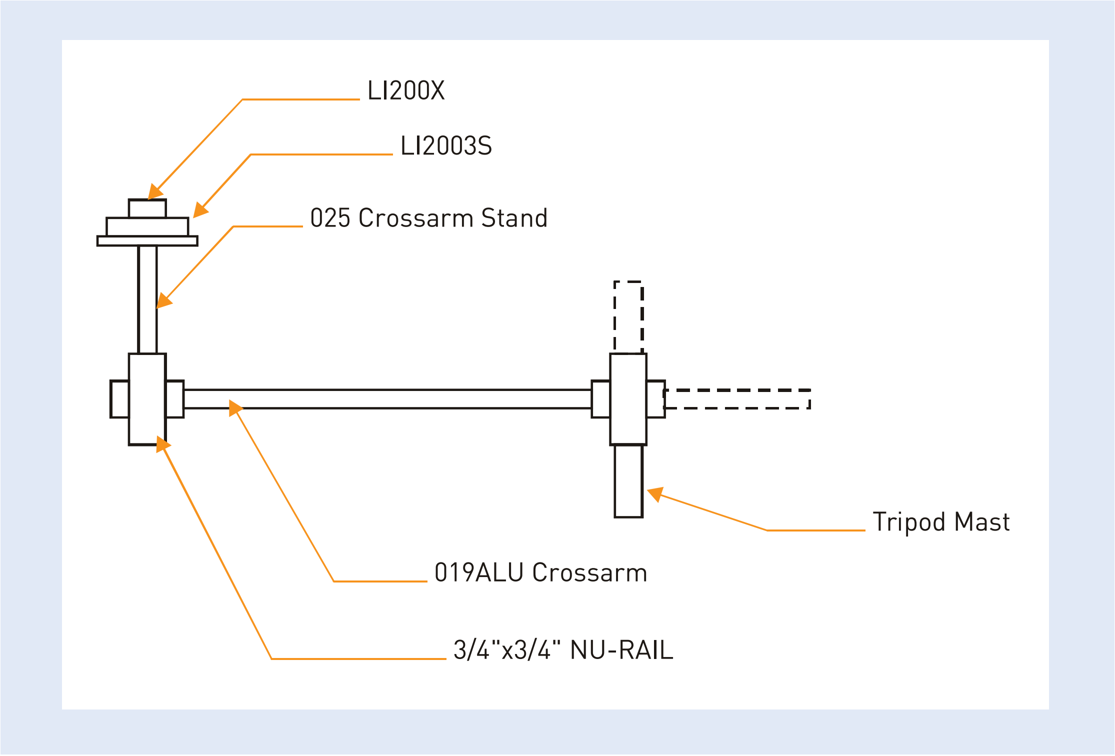


Figure 10: Installation of LI200 Pyranometer to Tripod

Fix the LI2003S base to the cross arm stand using the provided screws. Make sure the base is perfectly horizontal by adapting the adjustment screws. Towards this end, the air bell of the built-in spirit level should be exactly located in the middle of the circle on the glass.

Place the pyranometer in the base so that the cable fits into the slot. Tighten the pyranometer to the base plate with the hex screw.

The LI200X should never be shaded by the tripod tower or other sensors.

Attach the pyranometer cable to the wiring panel of the CR10X logger according to table 1 in paragraph 2.2, and Annex 2, as follows:

- red wire to terminal H2;
- black wire to terminal L2;
- white wire to left most G terminal of upper terminal block;
- clear wire to next left most G terminal of upper terminal block.

Remove the red protection cap after installing the sensor. Save this cap for shipping or storing the sensor.

3.3.3 Use

The operation of the LI200X pyranometer is fully automatic and no user actions are required. The appropriate instructions to this end are included in the METSTAT datalogger program. The reader is referred to paragraph 2.2 and Annex 3 in case of need of more information on METSTAT.

3.3.4 Maintenance

The following maintenance is required:

- During every visit to the Met Station, check if the level of the pyranometer is perfectly horizontal (the air bell of the spirit level should be in the middle of the circle on the glass), correct if necessary with the adjustment screws;
- Remove any dust or debris from the pyranometer with a soft bristle;
- Check if the drain hole next to the sensor is free of debris;
- Calibrate the LI200X every two years (contact Campbell Scientific).

Box 6: Caution While Cleaning the Solar Radiation Sensor

The surface of the silicon photovoltaic cell is sensitive to scratching. Handle the sensor with care while cleaning. Only use a soft bristle. Never use hard or sharp materials for this purpose.

3.3.5 Trouble Shooting

Problem 1: Solar radiation values are zero.

Remedy 1.1: Check if all LI200 wires are properly connected to the CR10X wiring panel. The reader is referred to table 1 in paragraph 2.2 and Annex 2 for the correct wiring of the LI200 to the CR10X.

Remedy 1.2: Re-load METSTAT following the instructions given in paragraph 2.5.

Problem 2: Solar radiation measurements are in a range well below expected values.

Remedy 2: Carefully clean the sensor or remove any object that is shading it.

3.4 CS500 Temperature and Relative Humidity Probe

3.4.1 General

The CS500 Temperature and Relative Humidity Probe electronically measures both temperature and relative humidity. It contains a platinum resistance temperature detector and a Vaisala INTERCAP capacitive relative humidity sensor. The probe is programmed to take measurements at a 5-minutes interval. The datalogger places all daily recordings in a temporary memory, and this information is then used to determine (a) hourly average temperature and relative humidity, (b) daily average temperature and relative humidity, and (c) daily maximum and minimum temperatures. Only these values are stored in the logger's Final Storage Area, and the temporary memory is erased at the end of a recording day.

The CS500 is powered by the CR10X 12V peripheral power terminal and draws about 2 mA current while active. To conserve energy, the datalogger is programmed to deactivate the CS500 when the probe is not measuring.

For detailed specifications, the reader is referred to corresponding Campbell Scientific Instruction Manual for the CS500 Temperature and Relative Humidity Probe.

3.4.2 Installation

The CS500 must be housed inside a solar radiation shield. Clamp the radiation shield to the tripod mast as shown in figure 11. Remove the yellow protection cap, place the CS500 into the radiation shield, and fix it with the mounting clamp. Keep the yellow protection cap for future shipping and storage.

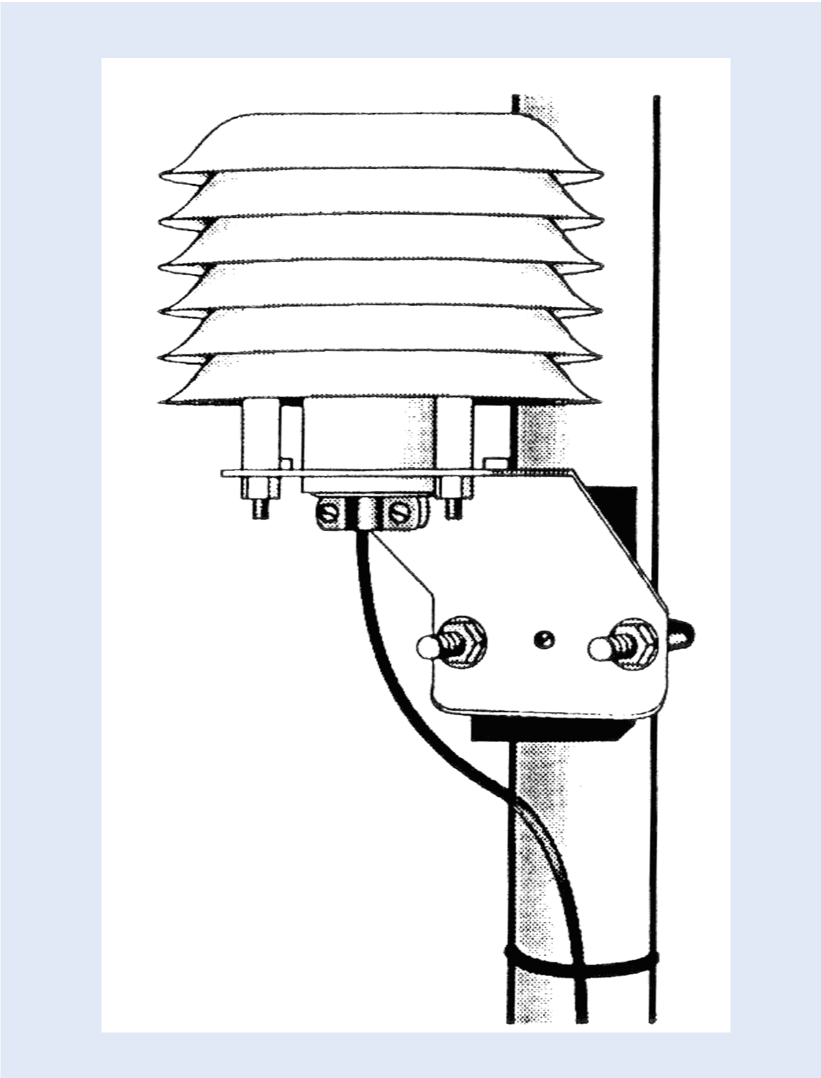


Figure 11: Radiation Shield for the CS500 Temperature & RH Sensor

Attach the CS500 cable to the wiring panel of the CR10X logger according to the wiring diagram in table 1 in paragraph 2.2, and Annex 2, as follows:

- black wire to terminal H1;
- clear wire to G terminal left of H1;
- brown wire to terminal L1;
- green wire to AG terminal right of L1;
- red wire to terminal SW 12V;

- jumper from terminal SW 12V CTRL to terminal C1.

3.4.3 Use

The operation of the CS500 is fully automatic and no user action is required. The appropriate operating instructions are included in the METSTAT datalogger program.

3.4.4 Maintenance

The CS500 only requires minimal maintenance, as follows:

- During each visit to the Met Station, check if the radiation shield is free from dust and debris;
- Each two years, replace the humidity chip (contact Campbell Scientific).

3.4.5 Trouble Shooting

Problem 1: Temperature and or Relative Humidity values are zero.
Remedy 1.1: Check if all CS500 wires are properly connected to the CR10X wiring panel. The reader is referred to table 1 in paragraph 2.2, and Annex 2, for the correct wiring of the CS500 to the CR10X.
Remedy 1.2: Re-load METSTAT following the instructions given in paragraph 2.5.

Power Supply

4.1 General

The Met Station is equipped with electronic sensors and an electronic datalogger. Hence electronics play an important role in the data acquisition process. Proper performance of electronic equipment depends to a large extent on a stable and reliable power supply. Failure of electronic equipment is all too often the result of power surges, power cuts and related spikes.

The above clearly indicates the crucial role of the power supply in the Met Station. Proper installation, use, and maintenance of this element will considerably improve the performance of the equipment, and significantly prolong the life span of the electronic components of the station.

The Met Station is equipped with a PS12LA power supply, which comprises of the following elements:

- Sealed rechargeable battery;
- Solar panel;
- Charging unit;
- Grounding;
- Wiring.

A rechargeable lead acid battery supplies a 12 V direct current to the electronic datalogger. The battery itself is charged by a photovoltaic solar panel. A regulator on the charging unit controls the power drain and recharge of the battery. This regulator can be perceived as the 'command and control center' of the power system.

Box 7: Only Use Campbell Scientific PS12LA

Never connect the system to any power source other than the Campbell Scientific PS12LA, as this may cause serious and irrevocable damage to the equipment.

The following paragraphs present the user instructions for installation, use, and maintenance of all hardware components of the power supply. The appropriate wiring of the sensors is included in respective sensor paragraphs.

4.2 Sealed Rechargeable Battery

4.2.1 General

The datalogger and sensors are powered by a YUASA 7 Ahr sealed rechargeable battery. It concerns a lead acid gel battery, which uses a non-liquid electrolyte. The battery is sealed at the factory and does not leak or spill. The user should not open the battery at any time since this may negatively affect the life span of the battery.

Battery lifetime varies between 2 and 10 years, depending on maintenance and charge. Most common failure of a battery is due to (a) prolonged deep discharge, (b) overcharge, or (c) fast charge. Experience in East Africa has shown that the battery should function properly for at least three years if operated according to guidelines specified in this text. Please keep in mind that the performance of the whole system relies heavily on the state of the battery.

There are inherent hazards associated with the use of a sealed lead acid battery. Under normal operation, a lead acid battery generate a small amount of hydrogen gas. This gaseous by-product is generally insignificant because the hydrogen dissipates naturally before building-up to an explosive level (4%). However, if a battery is shorted or overcharged, hydrogen gas may be generated at a rate sufficient to create hazard.

4.2.2 Installing/Changing the Battery

The PS12-LA power supply housing forms the battery holder. It is shown on figure 12, together with other elements of the power supply.

Follow the below specified guidelines to replace the battery:

- Detach the cover of the PS12-LA housing by unscrewing the two screw on both sides of the cap;
- Disconnect power to the datalogger by toggling the switch to OFF;
- Clip off the battery connector from the terminal INT;
- Take out the battery;
- Put in the new battery, make sure the battery terminals are on the side of the regulator;
- Plug the battery connector into the INT terminal, make sure the clip is properly attached;
- Reconnect power to the datalogger by toggling the switch to ON;
- Replace the cover.

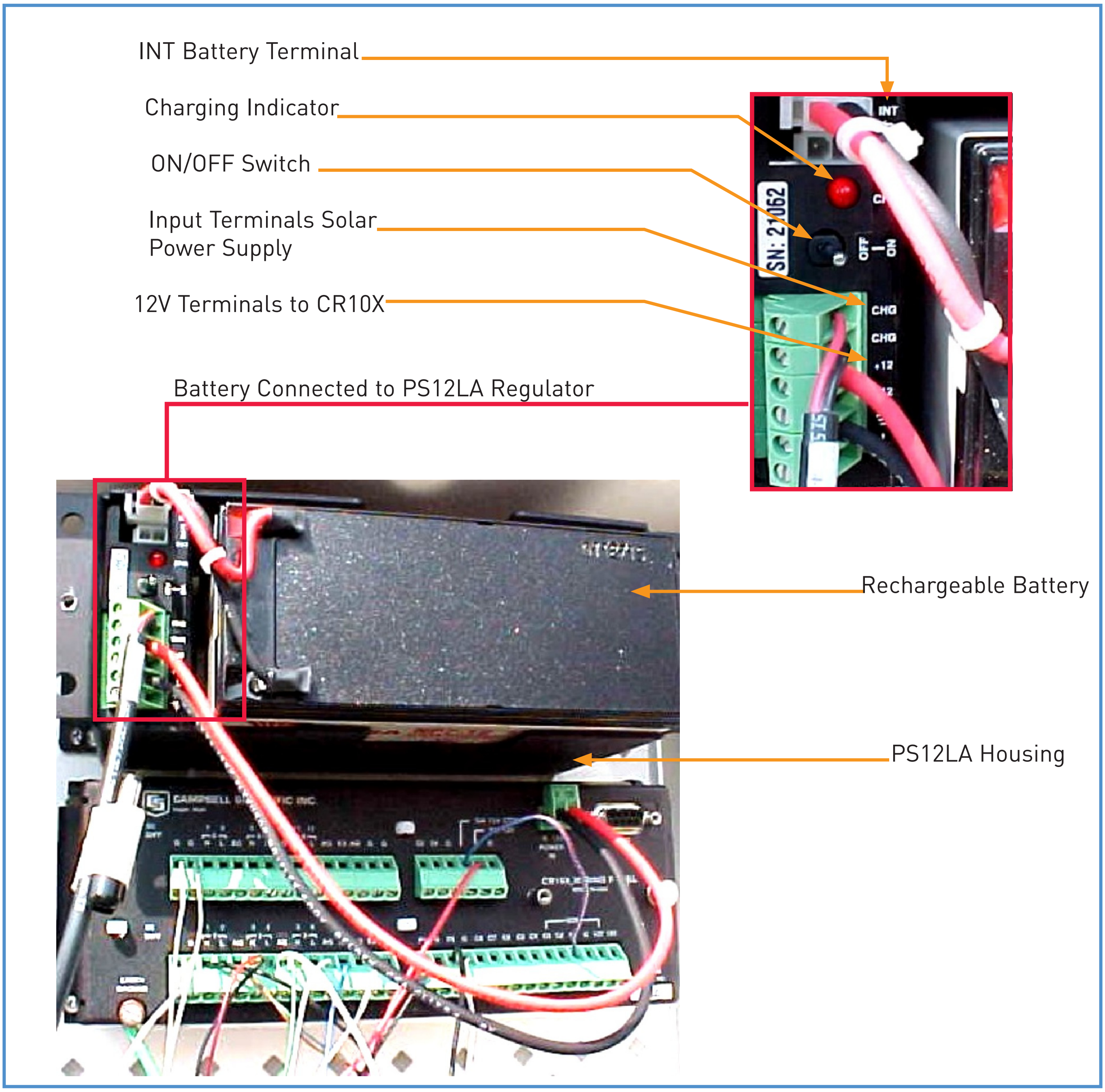


Figure 12: PS12-LA Power Supply for CR10X Storage and Control Module

4.2.3 State of the Battery

To avoid either deep discharge or overcharge, the amount of energy in the battery needs to be monitored. The State of Charge (SoC) is a good indicator for this. Table 2 presents the SoC for the Yuasa 7 Ahr sealed lead-acid battery as function of the voltage, for a situation when no load is attached. This is called the Open Circuit Voltage (OCV). Obviously, actual performance varies per individual battery, and therefore a lower and upper limit for the OCV has been defined.

Table 2: SoC Versus Open Circuit Voltage for a Yuasa 7 Ahr Lead Acid Gel Battery

State of Charge[%]	Open Circuit Voltage(lower limit [V]	Open Circuit Voltage(upper limit) [V]
100	12.80	12.80
90	12.65	12.65
80	12.50	12.50
70	12.35	12.35
60	12.20	12.20
50	12.05	12.05
40	11.90	11.90
30	11.75	11.75
20	11.60	11.60
10	11.45	11.45
0	11.30	11.30

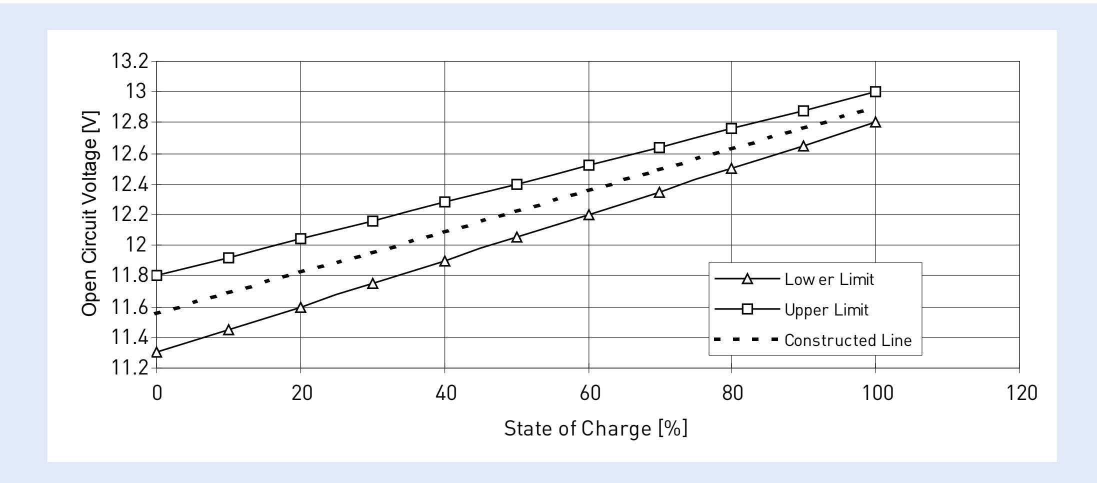
As indicated in Table 2, lead-acid rechargeable batteries have no uniform characteristics. This is partly because of the intrinsic behavior of batteries, but also a result of the individual history of a battery. A single deep discharge event will certainly change the performance of a battery.

It is for these reasons that we cannot define a clear, univocal relation between State of Charge and Open Circuit Voltage. Instead, such a relation falls within a band defined by a known upper and lower limit (see figure 13). However, one can obtain a good indication of the behavior of a battery by knowing the voltage in the fully charged state (SoC 100%), and presuming a straight line downwards from this point interpolated between the upper and lower limits.

The user should follow the below guidelines to construct the relation 'State of Charge versus Open Circuit Voltage' for an individual Yuasa 7 Ahr battery:

- Make sure the battery is fully charged (to this end, charge the battery for 48 hours using the CH12R charging unit; see paragraph 4.2.4 for detailed instructions on recharging a battery)
- Contact the volt meter's lead to the positive and negative battery terminals, and read the voltage;
- Presume this voltage corresponds with SoC 100%; hence a starting point of the curve is obtained;
- Draw a straight line starting from this point interpolated between the upper and lower limits.

Figure 13 presents an example of this procedure. It presumes a SoC 100% voltage of 12.9 V.



Given this individual SoC-OCV relation, the user can now assess the SoC of a known lead acid battery. To this end, follow the below instructions:

- Disconnect the battery from the load and/or charge;
- If the battery is being charged or discharged, wait 20 minutes for the battery to stabilize;
- Contact the volt meter's lead to the positive and negative terminals of the battery, and read the voltage;
- Compare the reading to individual SoC-OCV relation for the particular battery.

Never discharge a sealed lead acid gel batteries below 40% SoC as this may negatively affect the life span of the battery.

To keep track of their performance and state, each battery should be numbered and marked and an individual log should be kept, indicating:

- Date of purchase / delivery;
- Initial OCV;
- Dates of charge and OCV in fully charged state;
- Period of use including name of station and average load;
- SoC and OCV at end of period of use;
- Irregularities / remarks.

Annex 6 presents a sample form for a battery log.

Always make sure that the log is kept accurately. A duly kept logbook is invaluable in assessing the condition and state of a battery. It will indicate if a battery is reaching the end of its life span and needs to be disposed of and replaced. Timely replacement will ensure continuous station operation, without unexpected power failures, which may result in data loss, or worse, damage to the equipment.

METSTAT also includes a routine for measuring the battery voltage on a daily basis. However, the user cannot easily evaluate this information while on site, as it requires some data processing. Instead, these battery voltage recordings need to be examined after transfer of the data to the office PC. The reader is referred to Annex 6 for detailed guidelines for assessing battery performance using the daily voltage record.

The measurement schedule of the Met Station results in an average power drain of 1.14 mA. In case of the unlikely situation without external power, this would discharge a fully charged 7Ahr battery to a SoC of 80% after 50 days. Such situation could occur when the solar panel fails or get disconnected, or when the charging unit malfunctions. A discharge below a SoC of 80% will negatively affect the life expectancy of the battery. It is therefore advised to follow the below guidelines:

- Visit the meteorological station on a monthly basis;
- Visually check if all wires are connected properly, and if all contacts are clean and not corroded;
- Connect the CR10KD Keyboard and check the state of the battery using "star-six" mode; input location 23 is assigned to battery voltage;
- If the voltage is below the initial OCV minus 0.05 volt, a problem has occurred with the power supply; check the performance of the solar panel and regulator; make sure to identify and fix the problem;
- If the voltage is below 12.5 volt, replace the battery with a fully charged one;
- Take the battery to the Office and immediately recharge it slowly with the CH12R charging unit; follow the instructions under 'recharge'.

4.2.4 Recharge

If the SoC of a battery falls below 80%, it should be returned to the office for recharge. Proper recharge will significantly increase the life span of the battery, while improper recharge can destroy it. The user is therefore advised to carefully read the guidelines in this paragraph.

Overcharging a sealed (captive) electrolyte battery will cause loss of electrolyte and will strongly reduce battery life. Moreover, overcharging may lead to the formation of dangerous levels of highly explosive hydrogen gas. Likewise, fast charging greatly reduces the life of the battery by quickly lowering the level of electrolyte in the cells, herewith damaging the plates. The user is therefore advised to only recharge the battery using the provided CH12R charger. This unit includes a regulator, which monitors the voltage and battery state, and stops charging when the battery is full. It also contains a control device that limits the recharge current to the recommended low levels.

Box 8: Only Use Campbell Scientific CH12R Charging Unit

Never use a fast recharger as this may destroy the battery or can even be hazardous. Only use the Campbell Scientific CH12R charging unit.

The CH12R charging unit is identical to the charger/regulator in the PS12-LA power supply. It is powered by an 18V Alternating Currency source, supplied by International Power Sources, which operates on an input range of 100–240V. This 100-240V to 18V AC wall-charger can therefore be plugged-in directly in the mains anywhere in Africa without requiring an additional transformer. To operate the CH12R charging unit, follow the below instructions:

- Switch off mains power in the designated socket;
- Plug the 100V-240V to 18V wall-charger into the socket; if necessary use an appropriate plug adapter;
- Insert the two leads (black and white) from the wall-charger into the two terminals labeled CHG on the CH12R charging unit, polarity does not matter;
- Connect the battery to the CH12R charging unit by plugging the battery connector in the terminal labeled INT;
- Switch on the mains power; a red light (LED) indicates that the charging unit is powered;
- Necessary charging time depends on SoC of the battery; for full charge it is 40 hr;
- After charging, remove the battery from the CH12R charging unit, wait 20 minutes for the battery to stabilize and measure battery voltage;
- If the corresponding SoC is below 100%, continue charging process;
- If the corresponding SoC is 100%, store the battery in a wooden box in a cool, dry place.

A low State of Charge for a prolonged period (several months) may result in permanent loss of some of the battery capacity. Therefore, upon return to the office, immediately recharge a battery that has just been used in the field. Do not wait until the battery has to be used again to recharge it.

Lead acid gel batteries have a low self-discharge, which typically amounts to less than 5% per six months. However, it is still recommended to regularly check the SoC while the battery is in storage, and recharge it if its SoC falls below 80%. This will increase the life span of the battery.

Before use in the field, fully recharge the battery using the CH12R charging unit.

4.2.5 Battery in Storage

While in storage, treat the batteries as follows:

- Store the full battery in a cool, dry place on a shelf in a wooden box;
- Check the SoC every month using the volt meter;
- If SoC is below 80%, recharge the battery using the CH12R charging unit.

4.2.6 Maintenance

Lead acid gel batteries require little maintenance. The most important issue is to regularly measure the SoC to avoid deep discharge, as indicated in the previous paragraph. Other maintenance includes:

- Regularly clean the top of the battery to avoid high levels of self discharge due to acid mist accumulated on top of the battery;
- Regularly clean the terminals and contacts to ensure good electrical connection with the appliance;
- Regularly grease the terminals and contacts to avoid corrosion.

4.3 Solar Panel

4.3.1 General

The solar panel is a photovoltaic (PV) power source used for charging the sealed lead-acid battery of the Met Station. It therefore constitutes the primary energy source of the system, although it does not directly power the datalogger and sensors. The MSX10 solar panel itself does not include a regulator. Instead, the charging process is controlled by the regulator included in the PS12-LA power supply. The solar panel operates in both direct and diffuse light, but obviously not at night.

The solar panel concerns a polycrystalline module type MSX10 with a maximum output of 10 W. Detailed specifications are presented in the Campbell Scientific Instruction Manual on MSX10 Solar Panels.

4.3.2 Installation

To receive maximum insolation, the panel should be mounted facing south in the Northern Hemisphere, and facing north in the Southern Hemisphere. It should be attached to the tripod mast using the provided nuts and bracket, with a tilt angle of 80%. Make sure that no part of the panel is shaded or covered by trees, constructions, or other objects, as this will reduce the output or may even permanently damage the unit. Please note that even if a single cell is shaded, the output of a crystalline module will fall considerably. Figure 14 shows the mounting of the panel on the tripod.

Once the MSX10 is mounted properly, route the solar panel cable through the opening at the bottom of the protective ENC12/14 enclosure to the PS12-LA power supply, and insert the two pre-stripped and tinned leads into the terminal labeled 'CHG' on the unit. See figure 12 for the input terminals of the power supply. Polarity does not matter.

4.3.3 Use

Once properly installed and connected to the PS12-LA power supply, the MSX10 Solar Panel does not require any attention except for some periodic minor maintenance. There are no user actions required in operating the solar panel.

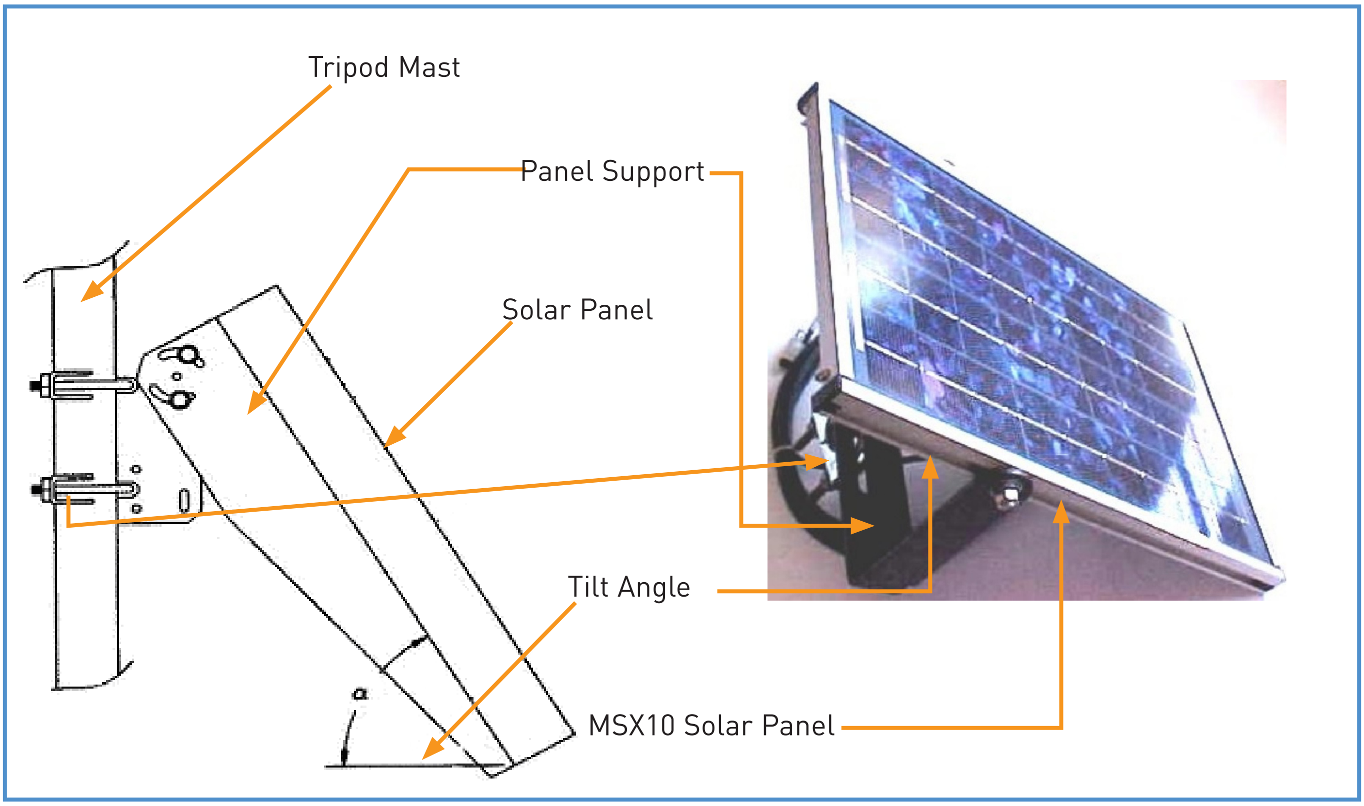


Figure 14: Mounting of the Solar Panel on the Tripod

4.3.4 Maintenance

The MSX10 Solar Panel requires a minimum of routine maintenance. The following is recommended:

- To improve the panel's efficiency, clean the glass plate during each visit with a soft, lightly moistened cloth. Do not use any abrasive pad or cleaner, as this may permanently scratch the glass. Please keep in mind that a dust cover on top of the module is reducing power output.
- Make sure that no part of the panel is shaded or covered while the rest of the panel is exposed to sunlight, as this can permanently damage the unit. Remove tree branches that may shade the panel or provide a source for leaves. Remove plants and trees that grow up around the tripod.
- Measure the voltage output of the panel if a problem is expected (for instance because of steady discharge of the battery under normal climatic conditions). Obviously, this test requires incident solar radiation. It also needs a load attached to the solar panel, which can be simulated with (a) a 75-ohm resistor cable, or (b) connection to the PS12-LA while the station is in operation. The panel is damaged if no voltage output is measured.
- Check occasionally for loose nuts in the mounting hardware.

4.3.5 Trouble Shooting

Problem 1: Battery is discharging steadily in spite of recent sunny periods.
Remedy 1.1: Clean the solar panel.
Remedy 1.2: Check if all wires are connected properly.
Remedy 1.3: Check if incoming solar radiation is not obstructed; remove obstructions.

4.4 Charging Unit

4.4.1 General

The regulator/charging unit of the PS12-LA power supply has three primary functions:

1. To provide a central connecting point for the solar panel, the datalogger, and the battery;
2. To manage the power supply to the datalogger, and to protects the battery from overcharge, fast charge, and deep discharge;
3. To allow the user to monitor the system and locate potential system problems.

As indicated in paragraph 4.2.4, deep discharge, overcharge, or fast charge strongly reduces the life span of a battery. To avoid these conditions, the regulator monitors the state of the battery, regulates the recharge current, and limits the power drain to within an acceptable range. Hence the charging unit/regulator plays an important role in safe guarding the system. Failure of this device often results in malfunctioning of other components of the Met Station.

4.4.2 Installation

Installing the charging unit/regulator requires only limited user actions, as this component is integrated into the PS12-LA power supply. The regulator itself is presented in Figure 12.

Similar to the instruction in paragraph 4.3.2, insert the leads from the solar panel into the terminals labeled CHG; polarity does not matter. Connect the battery by plugging the battery connector in the terminal labeled INT.

Connection of the charging unit/regulator to the datalogger is described in paragraph 2.2.

4.4.3 Use

Operation of the charging unit/regulator is almost completely automatic. User intervention is limited to toggling the power to the datalogger On/Off.

A red light (LED) indicates when a charging source is connected to the charging unit/regulator.

4.4.4 Maintenance

Apart from checking periodically if all contacts are firmly connected and not corroded, no maintenance is necessary.

4.5 Grounding

4.5.1 General

To protect the Met Station against lightning strikes, as well as to ensure proper functioning of the system, all components (datalogger, sensors, power supply, housing, mounts, etc.) need to be referenced to a single common earth ground. In the event of a lightning strike, the purpose of the earth ground is to minimize damage to the system by providing a path of low resistance to a point of low potential. This is achieved with a lighting rod connected with a copper cable to a 1.5 m long copper-grounding rod.

4.5.2 Installation

Drive the copper rod into the ground at a distance of about 1 meter from the tripod. Use the 12 AWG copper isolated wire to connect the grounding rod with the copper clamp. Make sure the contacts are clean and not corroded. Attach the other end of the grounding cable to the specified screw at the bottom of the protective enclosure.

4.5.3 Maintenance

During every visit to the Met Station, check if the grounding cable is properly connected to the grounding rod. Clean contacts if necessary.

Tripod

5.1 General

Sensors, protective enclosure ENC12/14 (containing datalogger and power unit), and solar panel are mounted to a tripod constructed from galvanized steel pipes. This tripod has a height of around 2 m and a base radius of 1.2 m, resulting in an extremely stable construction. Figure 15 presents a cross sectional profile of the tripod with the basic dimensions.

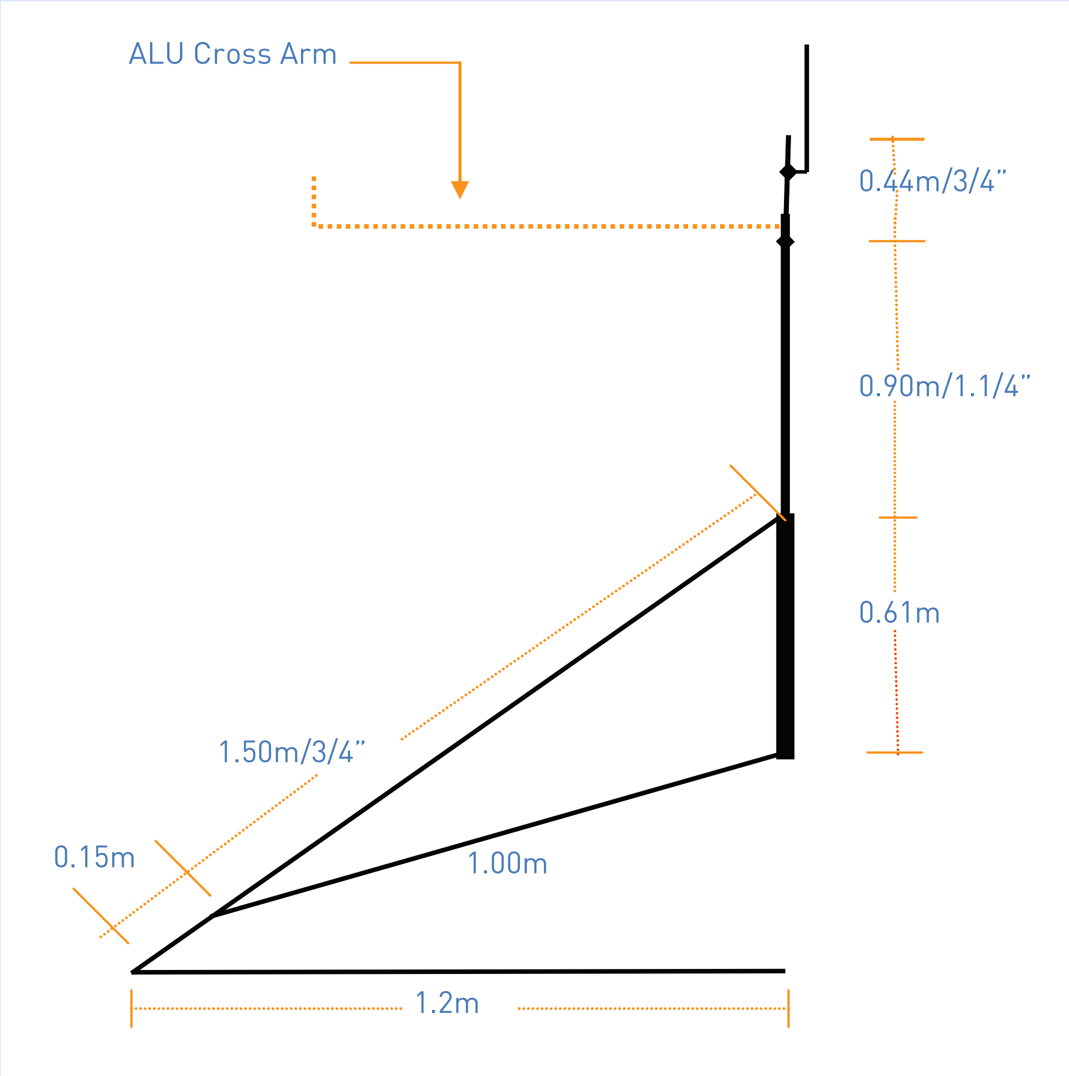


Figure 15: Cross Sectional Profile of Tripod.

5.2 Installation

Figure 16 shows the individual components of the tripod together with an identification number. Table 3 presents the specifications of all elements.

Table 3: Individual Components of Tripod		
No.	Item	Quantity
1	Lightning rod. Supplied	1
2	Lightning rod clamp. Supplied	1
3	Cross arm support: length = 0.44 m; diameter = ¾ inch; galvanized steel and to be cut locally	1
4	Bell reducer: one side ¾ inch thread, other side 1.1/4 inch thread, supplied but is also available locally.	1
5	Upper body: length = 0.90 m; diameter = 1.1/4 inch; galvanized steel with threads on bpot sides and to be availed locally.	1
6	upper tri-linear connection piece. Part of No. 7 supplied.	1
7	Lower body: length = 0.61 m; diameter = 1.1/4 inch; supplied & threaded.	1
8	Lower tri-linear connection piece. Part of No. 7 supplied.	1
9	Foot. Provided by supplier	3
10	Upper leg: length = 1.50 m; diameter = ¾ inch; galvanized steel, to be availed locally (no threads required).	3
11	Lower leg: length = 1.10 m; diameter = ¾ inch; galvanized steel, to be availed locally (no threads required)	3
12	Clamp bracket or slide collar. Provided by supplier with screws. In fact all the required screws are provided by the supplier.	3

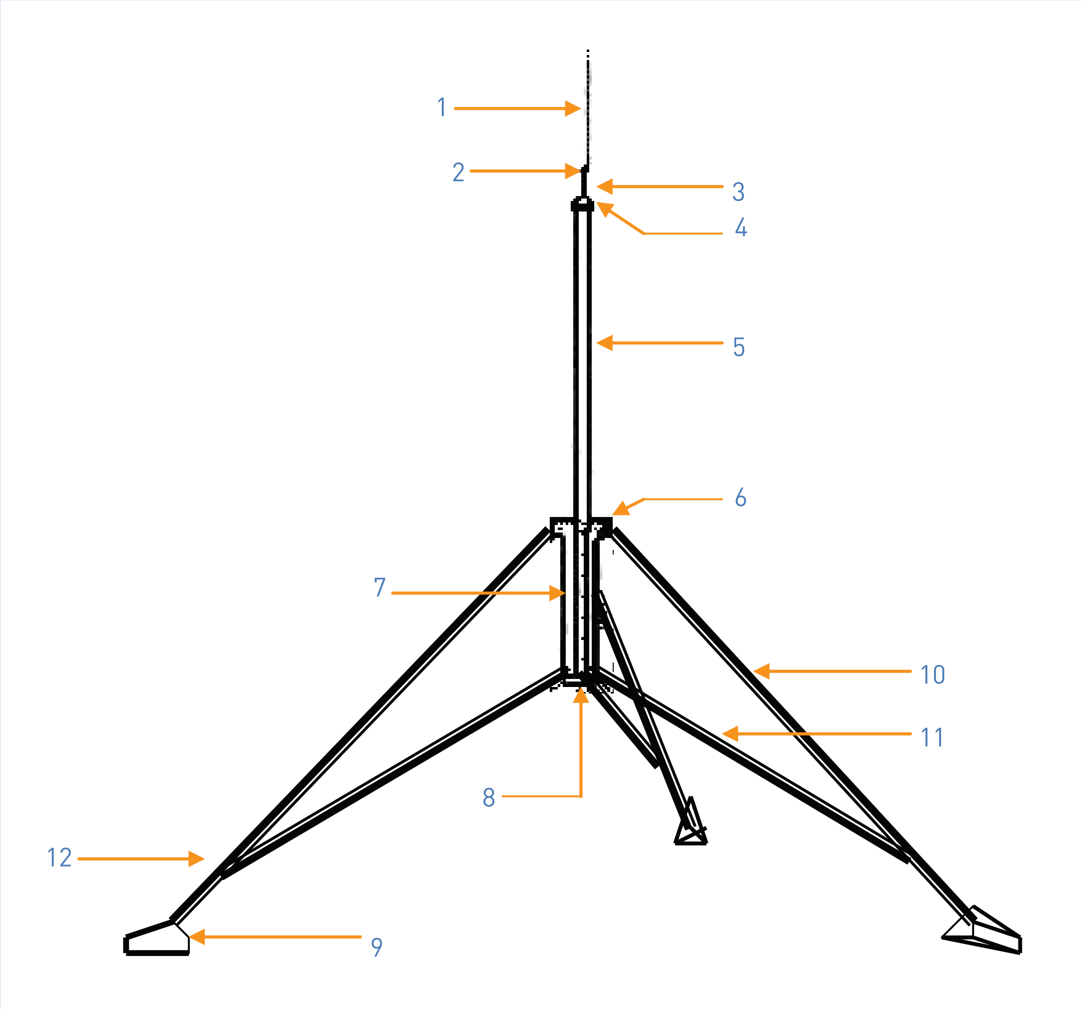


Figure 16: Individual components of Tripod

Construction of the tripod is a straightforward process. Foundation blocks with a solid embedded anchoring bold should be constructed at each 120 degrees of a circle with diameter of 2.4 meter. Place the tripod feet (no. 9) on these bolds and attach the nuts firmly.

Annex 10 presents detailed instructions for constructing the tripod.

Although all items are made out of galvanized steel, which should not rust, it is advised to paint the upper and lower body (items 5 and 7), and upper and lower legs (items 10 and 11). First apply a coating of zinc chromatic primer, then a layer of final paint. As all the remaining items are supplied by Campbell Scientific and made out of the best quality galvanized steel, there should be no need to paint them. However, if the environmental conditions in the region would provoke corrosion of these components, they should be painted according to the above guidelines.

5.3 Maintenance

Maintenance to the tripod is limited to periodically checking if all bolds and nuts are firmly attached (tighten when required) and removing corrosion and repainting if necessary.

Protective Enclosure ENC12/14

6.1 General

The fiberglass-reinforced polyester enclosure ENC12/14 serves as housing for datalogger and power unit. It is made of non-corrosive UV-stabilized material, with a white color to reflect solar radiation, hence reducing inside temperature and eliminating the need for a separate radiation shield. The ENC12/14 provides protection against water, dust and most environmental pollutants. It can be locked with a padlock to prevent non-authorized persons to access the inside equipment.

6.2 Installation

Attach the ENC12/14 firmly to the tripod's upper body using the provided clamps. Tighten the nuts securely.

Mount the datalogger and power unit to the back plate using the supplied plastic grommets and screws, as indicated in figure 6 in paragraphs 2.2. Route all sensor and solar panel wires through the enclosure conduit to the wiring panel of the datalogger. The user is referred to paragraph 2.2 and Annex 2 for instructions for proper wiring.

After wiring, attach the cables in an orderly manner to the side of the ENC12/14 using the provided cable ties and cable tabs.

Attach a humidity indicator on the inside of the protective enclosure.

Seal the gap between the sensor leads and the enclosure conduit with the provided sealing putty. However, make sure a tiny opening remains to vent possible hydrogen gas generated by the lead acid rechargeable battery.

To remove excess water vapor, place two packages of desiccant (4 units) in the enclosure.

6.3 Maintenance

Maintenance of the ENC12/14 is limited. During every visit to the Met Station, check if the enclosure is firmly attached to the tripod. If necessary fasten securely.

If the 40% ring in on the humidity indicator starts to turn pink, replace the two desiccant packs. At the same occasion, also change the humidity indicator.

During every visit, check if all cables are firmly connected to the wiring panel. If necessary fix securely.
During every visit, check if the grounding cable is firmly connected to the ground terminal of the ENC12/14. If necessary fasten firmly.

Remove any alien material from the enclosure. Make sure the conduit is almost closed. However, make sure the opening is not completely clogged to facilitate exit of possible hydrogen gas from the rechargeable battery.

6.4 Trouble Shooting

Problem 1: The desiccant pack is due to be replaced but they are out of stock.

Remedy 1.1: Keep an inventory of all consumables and timely order the items which stock is running low. Inquire at your contact person at Campbell Scientific on how to order new desiccants packs.
Remedy 1.2: Desiccant packs can be recovered by heating in an oven (or alternatively in a frying pan with cover) for 2 hours at 50° C. Make sure the temperature does not exceed 50° C as the paper bags might catch fire at higher temperatures and/or the chemical constitution of the desiccant may change.

It is not advised to subject a desiccant pack several times to this procedure as the drying power may diminish in the dehumidification process.

Met Station Compound

7.1 General

The datalogger housing, sensors, and solar panel are attached to a tripod tower, which is placed in the center of the fenced Met Station compound.

The compound is solely designated to the Meteorological Station. It should not be used for other purposes what so ever.

7.2 Construction

The compound should be constructed according to the design presented in Annex 7. This design stems from the Field Report on Survey and Design of Nabuyongo Meteorological Station in the Lake Victoria Basin by the National Focal Point Institution, Ministry of Water, Mwanza, Tanzania.

It has been adopted as the standard design for compounds for Automatic Met Stations installed under the Nile Basin Water Resources Project.

7.3 Maintenance

If constructed properly and not subjected to vandalism, the compound only needs minor maintenance. This includes the following:

- Check during every visit if the fence is still firmly in place without holes, make necessary repairs immediately;
- Check during every visit if the poles are still placed firmly in the ground, re-implant them securely if necessary;
- During every visit remove plants, weeds and trees growing up to the fence as well as other objects placed against it;
- During every visit, check if the door still closes properly and can be locked securely; make sure a padlock is in place;
- During every visit, remove all plants and trees growing in the compound, slash the grass and keep the ground level;
- During every visit, check if the grounding rod is still firmly in place and free of obstacles;
- Periodically, remove trees, plants and other objects in the immediate vicinity of the compound which could affect proper measurement of the climatological parameters or could shade the solar panel;
- During every visit, make sure the plaque containing information on the purpose and use of the Meteorological Station is still in place and readable.

Annexes

Annex 1: Installation and Operation Instructions for PCTour

1. General

PCTour is a DOS based software package provided by Campbell Scientific. It concerns a computer based guided tutorial that presents basic concepts of CR10X and software operations. For example, the functions of the I/O channels are discussed, as well as the concepts of Input, Intermediate, and Final Storage.

PCTour also briefly discusses PC208 software, including a discussion on EDLOG and SPLIT.

It is advised to go through this tutorial to grasp the basic concepts behind the METSTAT datalogger program.

Since PCTour is DOS based, it should either be run in MS DOS mode, or from the MS DOS Prompt in Windows 95 or newer versions. It is recommended to use MS DOS mode, as in this case a full screen is obtained.

2. Installation

Follow the below instructions to install PCTour:

- activate the MS DOS Prompt in the program menu, or
- restart the computer in MS DOS mode
- place the diskette labeled PCTour in drive A
- type A:\install
- an introduction screen appears, press ENTER to continue
- a screen asking for the destination directory appears; default is C:\PCTOUR; if wished, change to the appropriate destination and press ENTER to continue
- PCTour is installed without any further user interactions
- after installation has been completed successfully, type ESC to leave PCTour

To exit either MS DOS mode or the MS DOS Prompt in Windows 95, type EXIT. Windows 95 will restart automatically.

3. Running PCTour

Follow the below instructions to run PCTour:

- activate the MS DOS Prompt in the program menu, or
- restart the computer in MS DOS mode
- navigate to the folder containing PCTour using the appropriate DOS command:

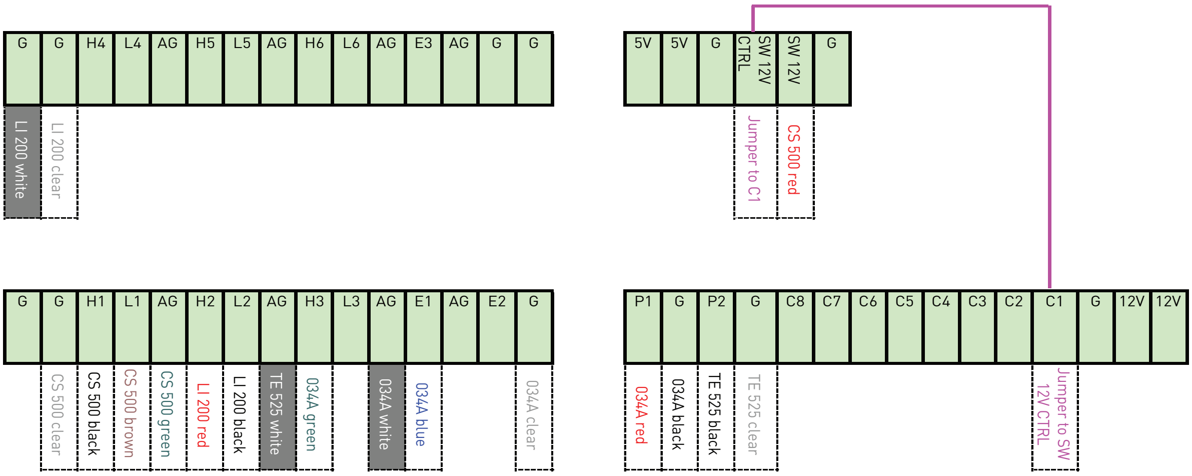
CD \PCTOUR "ENTER"

(provided PCTour is installed in the default directory called PCTOUR, otherwise, replace PCTOUR with the name of the alternative directory)

- type TOUR behind the MS DOS prompt, press ENTER
- PCTour starts, follow the on-screen instructions to operate the program
- to exit the program at any time, press ESC

To exit either MS DOS mode or the MS DOS Prompt in Windows 95, type EXIT. Windows 95 will restart automatically.

Annex 2: Wiring Diagram for CR10X Using METSTAT

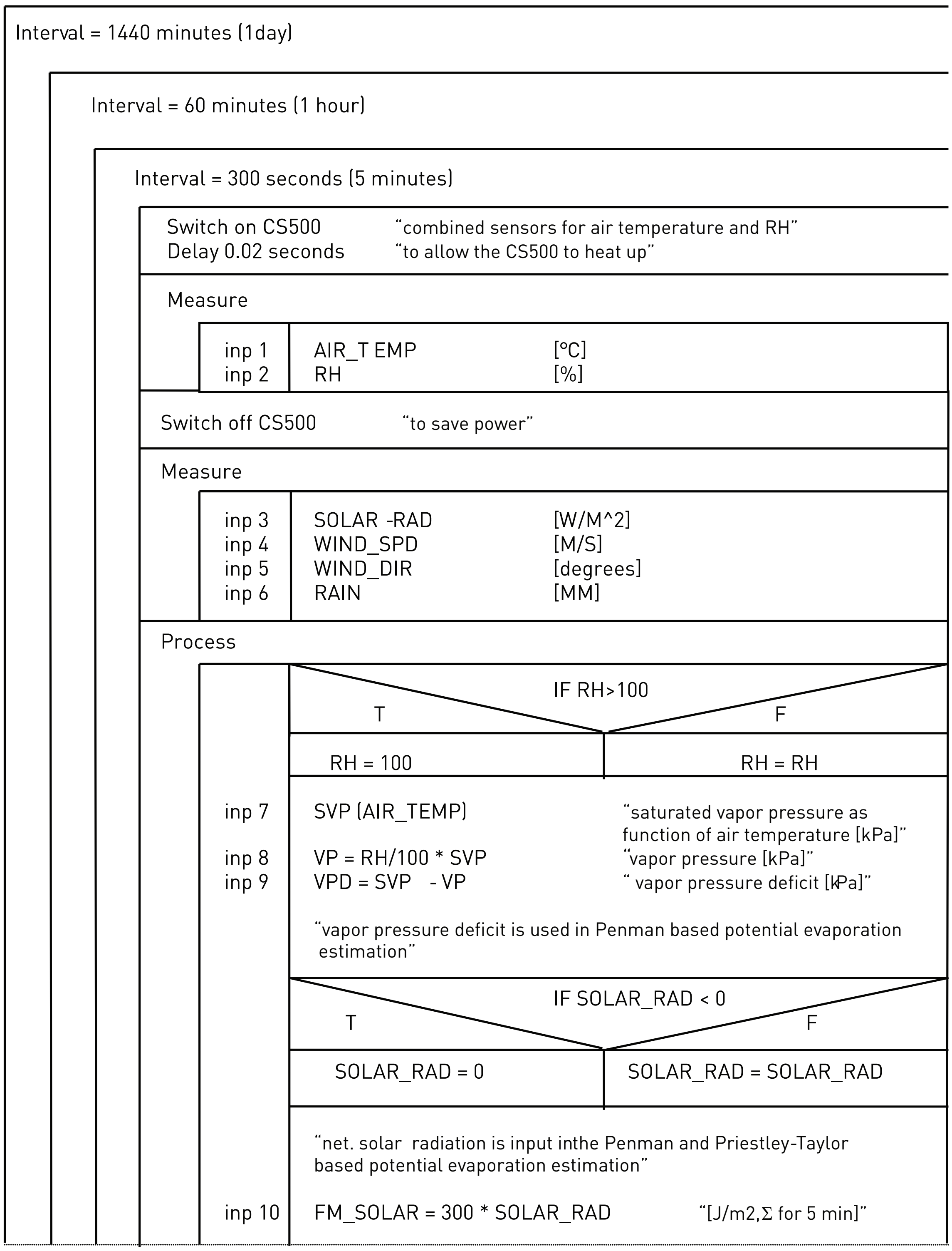


GCP/INT/752/ITA
WIRING DIAGRAM (for Campbell Scientific CR10X)
for Met Stations established by GCP/RAF/304/JPN and GCP/INT/752/ITA
based on METSTAT Datalogger Program
1998/2001, created by Bart Hilhorst/Shaukat Ali Khan

CS 500 = Combined Air Temperature and RH Sensor
LI 200 = Pyranometer (Solar Radiation Sensor)
TE 525 = Tipping Bucket Rain Gage
034A = Met One 034A-L Wind Direction & Wind Speed Sensors

Annex 3.1: METSTAT Structure Diagram

Structure Diagram for METSTAT, a Datalogger Program for the Meteorological Stations established by GCP/RAF/304/JPN and GCP/INT/752/ITA Projects Using Campbell Scientific CR10X Storage and Control Modules.



Structure Diagram (continuation1)

inp 20 AUX_OHS = OH_SOLAR "auxiliary step"
inp 11 OH_SOLAR = AUX_OHS + FM_SOLAR "cum. one hour solar rad."
inp 21 AUX_ODS = OD_SOLAR "auxiliary step"
inp 12 OD_SOLAR = AUX_ODS + FM_SOLAR "cum. one day solar rad."
inp 13 OH_AIRT = AIR_TEMP "one hour air temp"
inp 14 OH_VPD = VPD "one hour VPD"
inp 15 OH_VP = VP "one hour VP"

"for creating hourly/daily values"

IF WIND_SPD =< 0.2811

T	F
WIND_SPD = 0	WIND_SPD = WIND_SPD

"Penman based potential evaporation estimations include average wind speed in [m/s]"

inp 16 OH_WINDS = WIND_SPD "one hour wind speed"
inp 17 FM_RAIN = RAIN "five minutes rain"

IF FM_RAIN > 0

F	T
	SET ARRAY_ID = 300 OUTPUT ARRAY_ID STN -ID YEAR DAY TIME (hhmm) FM_RAIN

INSTRUCTION 96
"for automatic output to SM4M Storage Module once connected"

OUTPUT

SET ARRAY_ID = 200
OUTPUT
ARRAY_ID
STN -ID
YEAR
DAY
TIME (hhmm)
AVG(OH_AIRT)
AVG(OH_VP)
AVG(OH_VPD)
AVG(OH_WINDS)
SAMPLE(OH_S OLAR) "cum. one hour solar radiation in [MJ/M2]"

"after output all values are automatically set to zero"

SET OH_SOLAR = 0 "new hour => hr. cum. value = 0"

Structure Diagram (continuation 2)

```
OUTPUT
                inp 22    CREATE SIGNA TURE "SIGN1440"
                inp 23    MEASURE BATT_VOLT    "battery voltage"

    SET ARRAY_ID = 100
    OUTPUT
        ARRAY_ID
        STN -ID
        YEAR
        DAY
        AVG(AIR_TEMP)
        AVG(VP)
        AVG(VPD)
        MAX (AIR_TEMP)
        MIN (AIR_TEMP)
        SUM (RAIN)
        SAMPLE(OD_SOLAR)                "cum. one day solar rad. In [MJ/M2]"
        WIND VECTOR
                - scalar mean horizontal wind speed [m/s]
                - unit vector mean direction [degrees]
                - standard deviation of direction [degrees]

        SAMPLE(SIGN1440)
        SAMPLE(BATT_VOLT)

        "after output all values are automatically set to zero"

    SET OD_SOLAR = 0              "new day => day. cum. value = 0"
END
```

Annex 3.2: METSTAT Datalogger Program

METSTAT is a data logger program for the CR10X Control and Storage Module, intended for the Meteorological Stations established by the Lake Victoria Water Resources and Nile Basin Water Resources Projects. This program is based on the Structure Diagram presented in Annex 3.1.

The program is created in EDLOG and stored in the files "METSTAT.CSI" and "METSTAT.DLD" respectively. The latter concerns the compiled version.

```
=================================================================================
;{CR10X}
;
;DATA LOGGER PROGRAM FOR METEOROLOGICAL STATIONS IMPLEMENTED BY GCP/RAF/304/JPN AND GCP/
INT/752/ITA PROJECTS IN THE NILE BASIN REGION

;CREATED BY BART HILHORST, 19 JANUARY 1998
;FINAL MODIFIED VERSION CREATED BY BART HILHORST, 20 MARCH 1998

;WIRING SCHEDULE HAS BEEN DETERMINED BY SHORTCUT

;NO USE IS MADE OF FINAL STORAGE AREA 2 IN ORDER TO FACILITATE AUTOMATIC
;DOWN LOADING OF DATA UPON CONNECTION OF SM192 OR SM4M TO CR10X
;TO THIS END, DUE TO THE EXECUTION INTERVAL OF 300 SEC, THE SM192/SM4M HAS TO
;STAY CONNECTED TO THE CR10X FOR AT LEAST 10 MINUTES

*Table 1 Program
 01: 300       Execution Interval (seconds)

;==================== PART 0,  DATALOGGER ID ===================

1:  If time is (P92)
   1: 0        Minutes (Seconds --) into a
   2: 1440     Interval (same units as above)
   3: 30       Then Do

2:  Read ID (P117)
    1: 24      Loc [ LOGGER_ID ]

3:  End (P95)

;DETERMINE DATALOGGER-ID IN ORDER TO DISTINGUISH STATION IN CASE
;SEVERAL STATIONS ARE VISITED DURING THE SAME INSPECTION TRIP

;====================== END OF PART 0 ========================

;===================== PART 1, MEASUREMENTS ===================

;PART 1: MEASUREMENTS, ALL SIX SENSORS ARE MEASURED EVERY 5 MINUTES

;IN ORDER TO REDUCE POWER CONSUMPTION, CS500 IS ONLY SWITCHED ON
;DURING MEASUREMENT, DIRECTLY AFTERWARDS, IT IS SWITCHED OFF

;SWITCH ON CS500 (AIR TEMP AND RH SENSORS)
```

```
4:  Do (P86)
   1: 41       Set Port 1 High

;CONTROL PORT1 IS CONNECTED WITH A JUMPER TO SW12CTRL
;(SWITCHED 12 VOLT CONTROL)

5:  Excitation with Delay (P22)
   1: 3        Ex Channel
   2: 0        Delay W/Ex (units = 0.01 sec)
   3: 10       Delay After Ex (units = 0.01 sec)
   4: 0        mV Excitation

;DELAY OF 0.1 SEC TO ALLOW CS500 TO WARM UP AND STABILIZE
;INSTRUCTION (P22) ONLY SERVES FOR DELAYING THE PROGRAM
;NO ACTUAL EXITATION IS NEEDED. E3 IS NOT WIRED

6:  Volt (SE) (P1)
   1: 1        Reps
   2: 5        2500 mV Slow Range
   3: 1        SE Channel
   4: 1        Loc [ AIR_TEMP  ]
   5: 0.1      Mult
   6: -40      Offset

;TEMPERATURE MEASUREMENT WITH CS500 SENSOR, CONNECTED TO SINGLE
;ENDED CHANNEL 1. TEMPERATURE MEASURED IN DEGREES CELSIUS.

7:  Volt (SE) (P1)
   1: 1        Reps
   2: 5        2500 mV Slow Range
   3: 2        SE Channel
   4: 2        Loc [ RH        ]
   5: 0.1      Mult
   6: 0.0      Offset

;RELATIVE HUMIDITY MEASUREMENT WITH CS500 SENSOR, CONNECTED TO
;SINGLE ENDED CHANNEL 2. RH MEASURED IN PERCENTAGE.

8:  Do (P86)
   1: 51       Set Port 1 Low

;SWITCH OFF CS500

9:  Volt (Diff) (P2)
   1: 1        Reps
   2: 2        7.5 mV Slow Range
   3: 2        DIFF Channel
   4: 3        Loc [ SOLAR_RAD ]
   5: 200      Mult
   6: 0.0      Offset

;INCOMMING SOLAR RADIATION MEASUREMENT WITH LI200X SENSOR, CONNECTED
;TO DIFFERENTIAL CHANNEL 2.
;THE OUTPUT FROM LI200X IS 0.2 kW/M2, mV. MAXIMUM INCOMING SHORTWAVE SOLAR
```

```
;RADIATION AT THE EQUATOR IS AROUND 1000 W/M2. HENCE, 7.5 mV, COVERING 1500 W
;SHOULD BE SUFFICIENT. CHECK THIS DURING OPERATION.
;SOLAR RADIATION MEASURED IN J/S,M2.

10:  Pulse (P3)
  1: 1        Reps
  2: 1        Pulse Input Channel
  3: 22       Switch Closure, Output Hz
  4: 4        Loc [ WIND_SPD  ]
  5: 0.799    Mult
  6: 0.2811   Offset

;WIND SPEED FROM "MET ONE 034A-L WINDSET" SENSOR, CONNECTED TO PULSE
;CHANNEL 1, MULTIPLYER AND OFFSET GIVEN BY SHORTCUT DIFFER FROM THOSE
;IN THE MANUAL; VALUES FROM THE MANUAL ARE APPLIED.
;WIND SPEED MEASURED IN M/S

11:  Excite-Delay (SE) (P4)
  1: 1        Reps
  2: 5        2500 mV Slow Range
  3: 5        SE Channel
  4: 1        Excite all reps w/Exchan 1
  5: 2        Delay (units 0.01 sec)
  6: 2500     mV Excitation
  7: 5        Loc [ WIND_DIR  ]
  8: 0.2863   Mult
  9: 0.0      Offset

;WIND DIRECTION WITH "MET ONE 034A-L WINDSET" SENSOR, CONNECTED TO SINGLE
;ENDED CHANNEL 5, MULTIPLYER AND RANGE GIVEN BY SHORTCUT DIFFER FROM THOSE
;IN THE MANUAL; VALUES FROM THE MANUAL ARE APPLIED.
;WIND DIRECTION MEASURED IN DEGREES (NORTH = 0 DEGREE)

12:  Pulse (P3)
  1: 1        Reps
  2: 2        Pulse Input Channel
  3: 2        Switch Closure, All Counts
  4: 6        Loc [ RAIN      ]
  5: 0.254    Mult
  6: 0.0      Offset

;RAIN FROM TE 525 TIPPING BUCKET RAIN GAGE in MM (0.01 inch per tip), CONNECTED TO PULSE
;CHANNEL 2


;========================= END OF PART 1 =========================


;======================= PART 2: PROCESSING ======================

13:  If (X<=>F) (P89)
  1: 2        X Loc [ RH       ]
  2: 3        >=
  3: 100      F
```

```
4: 30      Then Do

14:  Z=F (P30)
1: 100      F
     2: 00       Exponent of 10
     3: 2        Z Loc [ RH       ]

15:  End (P95)

;IF RH>100, SET RH=100

16:  Saturation Vapor Pressure (P56)
  1: 1        Temperature Loc [ AIR_TEMP  ]
  2: 7        Loc [ SVP      ]

;CALCULATING SATURATED VAPOR PRESSURE AS FUNCTION OF AIR TEMPERATURE
;IN KILO PASCAL [KPA]

17:  Z=X*F (P37)
  1: 2        X Loc [ RH       ]
  2: 0.01     F
  3: 8        Z Loc [ VP       ]

;THIS EQUATION CALCULATED THE FIRST STEP IN "VP=RH/100*SVP"

18:  Z=X (P31)
  1: 8        X Loc [ VP       ]
  2: 9        Z Loc [ AUX_SVP   ]

;AUXILIARY STEP

19:  Z=X*Y (P36)
  1: 9        X Loc [ AUX_SVP   ]
  2: 7        Y Loc [ SVP      ]
  3: 8        Z Loc [ VP       ]

;THIS IS THE RESULTING STEP IN "VP=RH/100*SVP", IN [KPA]

20:  Z=X-Y (P35)
  1: 7        X Loc [ SVP      ]
  2: 8        Y Loc [ VP       ]
  3: 10        Z Loc [ VPD      ]

;CALCULATING "VPD=SVP-VP", VPD = VAPOR PRESSURE DEFICIT, IN [KPA]

21:  If (X<=>F) (P89)
  1: 3        X Loc [ SOLAR_RAD ]
  2: 4        <
  3: 0.0      F
  4: 30       Then Do

    22:  Z=F (P30)
     1: 0.0      F
     2: 00       Exponent of 10
```

```
    3: 3        Z Loc [ SOLAR_RAD ]

23:  End (P95)

;SOLAR RADIATION IS SET TO NUL IN CASE OF NEGATIVE VALUES, WHICH MAY OCCUR
;AT NIGHT

24:  Z=X*F (P37)
  1: 3        X Loc [ SOLAR_RAD ]
  2: 0.3      F
  3: 11       Z Loc [ FM_SOLAR  ]

;INCOMING SOLAR RADIATION IS IN W/M2, THUS J/S,M2, IN ORDER TO ARRIVE AT
;CUMMULATIVE VALUES, SOLAR_RAD HAS TO BE MULTIPLIED BY TIME IN SECONDS
;FIVE MINUTES SOLAR RADIATION (FM_SOLAR) = SOLAR_RAD*300
;THIS STEP IS AN AUXILIARY FOR CREATING HOURLY/DAILY VALUES
;THE RESULTING FM_SOLAR IS PRESENTED IN [KJ/M2]

25:  Z=X (P31)
  1: 12       X Loc [ OH_SOLAR  ]
  2: 13       Z Loc [ AUX_OHS   ]


26:  Z=X*F (P37)
  1: 11       X Loc [ FM_SOLAR  ]
  2: 0.001    F
  3: 14       Z Loc [ AUXFM_SO  ]

;TO TRANSFER FIVE MINUTE SOLAR RADIATION FROM [KJ/M2] TO [MJ/M2]

27:  Z=X+Y (P33)
  1: 13       X Loc [ AUX_OHS   ]
  2: 14       Y Loc [ AUXFM_SO  ]
  3: 12       Z Loc [ OH_SOLAR  ]

;INSTRUCTIONS 22 AND 23 FOR: "OH_SOLAR=OH_SOLAR+AUXFM_SO", IN ORDER TO CREATE
;CUM. HOURLY VALUES; THIS EQUATION IS NOT DIRECTLY ACCEPTED, HENCE THE AUXILIARY
;STEP; OH_SOLAR = CUMMULATIVE ONE HOUR INCOMING SOLAR RADIATION IN [MJ/M2]

28:  Z=X (P31)
  1: 15       X Loc [ OD_SOLAR  ]
  2: 16       Z Loc [ AUX_ODS   ]

29:  Z=X+Y (P33)
  1: 16       X Loc [ AUX_ODS   ]
  2: 14       Y Loc [ AUXFM_SO  ]
  3: 15       Z Loc [ OD_SOLAR  ]

;INSTRUCTIONS 24 AND 25 FOR: "OD_SOLAR=OD_SOLAR+AUXFM_SO", IN ORDER TO CREATE
;DAILY VALUES; THIS EQUATION IS NOT DIRECTLY ACCEPTED, HENCE THE AUXILIARY STEP
;OD_SOLAR = CUMMULATIVE ONE DAY INCOMING SOLAR RADIATION IN [MJ/M2]

30:  Z=X (P31)
  1: 1        X Loc [ AIR_TEMP  ]
```

```
  2: 17       Z Loc [ OH_AIRT   ]


31:  Z=X (P31)
  1: 8        X Loc [ VP        ]
  2: 18       Z Loc [ OH_VP     ]


32:  Z=X (P31)
  1: 10       X Loc [ VPD       ]
  2: 19       Z Loc [ OH_VPD    ]

;INSTRUCTION 26, 27 AND 28 ARE FOR CREATING HOURLY VALUES OF
;AIR TEMPERATURE, VP AND VPD

33:  If (X<=>F) (P89)
  1: 4        X Loc [ WIND_SPD  ]
  2: 1        =
  3: 0.2811   F
  4: 30       Then Do

    34:  Z=F (P30)
     1: 0.0      F
     2: 00       Exponent of 10
     3: 4        Z Loc [ WIND_SPD  ]

35:  End (P95)

;IF WIND_SPD=OFF SET VALUE => SET WIND_SPD TO 0

36:  Z=X (P31)
  1: 4        X Loc [ WIND_SPD  ]
  2: 20       Z Loc [ OH_WINDS  ]

37:  Z=X (P31)
  1: 6        X Loc [ RAIN      ]
  2: 21       Z Loc [ FM_RAIN   ]

;INSTRUCTIONS 32 AND 33 ARE FOR CREATING RAIN SERIES AND
;HOURLY WIND SPEED VALUES


;================= END OF PART 2, PROCESSING ===============



;==================== PART 3, DATA OUTPUT ==================

;======== OUTPUT OF 5 MINUTES RAINFALL DATA (FM_RAIN) ======

38:  If (X<=>F) (P89)
  1: 21       X Loc [ FM_RAIN   ]
  2: 2        <>
  3: 0.0      F
```

```
4: 30       Then Do

  39:  If time is (P92)
   1: 0        Minutes (Seconds --) into a
   2: 5        Interval (same units as above)
   3: 10       Set Output Flag High

  40:  Set Active Storage Area (P80)
   1: 1        Final Storage Area 1
   2: 300      Array ID

  41:  Sample (P70)
   1: 1        Reps
   2: 24       Loc [ LOGGER_ID ]

  42:  Real Time (P77)
   1: 1220     Year,Day,Hour/Minute (midnight = 2400)

  43:  Sample (P70)
   1: 1        Reps
   2: 21       Loc [ FM_RAIN   ]

44:  End (P95)

;========= END OF RAINFALL SERIES OUTPUT INSTRUCTIONS ==========

;======= TO ACTIVATE AUTOMATIC DATA TRANSFER TO SM192 =========

45:  Serial Out (P96)
 1: 71       SM192/SM716/CSM1

;DATALOGGER WILL CHECK EVERY FIVE MINUTES IF THE SM192 IS
;CONNECTED. IF NOT, IT WILL CONTINUE WITH THE NEXT STEP IN THE
;PROGRAM. IF CONNECTED, IT WILL TRANSFER ALL DATA IN THE FINAL
;STORAGE LOCATION AUTOMATICALLY TO THE SM192 WITHOUT ANY USER
;ACTION

;THIS COMMAND MAKES DATA TRANSFER FULLY AUTOMATIC

;======= END OF AUTOMATIC DATA TRANSFER ===================


;=============== CONTINUE WITH HOURLY OUTPUT ===============

46:  If time is (P92)
   1: 0        Minutes (Seconds --) into a
   2: 60       Interval (same units as above)
   3: 10       Set Output Flag High

47:  Set Active Storage Area (P80)
   1: 1        Final Storage Area 1
   2: 200      Array ID

48:  Sample (P70)
```

```
  1: 1       Reps
  2: 24      Loc [ LOGGER_ID ]

49:  Real Time (P77)
  1: 1220     Year,Day,Hour/Minute (midnight = 2400)

50:  Average (P71)
  1: 1       Reps
  2: 17      Loc [ OH_AIRT   ]

51:  Average (P71)
  1: 1       Reps
  2: 18      Loc [ OH_VP     ]

52:  Average (P71)
  1: 1       Reps
  2: 19      Loc [ OH_VPD    ]

53:  Sample (P70)
 1: 1       Reps
 2: 12      Loc [ OH_SOLAR  ]

;"OH_SOLAR" IN [MJ/M2]

;OUTPUT EVERY SIXTY MINUTES:
;AVERAGE ONE-HOUR-AIR-TEMP, AVERAGE ONE-HOUR-VAPOR-PRESSURE-DEFICIT
;CUMMULATIVE ONE-HOUR-SOLAR-RADIATION, AVERAGE ONE-HOUR-VAPOR-PRESSURE

54:  Wind Vector (P69)
  1: 1       Reps
  2: 0000    Samples per Sub-Interval
  3: 0       S, é1, & å(é1) Polar
  4: 4       Wind Speed/East Loc [ WIND_SPD  ]
  5: 5       Wind Direction/North Loc [ WIND_DIR  ]


55:  If time is (P92)
  1: 0       Minutes (Seconds --) into a
  2: 60      Interval (same units as above)
  3: 30      Then Do

    56:  Z=F (P30)
     1: 0.0     F
     2: 00      Exponent of 10
     3: 12      Z Loc [ OH_SOLAR  ]

57:  End (P95)

;AFTER THE OUTPUT PROCESS, SET CUMMULATIVE "OH_SOLAR" TO ZERO


;=============== END OF HOURLY OUTPUT =======================
```

```
;============= CONTINUE WITH DAILY OUTPUT ===================

58:  If time is (P92)
  1: 0        Minutes (Seconds --) into a
  2: 1440     Interval (same units as above)
  3: 10       Set Output Flag High

59:  Set Active Storage Area (P80)
  1: 1        Final Storage Area 1
  2: 100      Array ID

60:  Signature (P19)
  1: 22       Loc [ SIGN1440  ]

;CREATE DAILY PROGRAM SIGNATURE TO MONITOR ADEQUATE PROGRAM PERFORMANCE

61:  Sample (P70)
  1: 1        Reps
  2: 24       Loc [ LOGGER_ID ]

62:  Real Time (P77)
  1: 1200     Year,Day (midnight = 2400)

63:  Average (P71)
  1: 1        Reps
  2: 1        Loc [ AIR_TEMP  ]

64:  Average (P71)
  1: 1        Reps
  2: 8        Loc [ VP        ]

65:  Average (P71)
  1: 1        Reps
  2: 10       Loc [ VPD       ]

66:  Maximize (P73)
  1: 1        Reps
  2: 10       Value with Hr-Min
  3: 1        Loc [ AIR_TEMP  ]

67:  Minimize (P74)
  1: 1        Reps
  2: 10       Value with Hr-Min
  3: 1        Loc [ AIR_TEMP  ]

68:  Totalize (P72)
  1: 1        Reps
  2: 6        Loc [ RAIN      ]

69:  Sample (P70)
  1: 1        Reps
  2: 15       Loc [ OD_SOLAR  ]
```

```
;"OD_SOLAR" IN [MJ/M2]


70:  Wind Vector (P69)
  1: 1        Reps
  2: 0000     Samples per Sub-Interval
  3: 00       S, é1, & å(é1) Polar
  4: 4        Wind Speed/East Loc [ WIND_SPD  ]
  5: 5        Wind Direction/North Loc [ WIND_DIR  ]

;THE ABOVE OUTPUTS: ALL REQUIRED DAILY VALUES

71:  Sample (P70)
  1: 1        Reps
  2: 22       Loc [ SIGN1440  ]

;OUTPUTS SIGNATURE

72:  Batt Voltage (P10)
  1: 23       Loc [ BATT_VOLT ]

73:  Sample (P70)
  1: 1        Reps
  2: 23       Loc [ BATT_VOLT ]

;SAMPLES AND OUTPUTS BATTERY VOLTAGE

74:  If time is (P92)
  1: 0        Minutes (Seconds --) into a
  2: 1440     Interval (same units as above)
  3: 30       Then Do

     75:  Z=F (P30)
      1: 0.0      F
      2: 00       Exponent of 10
      3: 15       Z Loc [ OD_SOLAR  ]

76:  End (P95)

;AFTER DAILY OUTPUT PROCESS, SET CUMMULATIVE "OD_SOLAR" TO ZERO

;====================== END OF DAILY OUTPUT ===================

;************************ END OF PROGRAM ********************


*Table 2 Program
 02: 0.0000    Execution Interval (seconds)

*Table 3 Subroutines
```

Annex 4: Input Storage Locations Used by METSTAT

See METSTAT Structure Diagram presented in Annex 3.1 for the use of the various variables. Use "*6" Mode and press "A" equivalent to "enter" to proceed from one variable to another.

Annex 4: Input Storage Locations Used by METSTAT			
Address	METSTAT Code	Description	Unit
1	[AIR_TEMP]	Air Temperature	[°C]
2	[RH]	Relative Humidity	[%]
3	[SOLAR_RAD]	Solar Radiation	[W/M2]
4	[WIND_SPD]	Wind Speed	[M/S]
5	[WIND_DIR]	Wind Direction	[degrees]
6	[RAIN]	Rainfall	[MM]
7	[SVP]	Saturated Vapor Pressure	[kPa]
8	[VP]	Vapor Pressure	[kPa]
9	[AUX_SVP]	Auxiliary Value	na
10	[VPD]	Vapor Pressure Deficit	[kPa]
11	[FM_SOLAR]	Cumulative 5 Minutes Solar Radiation	[J/M2]
12	[OH_SOLAR]	Cumulative 1 Hour Solar Radiation	[KJ/M2]
13	[AUX_OHS]	Auxiliary Value	na
14	[AUXFM_SO]	Auxiliary Value	na
15	[OD_SOLAR]	Cumulative 1 Day Solar Radiation	[MJ/M2]
16	[AUX_ODS]	Auxiliary Value	na
17	[OH_AIRT]	Average 1 Hour Air Temperature	[°C]
18	[OH_VP]	Average 1 Hour Vapor Pressure	[kPa]
19	[[OH_VPD]	Average 1 Hour Vapor Pressure Deficit	[kPa]
20	[OH_WINDS]	Average 1 Hour Wind Speed	[M/S]
21	[FM_RAIN]	Cumulative 5 Minutes Rainfall	[MM]
22	[SIGN1440]	METSTAT Program Signature	na
23	[BATT_VOLT]	Battery Voltage	[V]
24	[LOGGER_ID]	Datalogger ID	na

Annex 5: Guidelines for Assessing Station Performance Using Daily Signature and Battery Voltage Recordings

5-A General

METSTAT includes routines to monitor two essential station performance indicators, namely (1) battery voltage and (2) the signature of the active datalogger program.

The Open Circuit Voltage (OCV) of the battery in use is measured automatically on a daily basis. The voltage recordings are stored in the logger's RAM and periodically transferred, together with all meteorological information and through the SM4M/SM192 Storage Modules, to a personal computer.

A series of daily battery voltage recordings gives a clear indication of the state of the battery and the performance of the charging components. This information can be used to identify possible power failures at an early or intermediate stage, hence avoiding data loss and/or damage to other system elements.

The signature concerns a number, which is a function of the actual text of the active datalogger program. Change of a single letter will result in a different number. Consequently, an alteration of the signature indicates a corrupted datalogger program.

The program signature is determined on a daily basis and stored in the logger's RAM. It is retrieved together with all other recordings in the Final Storage Area through the SM4M/SM192 Storage Module.

The appropriate instructions to transfer information from the logger's RAM to the SM4M/SM192 are given in paragraph 2.3.

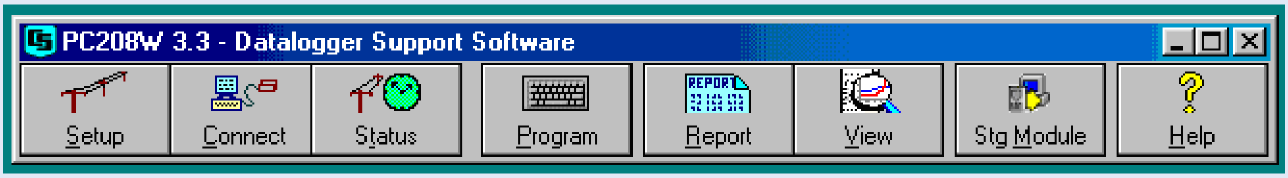
The appropriate instructions to transfer information from the SM4M/SM192 to PC are given in "Manual on Data Retrieval, Processing and Final Storage in the Nile Basin Database" or in Campbell Scientific' Instruction Manual for PC208W Datalogger Support Software.

The recorded station performance indicators can be accessed using the REPORT (a.k.a SPLIT) module of PC208W (version 2.2). The remainder of this annex presents detailed instructions how to view, and interpret this information.

5-B Assessing Station Performance Information

Station performance information, i.e. daily battery voltage and program signature recordings, can be examined using PC208W Datalogger Support Software, which icon is presented below.

Double click this icon to activate PC208W. The following toolbar appears:

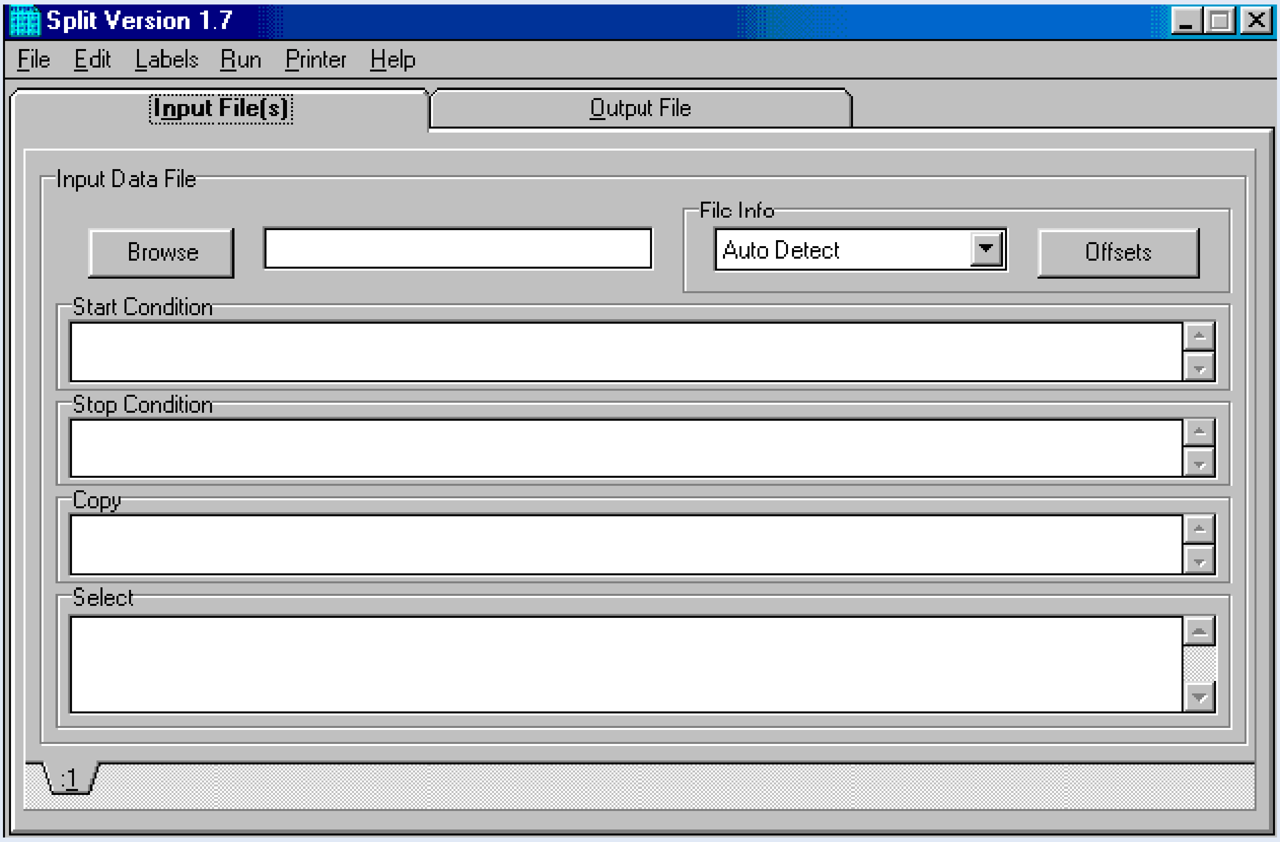


Double click the REPORT icon to start the REPORT module (a.k.a. SPLIT) used to extract station performance information from the data file. The SPLIT Version 1.7 window appears on the screen, as shown below.

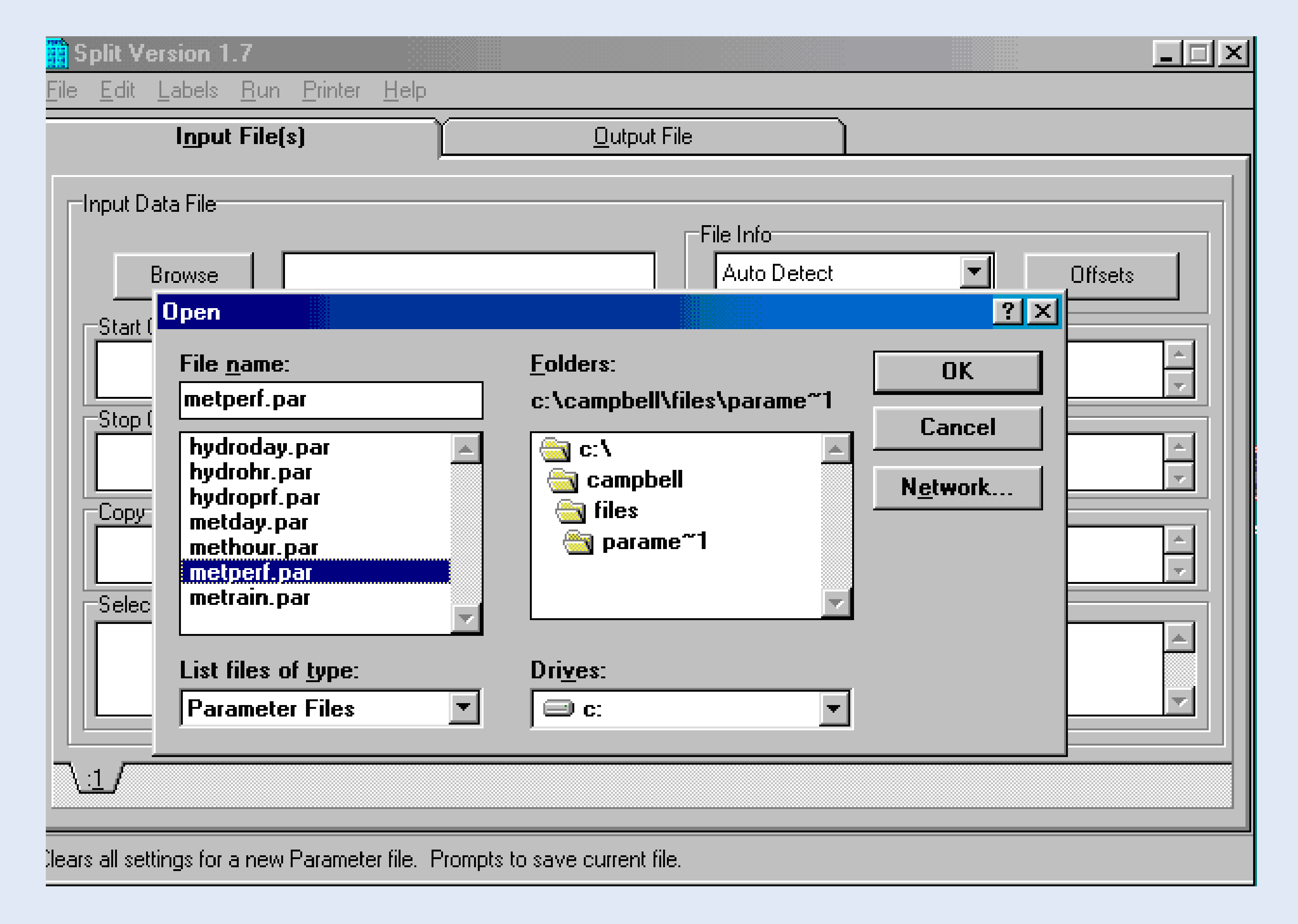
This window is used to select the appropriate data file, containing all Met Station data values for the recording period, and a pre-programmed "parameter" file called METPERF.PAR, which function as to automatically split station performance information from the rest of the station output.

To open METPERF.PAR, follow the below instructions:

- click the "OPEN" instruction of the "FILE" menu
- navigate to the location which contains the METPERF.PAR file
- select this file and click "OK"\

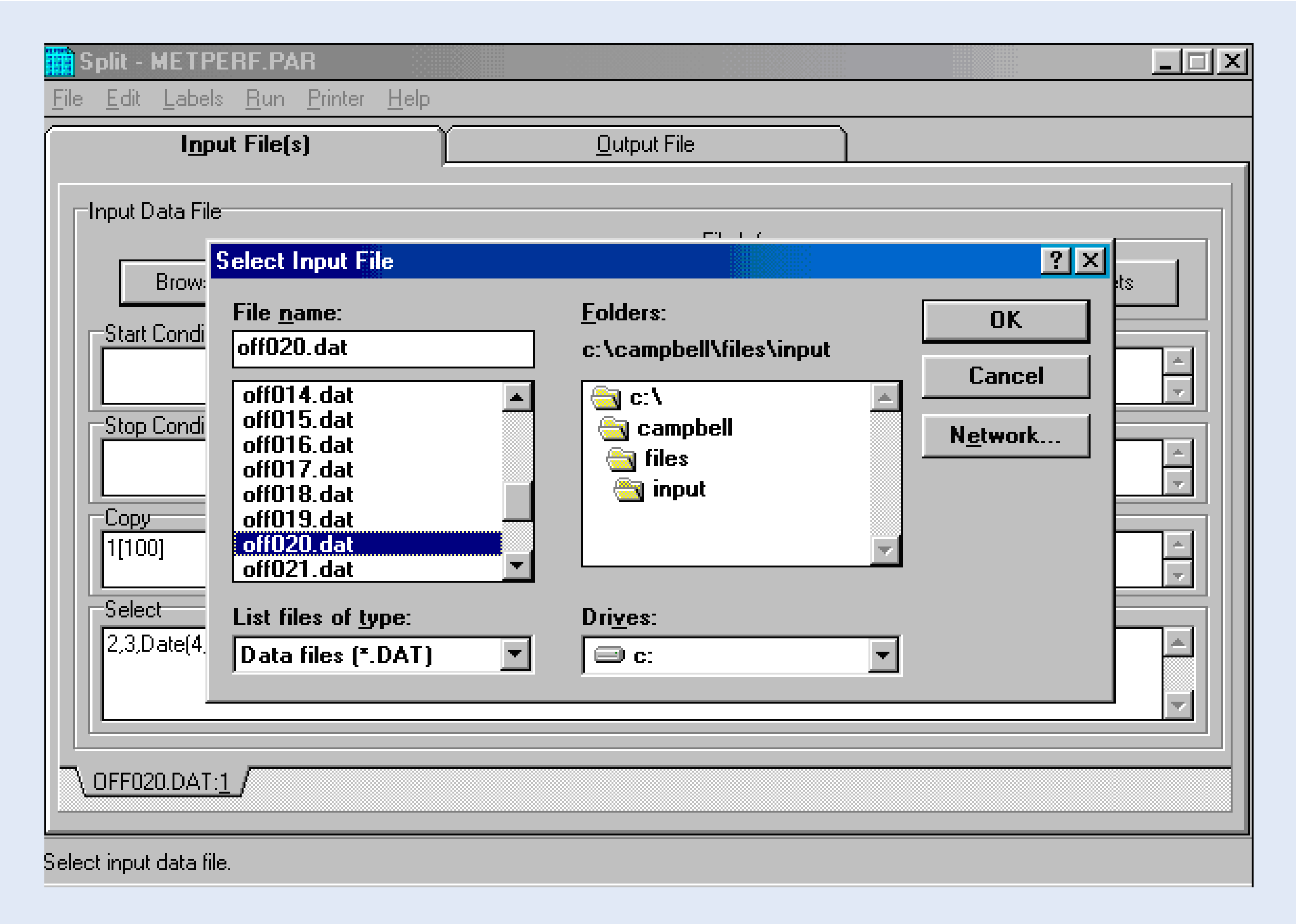


SPLIT recalls the last four "PAR" files which have been used. If METPERF.PAR would be among these four, open this file by double clicking its name. Otherwise navigate to C:\, double click "Campbell" folder, double click on "Files" folder and then double click on "Parameter" folder. Select "metperf.par" file on the left side of the window as shown below and then click "OK":

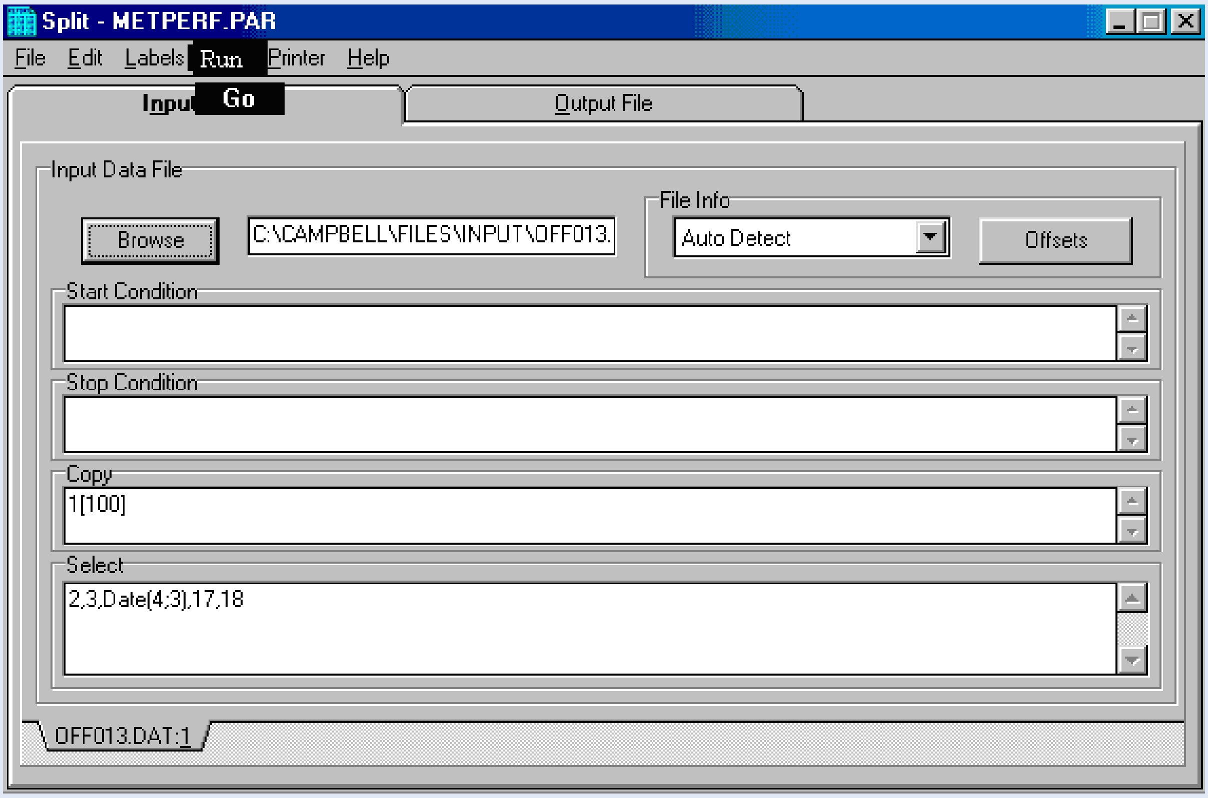


Next, the appropriate data file, containing the complete Met Station recordings, should be selected. Click "Browse" and navigate to the appropriate "DAT" file. Select and click OK.

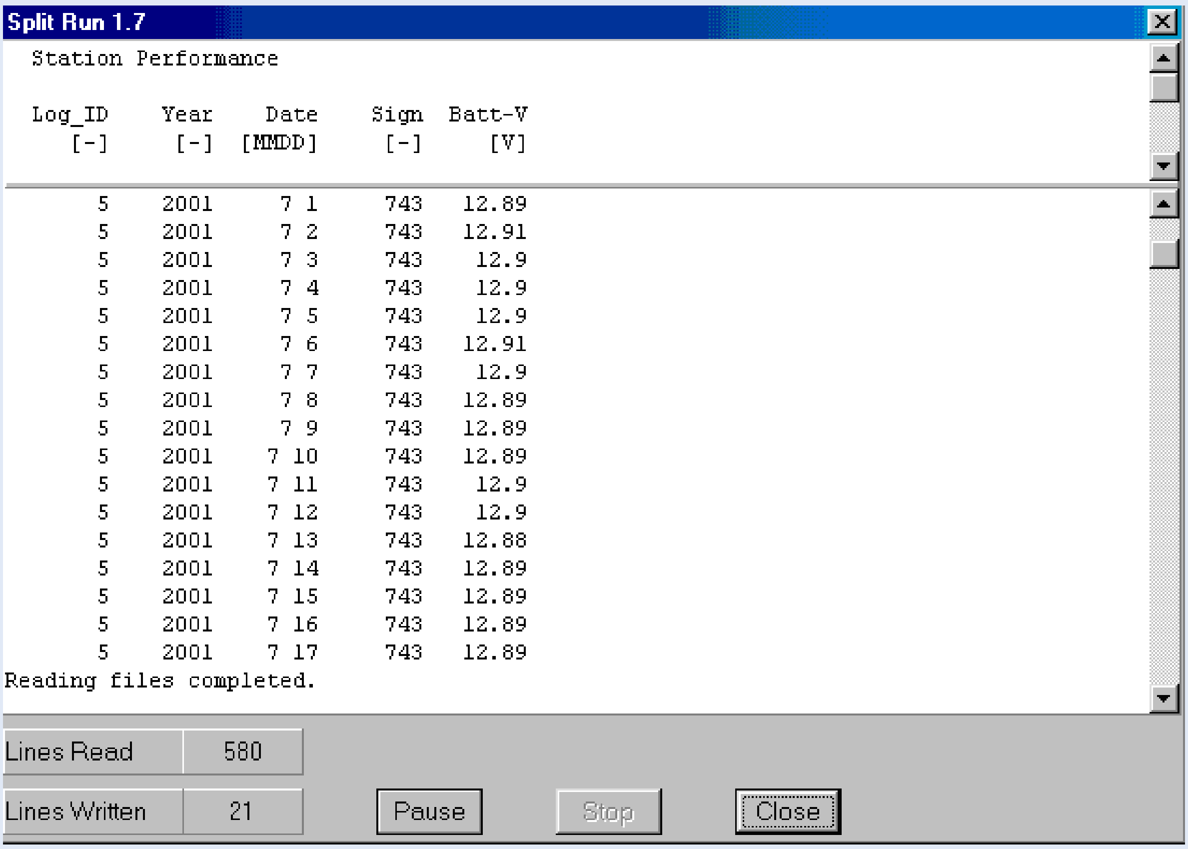
This process is pictured on the following screen:



After selecting the right input file, execute SPLIT by clicking the GO instruction on the RUN menu, as shown below:



After running the METPERF.PAR file in SPLIT with the appropriate data file, the following station information appears on the screen:



Column 1 contains the datalogger-ID; column 2 and 3 contain year, month and day respectively; column 4 gives the datalogger program signature, and column 5 presents the daily battery voltage recordings.

5-C Interpreting Station Performance Information

Interpreting station performance information is a straightforward process. There are basically the following options:

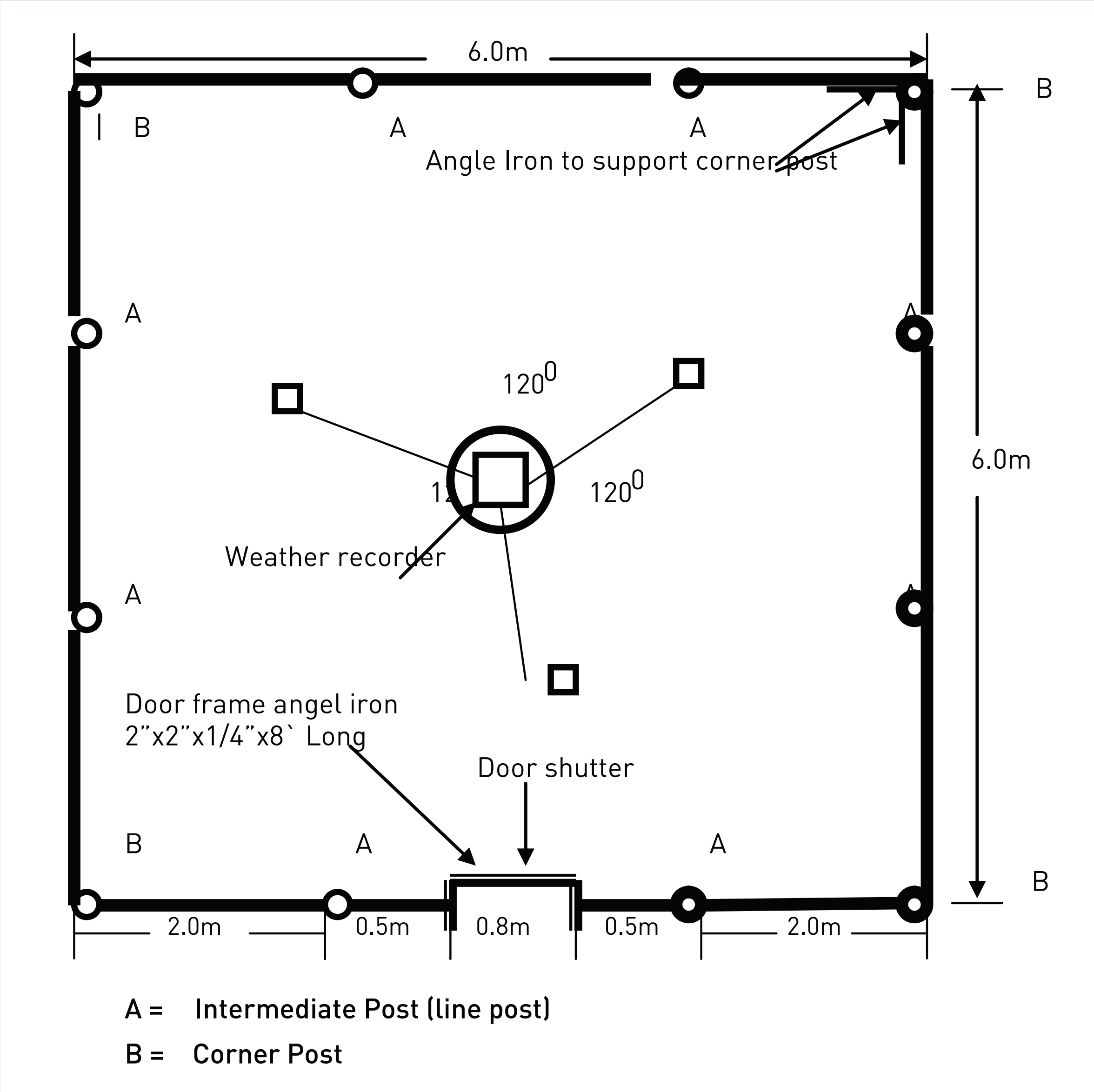
1. The values of daily battery voltage recordings are fairly constant, as in the above example. Battery and power supply are working properly. The minor variations (± 0.03 V) are due to temperature fluctuations and/or measurement errors. The battery is either newly charged or then it has been charged continuously from the solar panel.
2. Battery voltage recordings show a persistent negative trend. This indicates that either the power supply is not functioning properly, or that the power drain is in excess of the capacity of the solar panel. The reader is referred to the Solar Panel Trouble Shooting paragraph 4.3.5 for information on how to deal with this situation.
3. Datalogger program signature is a constant number during the recording period, as in the above example. The logger's RAM contains a correct version of METSTAT. There is no need to reload the program.
4. The datalogger program signature has changed during the recording period. METSTAT has been corrupted or illegally modified and needs to be reloaded. The reader is referred to paragraph 2.2 for detailed information on how to (re-) load the METSTAT datalogger program into the CR10X Storage and Control Module.

Annex 6: Batterry Log Book Specimen

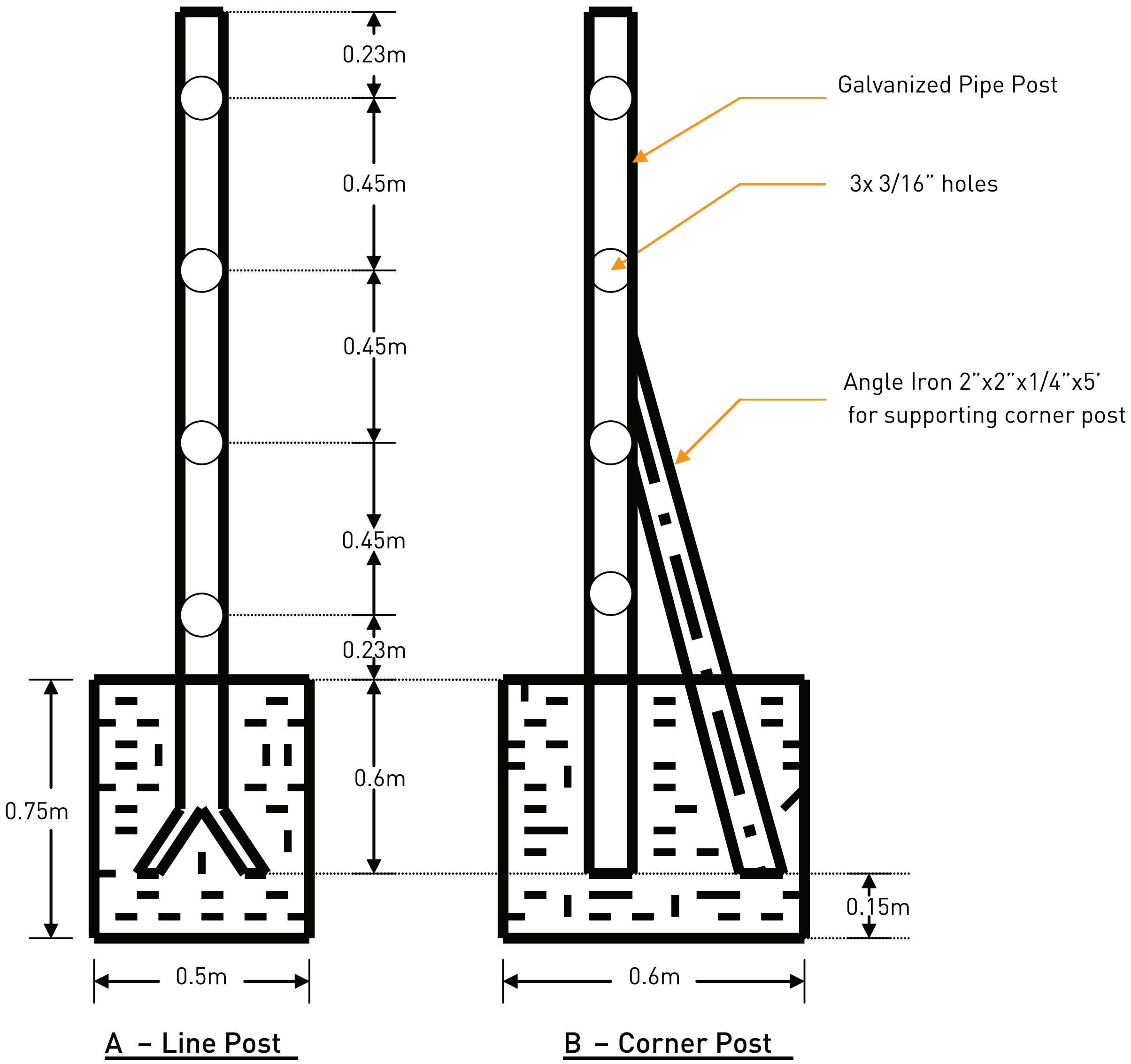
Battery Specifications			
Number:		Make:	
Main Office:		Type:	
Date of Purchase:		Capacity:	

Battery Log						
Date	Initial Voltage [V]	Initial SoC [%]	Activity	Final Voltage [V]	Final SoC [%]	Remarks

Annex 7: Design of Met Station Compound



Ground Plan of the Automatic Weather Station



0.23m
0.45m
0.45m
0.45m
0.23m
0.6m
0.75m
0.5m
Galvanized Pipe Post
3x 3/16” holes
Angle Iron 2”x2”x1/4”x5’
for supporting corner post
0.15m
0.6m
A – Line Post
B – Corner Post

Annex 8: Guidelines for Loading METSTAT Datalogger Program into Program Location 8 of the SM4M/SM192 Storage Module

8-A General

It is advised to permanently store METSTAT datalogger program in program location 8 of the SM4M or SM192 Storage Module. In this case, reloading METSTAT into the CR10X is automatically accomplished by connecting the SM4M/SM192 to the logger, and toggling the switch on the PS12-LA power supply OFF/ON. METSTAT is then stored in the logger's RAM, and made the active datalogger program without any further user intervention.

This annex presents detailed instructions how to store METSTAT into program location 8 of the SM4M or SM192.

8-B Hardware Connection

Figure A8 presents the hardware components required for connecting the SM4M/SM192 to PC.

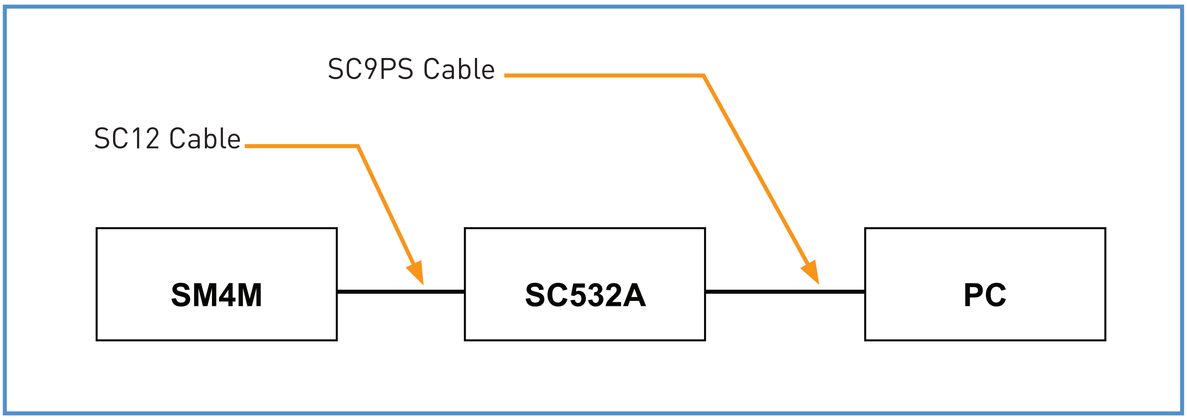


Figure A8: Hardware Components Involved in Connecting SM4M or SM192 to PC

The SC532A interface converts the specific data structure of the SM4M/SM192 to RS-232 Personal Computer compatible format. Since it runs on 110 V, use a 220-110 transformer between mains and the SC532.

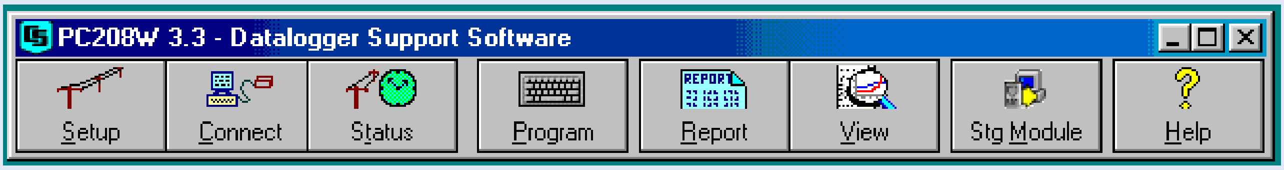
Note: Do not keep 220-110V transformer near to the PC/Monitor otherwise the screen will start flickering.

Connect the SC9PS cable to the SC532A and serial port 1 or 2 of the PC. Connect the SM4M/SM192 with the blue SC12 cable to the SC532A interface. All hardware components are now installed. Make sure power is supplied to the SC532A.

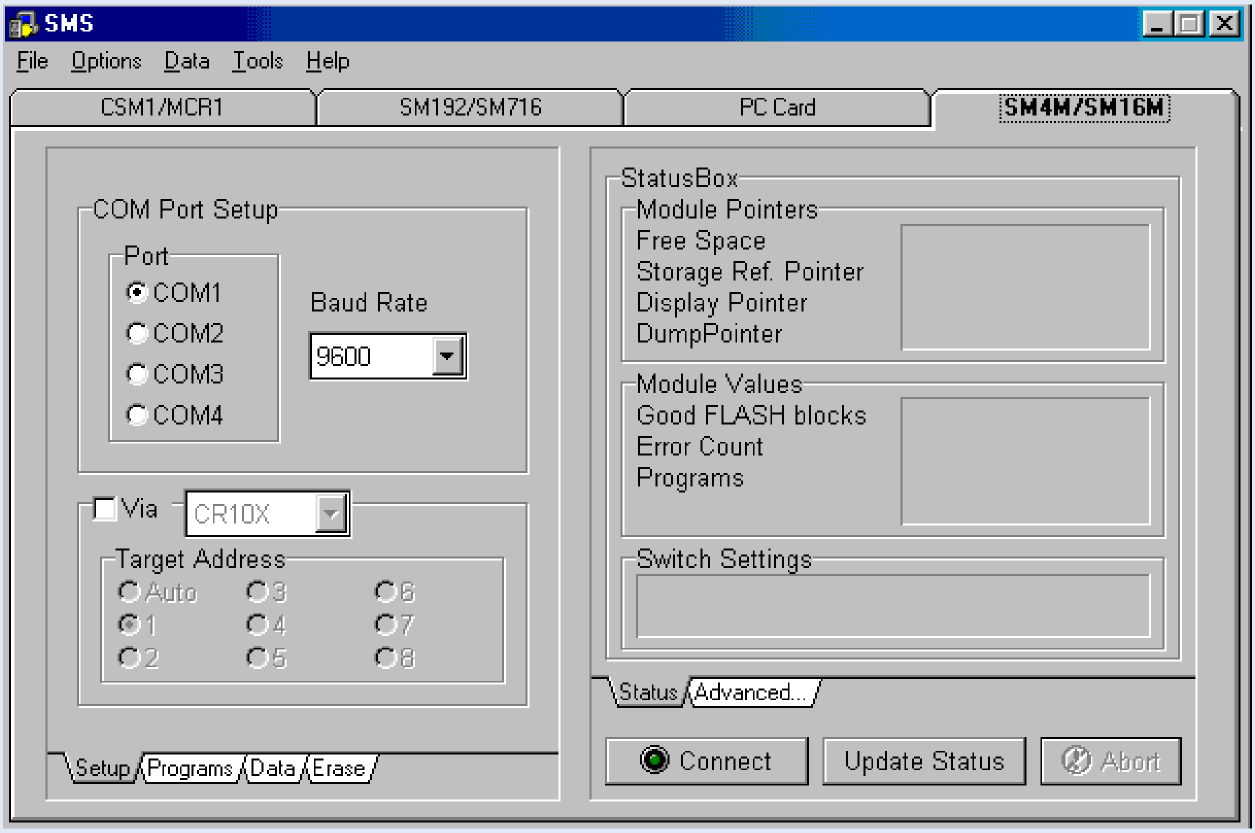
8-C Loading METSTAT into SM4M/SM192

Communication between SM4M/SM192 and personal computer is enacted through the PC208 Datalogger Support Software, which icon is presented below:

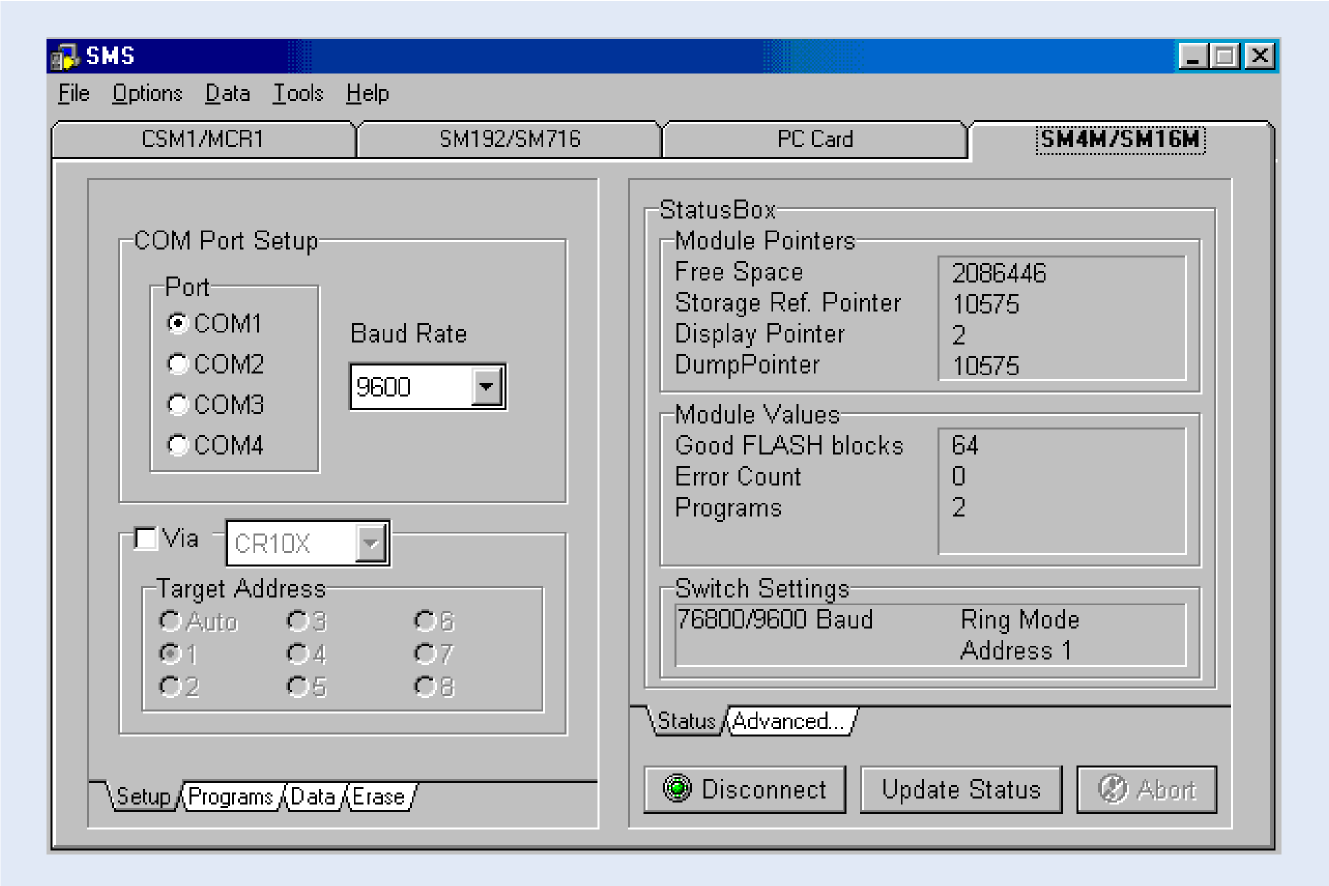
Double click this icon to activate PC208W. The following toolbar appears:



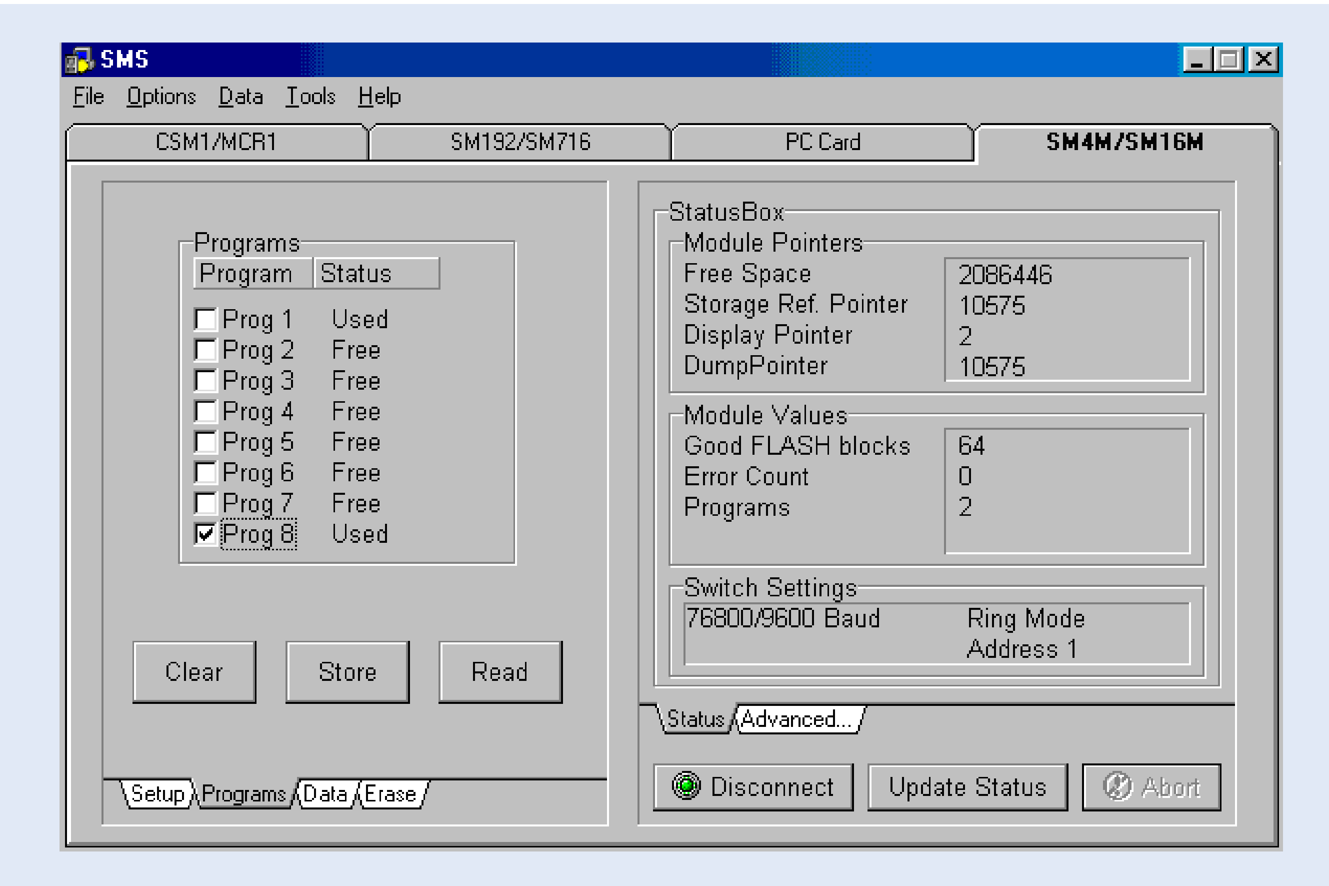
Double click the Stg Module icon. In the window that appears, first click the "SM4M/SM16M" tab at the right most corner of the screen, and subsequently the "Setup" tab at the bottom-left. The following window shows up.



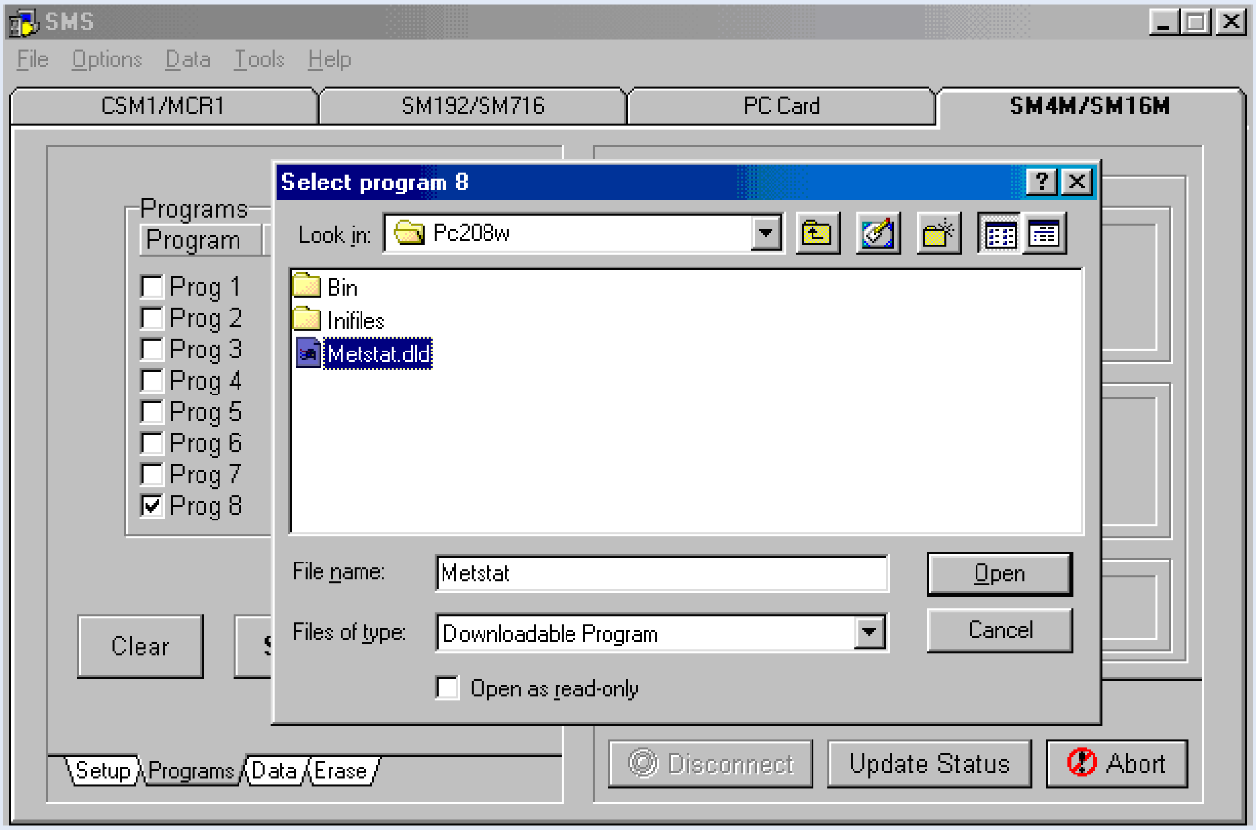
In this setup window, select the appropriate COM port. A default Baud Rate of 19200 is OK or otherwise change it to lower baud rate if necessary. Click the Connect button to connect the Storage Module to the PC. If communication is successfully established, the below screen appears.



Clicking the "Programs" tab brings up the Program Control Option screen, which shows that program location 8 is presently free.

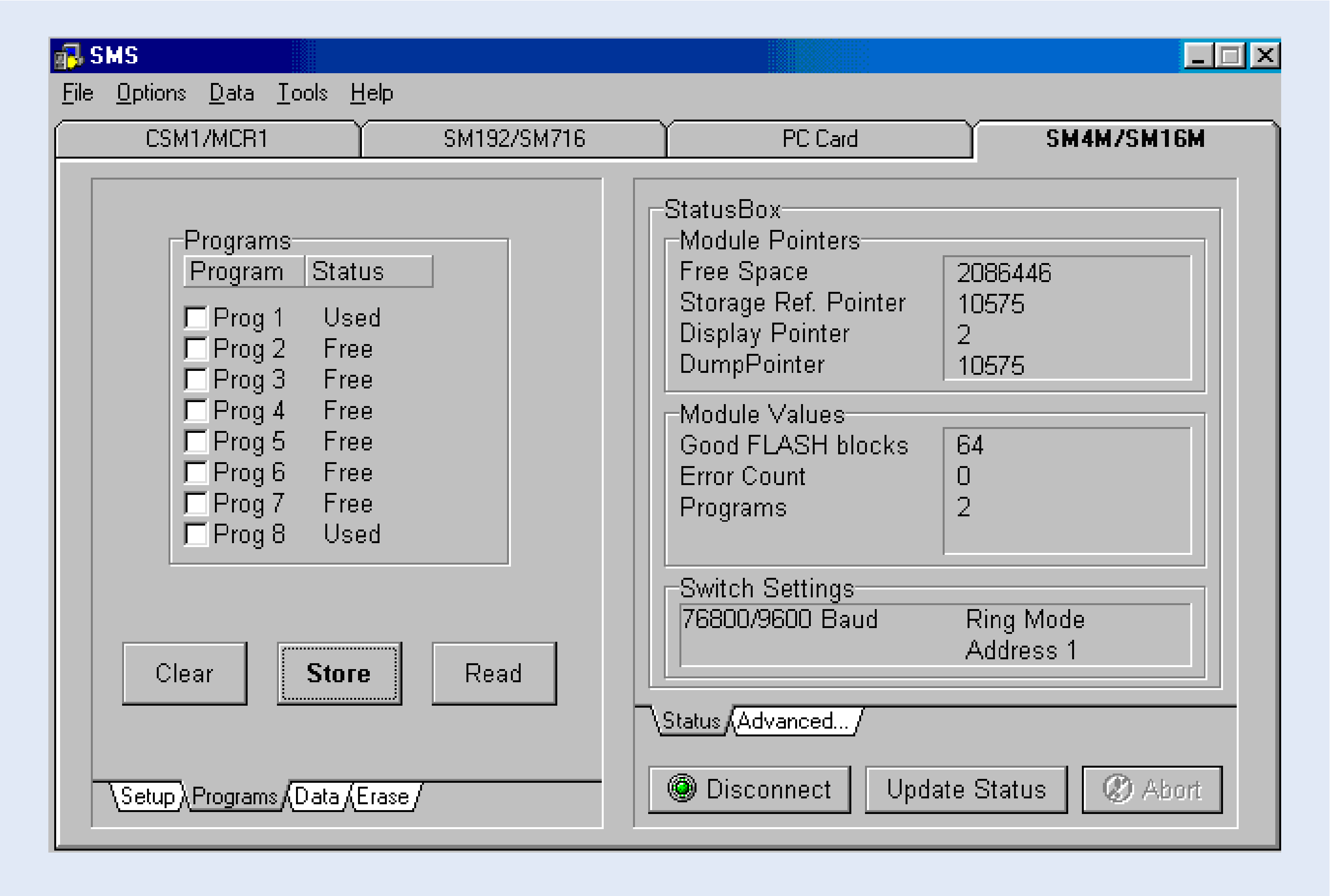


To load METSTAT in program location 8, check the box in front of "Prog 8" and click "Store". A navigation screen appears as presented below.



Navigate to the location, which contains the METSTAT.DLD file. Select this file and click Open.

METSTAT is now loaded into program location 8 of the SM4M. Once this process is successfully completed, the status of "Prog 8" has changed to "used", as shown in the below window.



Disconnect the SM4M by clicking the Disconnect button. METSTAT has successfully been stored in program location 8 of the SM4M Storage Module.

Procedure is the same for storing the program in location 8 of the SM4M and SM192.