

Copyright 2007, Dynamax Inc

All Rights Reserved

This manual refers to FLGS-TDP Model XM1000 sap velocity system with CR1000 data logger, including PC400 data logger support software.

Specifications are subject to change. Dynagage is a new product for experimental purposes under development. DYNAMAX Inc assumes no liability for customer assistance, infringements of patents or copyrights arising from the use of this product. US Patents covering the construction of various stem flow gauges are No 5,337,604 and 5,269,183. DYNAMAX does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, or other intellectual property right of DYNAMAX relating to this product, or process. There are no implied warranties of merchantability or of fitness for a particular purpose given with the sale of any goods. DYNAMAX Inc shall not be liable for consequential, incidental or special charges.

IBM is a registered trademark of International Business Machines

VELCRO is a trademark of Velcro USA

Dynagage, Flow32, Flow32W, TDP, FLGS-TDP, XM1000 and Dynamax are trademarks of Dynamax Inc

CR1000, CR Basic, PC208W, PC400 and LoggerNet are trademarks of Campbell Scientific Inc

Windows, Windows 95, Window 98, Windows NT, Windows2000, Windows Millennium, Microsoft Office, Microsoft Excel are trademarks of Microsoft Corporation.

Updated: 04/04/2007

TABLE OF CONTENTS

1.0	<i>INTRODUCTION TO FLGS-TDP</i>	6
1.1	FLGS-TDP Packaging - Control System Assembly Overview	7
1.2	Communication Options	9
1.3	Operation Overview And Quick Start Guide	10
1.3.1	Set Up Tools And Supplies	10
1.3.2	Accessories	10
1.3.3	Overview	11
1.4	Unpacking, Bill Of Materials	12
1.4.1	Bill Of Materials	12
2.0	<i>Thermal Dissipation Sap Velocity Sensor (TDP)</i>	14
2.1	Introduction	14
2.2	Principles	14
2.3	TDP Probe Description	19
2.4	TDP Specifications	19
3.0	<i>Sap Flow Computation</i>	20
3.1	Software Programming and Calculations	20
3.2	Sapwood Area	21
3.3	References	23
4.0	<i>TDP Sensor Installation</i>	24
4.1	Preparation of Probe Site	24
4.2	Installing the TDP Probes	26
4.3	Thermal and Rain Insulation	27
4.4	Probe Removal	28
5.0	<i>GENERAL SYSTEM SET UP - OPTIONS</i>	30
5.1	Field Installation	30
5.1.1	Sensor Connection To Logger	31
5.2	System Set Up	32
5.3	Solar Power - Batteries - Charger - Expansion Options	33

5.3.1	Solar Panel Requirements	33
5.3.2	Solar power Budget Sheet.....	34
5.3.3	Worldwide Solar Distribution Chart -Worst Case Winter Data Esh.....	35
5.4	120 VAC Power	36
5.5	Setting The Sensor Input Voltage.....	37
6.0	<i>SOFTWARE INSTALLATION</i>.....	40
6.1	PC400 Installation.....	41
6.1.1	Working Directory Location	42
6.2	FLGS-TDP software installation	43
7.0	<i>USING PC400</i>	44
7.1	Launch Pc400	44
7.2	Setup, Program Logger And Communications	45
7.3	Connect To Logger.....	49
7.4	Programming the Logger	50
7.4.1	Modifying the program	50
7.4.2	Programming the Logger	55
7.5	Monitor Data In Real-Time.....	56
7.6	Adavnced PC400 Features	57
7.6.1	SHORT CUT/ SCWIN.....	57
7.6.2	Program Logger/ EdLog	57
7.6.3	Program Logger/ CRBasic	57
7.6.4	Other Features (Not applicable to FLGS-TDP system)	57
8.0	<i>DATA RETRIEVAL AND PROCESSING</i>.....	58
8.1	Collect Data For Offline Processing	58
8.2	Graphics Mode Display - File Data	60
9.0	<i>RECALCULATE SAP FLOW USING EXCEL</i>	64
10.0	<i>COMMUNICATIONS</i>	68
10.1	RF Modem (RFMX).....	70
10.1.1	Specifications	71
10.1.2	List of Hardware	71
10.1.3	Programming.....	72
10.1.4	Antenna/ Tower.....	72
10.1.5	Host Modem Installation.....	73
10.1.6	Remote Station Installation	73

10.1.7	Use of Repeater	74
10.2	Dual band cellular wireless Modem (GSM).....	75
10.3	Short-haul Modem (SHM)	78
10.3.1	Specifications	78
10.3.2	Hardware Configuration.....	79
10.3.3	Troubleshooting	79
10.4	Modes of Communication	80
10.4.1	Modes of Configuration	80
10.4.2	A sample large scale setup	83
APPENDIX A:	<i>TDP SENSOR DRAWING/ CHANNELS.....</i>	85
APPENDIX B:	<i>FLGS-TDP SYSTEM WIRING.....</i>	91

1.0 INTRODUCTION TO FLGS-TDP XM1000

FLGS-TDP XM1000 is the newest completely integrated measurement system and CR1000 data logger for TDP sap velocity sensors. The new XM1000 model version of our TDP Sap Flow System includes the latest **Expanded Memory** Datalogger platform, and **Extended** features such as Real-Time sap flow calculations and Auto Zero. Each FLGS-TDP system can read up to 32 TDP10/30/50 sensors. This basic system can be expanded with an additional subsystem to read an additional 32 sensors. Each TDP thermocouple is connected to a differential channel on the logger. All the necessary electronics, software and sensors are assembled into a full and complete solution. Field or greenhouse sap flow measurement is accomplished with FLGS-TDP in an easily expandable set of custom modules. The unit is programmed with a maintenance program to facilitate the user in monitoring the

The new FLGS-TDP system is a completely integrated unit with the following key components:

- Advanced data logger with easy programming, data storage and retrieval capabilities - CR1000
- XM1000 release has 2 MB data memory, for up to 100,000 data values - up to 200 days of records.

Data tables for every file output need:

- a. TableDT – The raw DT, differential temperatures with date and time stamps.
 - b. TableTC – Raw sensor temp signals, maximum dT @zero; Velocity, flow, and status
 - c. TableTDP – Computed hourly flow rates, indexed sap flow, and sensor status
 - d. TableHR – An indexed sap flow for all sensors combined
 - e. TableDY – Accumulated daily sap flow with one daily total, a day-by-day report.
- Set up for your specific trees, sap flow area, and tree indexing by leaf or stem area. These features may be applied as needed to generate the indexed sap flow tables above.
 - Multiplexer for expanded channels, AM16/32
 - High-efficiency Adjustable voltage regulators, AVR, two units supplying 4 different voltages

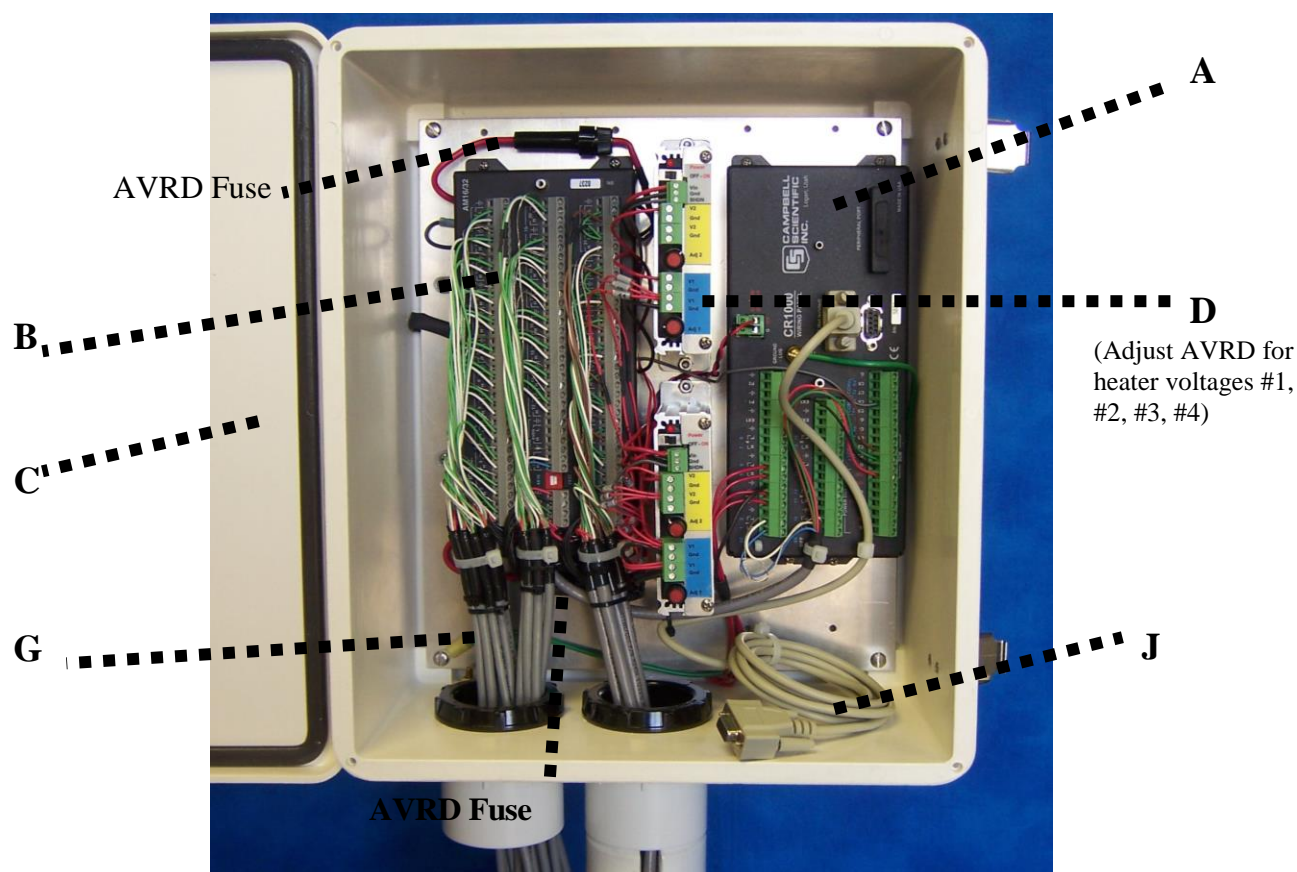
TDP10/30/50 sensors are single point measurement sensors and each sensor occupies one differential channel. FLGS-TDP system integrated with CR1000 data logger and multiplexer can accommodate up to 32 TDP10/30/50 sensors. A TDP80 sensor has two points of measurements and occupies two channels on the multiplexer, hence 16 TDP80 sensors can be connected on one FLGS-TDP system. Similarly, a TDP100 sensor has three points of measurements and occupies three channels on the multiplexer, hence 10 TDP100 sensors can be connected on one FLGS-TDP system. A combination of TDP sensor types can be connected to the FLGS-TDP system.

In addition to the above-mentioned basic configurations, FLGS-TDP system can be customized to add other sensors such as dendrometer, temperature, solar radiation etc. in limited numbers on the open channels available on CR1000 data logger. These changes require modification in the program and storage data tables.

1.1 FLGS-TDP XM1000 Packaging - Control System Assembly Overview

A standard 32 sensor Model XM1000 FLGS-TDP includes:

- a) CR1000 Logger
- b) Input Multiplexer for 32 thermocouple based sensors (Cat no AM16/32)
- c) Weather proof System Enclosure (Cat no ENC12-14), with pole mounting brackets and U clamps.
- d) Voltage Regulator (2-units):
 - AVRD - Dual voltage-regulated adjustable outputs and power-down voltage control input.
 - Fused AVRD circuit protection
- e) Optional Solar Panel (Cat no. MSXxxR, xx = WATTS power) - or
- f) 120/220 V AC Battery Charger and 7 AH Sealed Lead Acid Battery (Cat no. CHG220)
- g) Sensor Cables with installed at multiplexer. (Same in number as the number of sensors ordered)
- h) Grounding cable (green) to earth ground rod (user supplied).
- i) Wiring Harness for Battery, Solar Panel, or CHG220 connection terminals (red and black wires)
- j) Direct PC RS232 Link for Program Download, Real Time Monitor, and Data Retrieval, 6' communication cable.
- k) For advanced applications requiring higher data storage capacity a Compact flash memory card interface can be connected to the data logger, this interface module can be used with locally available Compact flash memory cards both to expand the available data memory and for data shuttle applications.
- l) TDP10/30/50/80/100 sensors as per the order.
- m) Installation equipment including weather shield for TDP sensors



Customer Provided Requirements:

In addition to the equipment supplied by Dynamax, user requires the following equipment or tools to install the FLGS-TDP system in the field. This list is provided here as a guideline only and is neither intended to be an absolute requirements. Some installation locations, types of installation require different tool set or directions.

35 mm (1.5 ") mounting pole, or suitable alternative mounting for field installation of FLGS-TDP enclosure.

Grounding Rod - 4-6 ft copper stake and ground wire clamp.

For CHG120, A ventilated battery box (ENC-PL) to enclose Charger and separate sealed lead acid battery. Grounded Outlet for 120V power within reasonable range of the charger, 100 to 200 ft. An extension cord and conduit to carry 120 V AC line power if available.

(For	Solar	Panel	Option)
12 V marine or deep cycle battery(s) (60 Ahr minimum) for solar panel storage device. See Section 6.3 for the guidance on number of batteries and solar panels required for a good safety margin. Plastic battery box(es) to keep battery dry. May be purchased from battery supplier or Dynamax Model ENC-PL.			

In field protection options for sensor cables and protection from mice, deer, or other animals:

1. Electrical cable conduit or
2. Bury Cables, or
3. Elevated and tied to trees or stakes or
4. Slotted cable wrap, plastic protection sleeve from hardware or electrical supply stores

System Requirements:

IBM Compatible 32-bit PC, at least a Pentium II or equivalent processor,

Minimum 80MB free space on Hard Drive

Minimum of 128MB of RAM

CD-ROM drive

At least one COM port, RS232 serial data port, available.

- An USB port can be used in place of a RS232 serial port with USB-serial adapter.

Recommended operating systems include Windows NT, Windows 2000, and Windows XP.

With limited capabilities PC400 software can be run on a Windows 98 platform (not recommend).

Application software for spreadsheet and graphing, Microsoft Excel 97 or higher or equivalent.

SVGA monitor recommended, 800 by 600 pixel is recommended. Graphics card in 16-bit (64k) color mode or better recommended.

Extension Cables:

The maximum recommended extension cable is 100 ft (EXTP-100) in addition to the standard 8 ft (8' pigtail), for a total of 100 ft (33 m). Since the extension cables include 4 to 6 wires plus a shield, any connector between the sensor and the logger requires at least 5 conductors. These connectors are supplied with the TDP sensor and are weatherproof locking connectors. The MEC connectors are found about 0.5 m from the logger enclosure so that the rest of the extension cables can be separated for easy transportation and storage.

1.2 Communication Options

FLGS-TDP Sap Velocity logger offers a variety of communication choices of user to establish communication between logger and PC using PC400 or LoggerNet software. For optional RS232, 150 to 250 ft RS232 extension cables can be added for direct communication at 1200 baud. Cat no FL32-EXT, 50 m extension. In addition, FLGS-TDP system supports remote communication options given below with easy to use software features.

(Model COM210) Land-line Modem for remote field retrieval and control:

Customer provides telephone connections and PC MODEM (Hayes compatible) at computer location. Many models are supported by the telecommunication software package included in data logger support software.

(Model: SHM) Short haul modem for communication using 4-wire cable:

For cable communication of up to 4Miles not possible using 9-wire serial cable. DIP switch selectable. Easy to install and establish communication. Short-haul modems are line-powered, i.e. takes power from communicating device PC or Data Logger. Refer to sections 15.2 for a detailed discussion on Modem setup and hardware required.

(Model: RFMX)Radio Modem 900 MHz/ 2.4GHz:

Stand-alone radio modems provide efficient and low-cost serial communication to remote installations for long distances of up to 40 Miles @ 9600 baud rate. These modems allow point-to-point and point-to-multi-point configurations between central PC and multiple data loggers connected to it. RFMX modems can be setup using LoggerNet or PC400 software. RFMX is also offered in a modem kit (Model: RFMXMK) with surge protector, high-gain antenna and connectors assembled in a weatherproof enclosure optional solar panels for continuous powering the modem. Refer to sections 15.1 and 15.3 for a detailed discussion on Modem setup and hardware required. For frequency (product) selection suitable to your project contact Dynamax representative.

(Model: GSM) Dual-band GSM Cellular modem (900/1800, 850/1900):

GSM cellular modem for serial data rates of up to 115,200 bps, using cellular network where available. GSM modem is a very low power modem with battery capacity of 33Hours of communication and 20Days on idle. GSM modem installed in remote site can be connected to PC using a 56K landline modem (Model: DNX9600) and telephone network. GSM-CMK is a cellular modem kit that includes modem, surge protector, antenna and 15' long antenna cable assembled in a weatherproof enclosure, optional solar panels for continuous powering the modem. Software setup for GSM modem is same as that of Data Modem. For frequency (product) selection suitable to your project contact a Dynamax representative.

1.3 Operation Overview And Quick Start Guide

1.3.1 Set Up Tools And Supplies

Tools and supplies usually necessary: Volt - Ohm meter (VOM) caliper or flexible measuring tape 1/2" or 13 mm open end wrench small flat blade screwdriver (included with FLGS-TDP) sharp knife electrical tape - vinyl aluminum foil medium sandpaper paper towels water nylon tie wraps, clear packing tape, or white vinyl tape to secure weather shields.

1.3.2 Accessories

Depending on the location and the selection of power options the customer provided accessories are the following:

- 1) One or more 12V 60- 80Ahr deep cycle marine grade lead acid battery
 - When using solar array with numerous tree gauges see section 5.3 for details on computing the total battery and solar panel requirements.
- 2) Use solar power calculator Excel application to determine the power and number of batteries required for your application. The excel spreadsheet is included in your installation CD. See Section 5.3
- 3) Battery boxes for charger and batteries if outside. Most inexpensive automotive or motorboat battery boxes are available with tie down strap from automotive stores or hardware supply stores. The Battery boxes are usually heavy-duty plastic construction able to keep out moisture and to prevent contamination. Shade the battery boxes to keep the temperature from going too high inside on hot days.

WARNING:

USE SEPARATE BOXES TO HOLD THE CHARGER AND THE BATTERY, EXPLOSIVE GASES FROM THE BATTERY MUST NOT BE ALLOWED TO BE TRAPPED IN THE SAME ENCLOSURE AS THE BATTERY CHARGER.

- 4) 1.5 " diameter galvanized pipe with end cap, 4 to 6 ft long. One pipe per module.
- 5) Two 2 -1/8" "U" bolt for each solar panel
- 6) Implements to set pipe / mix concrete. Concrete mix to set pipe in soil for a more permanent setup.
- 7) PVC conduits and elbows if underground wiring is needed.
- 8) Four to six feet (1-2 m), copper grounding rod and clamp.
- 9) Padlock to secure enclosures outdoors

1.3.3 Overview

- A. Site survey, preparation, plant survey, and plant preparation.
- B. Unpack system and sensors
- C. Mount FLGS-TDP Enclosure(s), and connecting control cables Connecting Power
Grounding
 Connect personal computer
- D. Install utilities from PC support software CDs
PC400 setup.exe
FLGS-TDP programs from the disk
- E. Install TDP sensors, cable connection, and radiation, heat, weather shielding.
 Measure diameters or circumference on the trees where you install the sensor. Record values and calculate sap wood stem area.
- F. Load Maintenance software to check installation and to set the Sensor Voltages with AVR. **Download Test** to logger and monitor, set voltages
- H. Download FLGS-TDP.cr1 control program, and set the logger internal clock with the PC time/date.
Click on the Set Datalogger Clk
- L. Retrieve flow information from TC, TDP, HR and DY tables and save files on disk
PC400 -> Connect -> Collect all button
- M. Display, print, and format flow information saved on the files on disk.
PC400 -> Connect -> View -> Open File ->Click on plot button
- N. If necessary, sap flow can be recalculated from the basic differential data dT using automated Excel spreadsheet application. This application spreadsheet performs autozero every day.
TDP Sap Vel-Analysis-ETo.xls

With experience each of the steps above can take as little as five to 15 minutes to perform except for sensor installation (5 -10 minutes each). The sensor installation can take much longer depending on the species if there is any special preparation required, and it depends on the number of plants. Site preparation may require conduit installation or added precautions if there is going to be tillage or other heavy equipment among the plants to be tested.

To efficiently install and learn these steps, only this manual is required. All steps above are explained in detail, and example screen menus and printouts are provided as the operations are described. All of the data retrieval examples in this manual are run using sample data, which is provided, on the FLGS-TDP software CD. A fast learner should become familiar with this entire manual by running the examples and checking printouts to see if the results are the same as provided herein. The essential installation instructions of the TDP sensor are covered first in the upcoming chapters. PC400 logger software support manual may be needed to handle unusual questions about custom systems. In any case the help files with PC400 contain extensive on line support, so the manual is not normally required.

Additional manuals are also provided for detailed information on the datalogger and peripherals, the CR1000 Logger Manual, Multiplexer and the PC400 software support manual, which supports IBM compatible PC's. The user will not normally need to get into these manuals, because the component

connections are either done at the factory, or the essential information is already included in this manual. If special weather sensors or other customized operation is desired, the additional manuals provide all the information necessary.

1.4 Unpacking, Bill Of Materials

Using the following bill of materials, open the cartons and check off the items to see that all material was received in good condition. Notify Dynamax no later than 10 days after receipt if there are any discrepancies. Notify the shipper and Dynamax immediately if goods are damaged in transit by mishandling. The white FLGS-TDP enclosure contains the logger, the AM16/32 multiplexer, two AVR D regulators, and the RS232 interface cable. Gauge cables, 12 V power leads, and 5' RS232 interface cable, exit from the bottom of the system enclosure. Each sensor lead is labeled with a sequence number. Be careful at all times not to step on or otherwise bend the gage connector leads.

FLGS-TDP software is packaged with this manual, one PC400 CD-ROM and one FLGS software disk.

1.4.1 Bill Of Materials

FLGS-TDP Bill of Materials

- a- Completely assembled standard FLGS-TDP system with requested number of TDP sensor pigtails.
 - b- CR1000 - data logger in enclosure
 - c- AM16/32 - Multiplexer in enclosure
 - d- PC400 logger support software CDROM
Optional LoggerNet software may be obtained for network applications.
FLGS-TDP program CDROM
 - e- 120 / 220 V Battery Charger and 7Ah 12 battery
 - f- 2-units of AVR D dual voltage regulator
 - g- 5' communication cable in enclosure.
 - i- Spares Kit, Screwdriver
 - j- One TDP J1 Installation kit with drill bits, a template and extraction tool.
- Manuals:
- FLGS-TDP XM1000 Installation and Operation Manual
 - FLGS-TDP Software CD
With Logger control software, and installation video.
 - PC400 - PC Software Support Utility Manual (on CD)
 - Optional LoggerNet - PC Software Support (on CD)
 - CR1000 - Operators Manual (Bound)
 - AM16/32 - Multiplexer Instruction Manual
- EXTERNAL Solar Power Source (when ordered)
- j- MSXxxR Solar Panel, xxWatts with regulator
 - k- Regulator/ Battery Charger installed in panel
 - l- Solar Panel Pole Mounting Kit with U bolts

2.0 Thermal Dissipation Sap Velocity Sensor (TDP)

2.1 Introduction

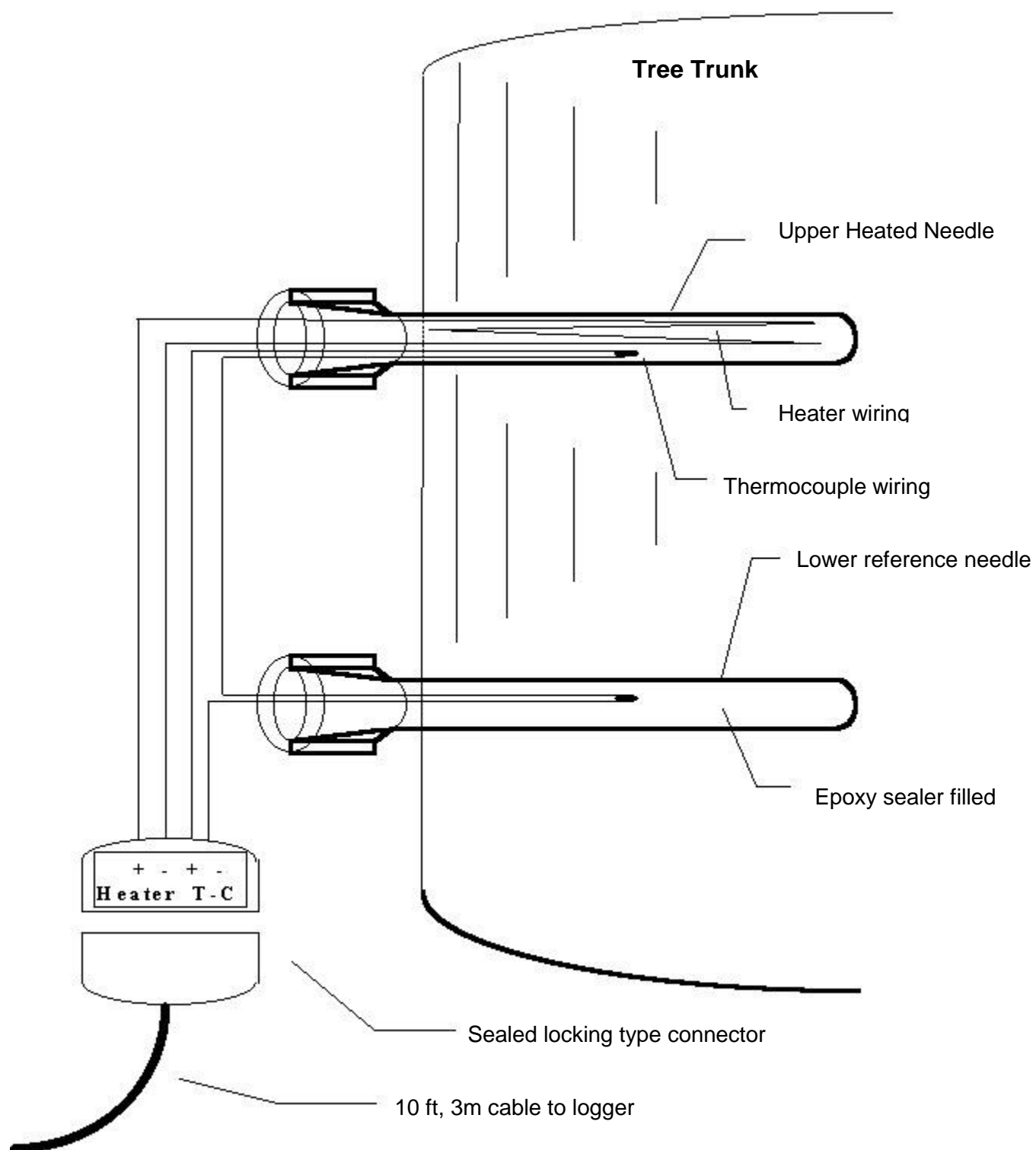
The transpiration rate of whole plants is closely approximated by the sap flow rate in the main stem or trunk. This quantity, expressed in g/h or similar units, can be measured and recorded *in situ* and non-invasively with Dynamax stem gages, which are wrapped around the stem or trunk. When the trunk diameter exceeds 50 mm (2 inches), the gages become larger and more complex. For trunks larger than 125 mm (5 inches), using stem gages is not practical. Also, each Dynamax trunk gage from 50 mm to 100 mm has 16 T-C junctions differentially arranged in four separate measurement locations around the trunk, making them more costly.

For these reasons there is a need for a relatively simple and affordable device to continuously monitor the sap flow rate in trees of all sizes. A method for that purpose was proposed by Granier (1), who inserted a needle, containing an electric heater, in the sapwood of a trunk and measured the difference between the temperature of the heated needle and that of the sapwood some distance below the needle. The method is relatively simple and it can be automated with a digital datalogger. Now, the apparatus is commercially available in a fully packaged form, ready to use. In the following sections, Dynamax describes a new product that meets the above needs, and provides instructions for its use.

2.2 Principles

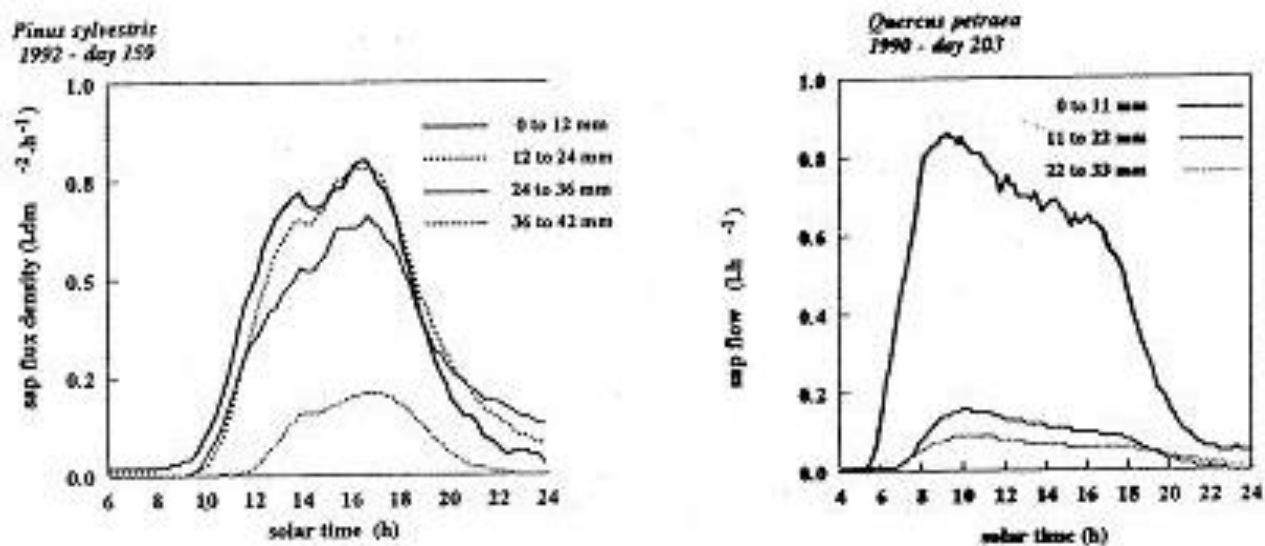
The Thermal Dissipation Probe (TDP) heated needle is an improved heat dissipation sensor, as proposed by Granier, which measures the temperature of a line heat source implanted in the sapwood of a tree, referenced to the sapwood temperature at a location well below the heated needle. The probe measures the sapwood heat dissipation, which increases with sap flow and the resultant cooling of the heat source, as the apparent thermal conductance of sapwood increases with sap velocity. When the sap flow velocity is zero or minimal, the temperature difference (dT) between the two sensors is maximal. When the flow increases, this temperature difference decreases. This approach enables the measurement of sap flow velocity with inexpensive equipment from a known relation between dT and the sap velocity.

An important feature of the Thermal Dissipation Probe (TDP) is that a constant heat method is used, that is, the heating element of the probe stays on and permits continuous and frequent measurements. This is in contrast to the heat pulse method, or the Heat Pulse Velocity method (HPV), in which the sap velocity is found from the time lag between pulses and the distance between sensors. In heat pulse systems time and distance are critical, whereas in the Thermal Dissipation Probe (TDP) method, neither time nor distance are critical. In addition, the HPV method requires a waiting period between readings, whereas with the TDP method the signals are continuously available to the logger. In the Dynamax TDP method, the difference in temperature between the probes, dT , is recorded and automatically converted to sap velocity and then sap flow with in the logger.

TDP Sap Velocity Probe

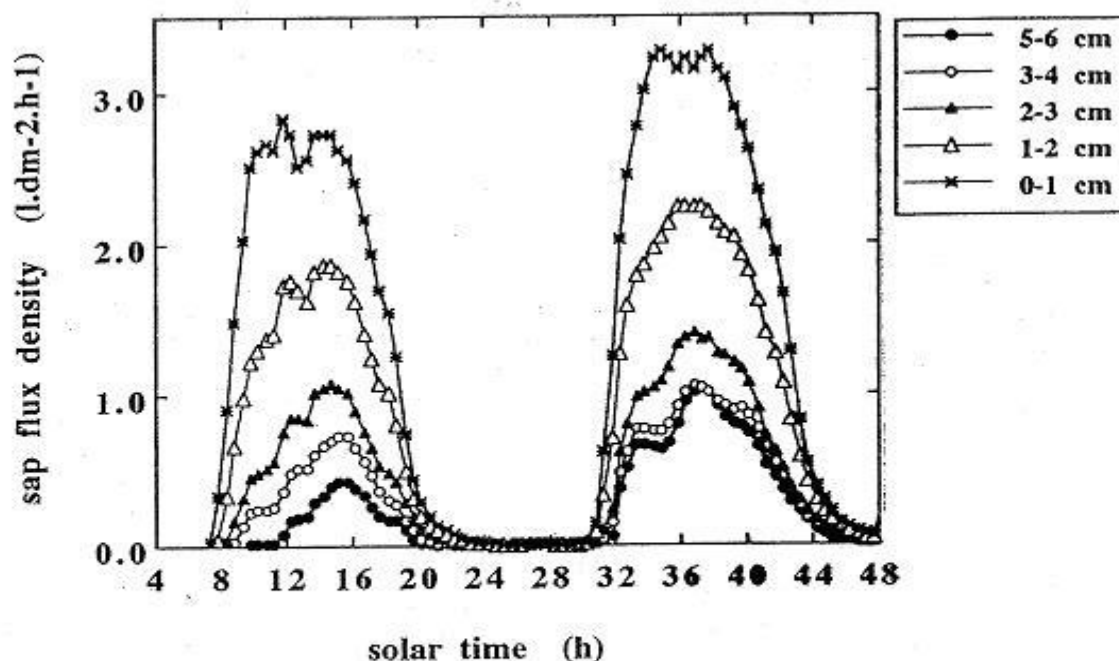
Granier defined a dimensionless "flow index" (K), calculated from the measured temperature difference and the maximum value thereof, occurring at zero flow velocity. He then established an empirical relation between the value of K and the actual sap flow velocity, measured in m/s, using trunk sections of 40 - 50 mm diameter. This exponential relation did not differ significantly between a numbers of common tree species.

Since the TDP method gives a continuous record of sap flow velocity, it also records the sap flow rate, as the product of the former with the sapwood area. This area must be determined for each tree specimen on which measurements are made. Clearly, this produces an estimate of the sap flow rate, but one that may be sufficiently close for many purposes. To determine the sap flow rate more accurately the multiplier must be found from an empirical calibration of each trunk under study. In this respect, the TDP method does not differ from the heat pulse method. The Dynagage heat balance sensors, on the other hand, make an absolute measurement of the sap flow rate, requiring no calibration or the measurement of a "flow index".



**Radial variation of sap flow within
Scots pine and Oak stems**

It should be understood that the sap flow velocity varies within the sapwood, as shown by Granier (unpublished data). Therefore, what is being measured with the TDP method is an integral of the sap flow velocity over the radial thickness of the sapwood. In addition, the actual or microscopic velocity of the sap in the xylem vessels, as measurable with dye tracers, is significantly greater than the macroscopic velocity indicated by the TDP method, since the presence of the needles averages their temperature over the entire sapwood in which they are embedded. The fact that the length of the needle and the thickness of the sapwood cannot be exactly the same, introduces some uncertainty in the calculation of the sap flow velocity, reflected in the relation between the latter and the temperature difference dT , as evident from the work by Granier (1, Figure 2).

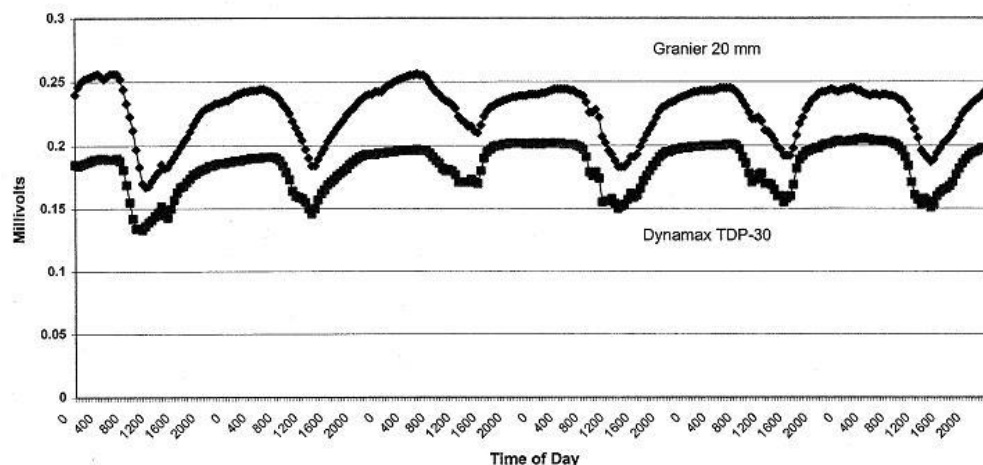


Variation of sap flux density according to the depth in a beech (radius 15 cm), during two bright days.

In spite of the two sources of error cited in the two paragraphs above and the possible effects of environmental parameters on the temperature difference ΔT , the method produces reproducible results and reasonable agreement with independent estimates of the sap flow rate (Granier, 3).

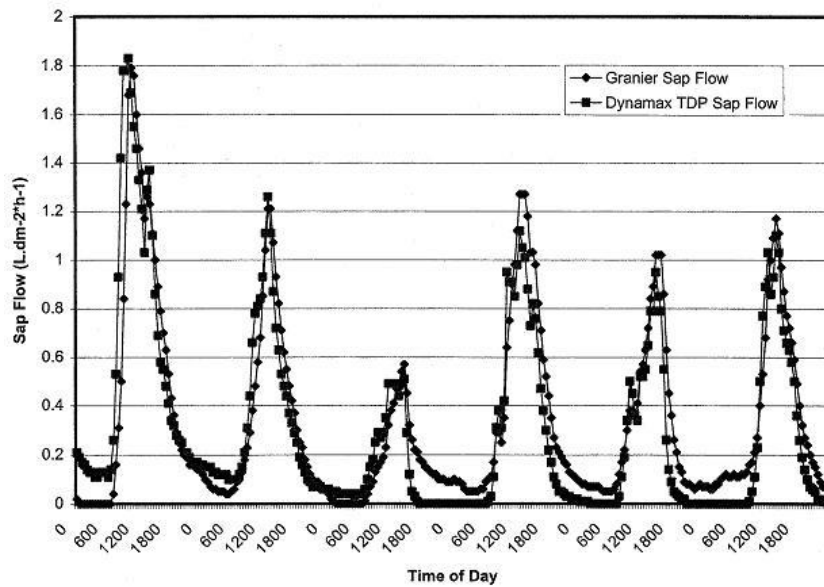
In contrast, Dynagage heat-balance sensors make an absolute measurement of the heat carried by the sap and require no calibration or calculation of a "flow index". Dynagage trunk flow sensors can be used to calibrate the TDP sensor method. Another calibration option is to weigh the whole tree periodically, but this is often impractical or not affordable.

TDP Signal Chart

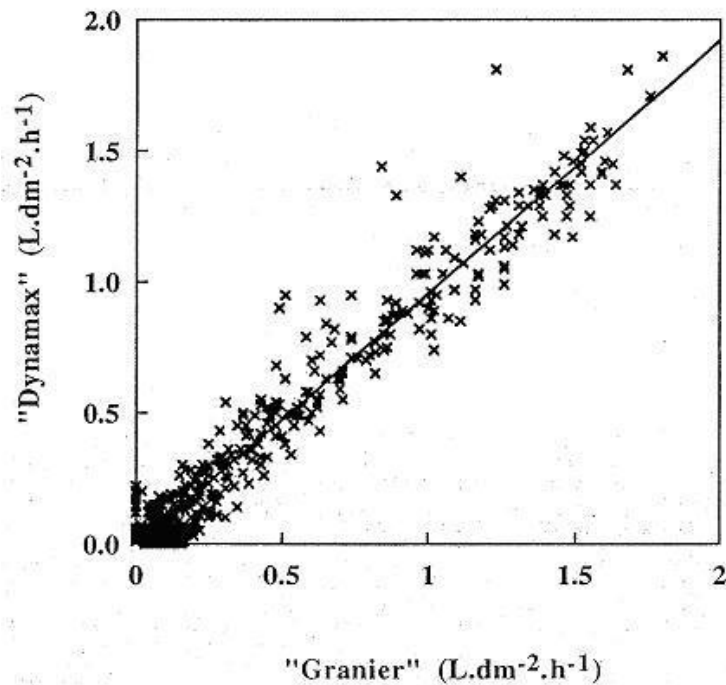


Comparison of Granier and Dynamax Sapflow meters.
 DOY254-259, A. Granier, 1996
 TDP-30 @65 ma / Granier @ 120 ma.
 Data Courtesy of INRA

Sap Flow Comparison TDP & Granier Probes
15 Year old Douglas Fir
Data expressed as sap flux density



$$y = 0.964x - 0.008 \quad r^2 = 0.951$$



Comparison of Granier and Dynamax sapflowmeters
on a 15 year-old Douglas-fir. Data are expressed in
sap flux density (litres.dm⁻².h⁻¹).
1996, DOY 253 to 264

2.3 TDP Probe Description

A probe set consists of two needles, a heated needle above and a reference needle below. The heated needle has a heating element and a copper-constantan thermo junction inserted in a 1.2 mm diameter (o.d.) stainless steel tube that is 30 mm long (see Figure 1). The longer TDP-80 probes (80 mm long) are supplied with two thermo junctions in each needle to give two temperature differences across the sapwood area. The reference needle has no heating element. The probe electronics are sealed with an epoxy resin that is impervious to water.

In many tree species, the sapwood comprises the outer part of the (ring-porous) trunk to a depth of 30 to 40 mm. In some species the xylem is more dispersed throughout the trunk and the use of the 80 mm probe (TDP-80) is recommended over that of the 30 mm one (TDP-30). The TDP probe is installed into the trunk in a vertical line with the needles 40 mm apart. The heated probe is supplied with a constant electric voltage and the temperature difference between the probes is monitored. The power of the heating element is about 0.20 Watts, which raises its temperature by approximately 8 to 10 C, when the velocity is at or near zero.

Because sap flow varies around the circumference of trees, more than one probe can be inserted into a single trunk to make more representative flow calculations. Dynamax recommends installing 2 probe sets per tree for trees 5" to 8" (125 to 200 mm) in diameter, and 4 probe sets per tree for trees over 8" (200 mm) in diameter. This means that our fully expanded 60-channel logger system can monitor up to 15 large or 30 small trees, using available extension cables.

2.4 TDP Specifications

TDP Size	Length	Diameter	Spacing	Power	Cable/ Standard	Heater Resistance	Operation Voltage	TC Connections
TDP10	10 mm	1.2 mm	40 mm	.08 to .12 W	10ft./5 Cond	26 ohms	2V	1 T-Type
TDP30	30 mm	1.2 mm	40 mm	.15 to .2 W	10ft./5 Cond	50 ohms	3V	1 T-Type
TDP50	50 mm	1.65 mm	40 mm	.32 W	10ft./5 Cond	78 ohms	5V	1 T-Type
TDP80	80 mm	1.65 mm	40 mm	.5 W	10ft./6 Cond	110 ohms	7.5V	2 T-Type
TDP100	100 mm	1.65 mm	40 mm	.44 W	10ft./7 Cond	145 ohms	8V	3 T-Type

Extension Cables Extension Cables are available in 25ft, 50ft and 75ft lengths. Other lengths are available. The sensor cables come with male and female sealed environment locking-type connectors for fast connection to extension cables.

3.0 Sap Flow Computation

3.1 Software Programming and Calculations

The Granier method is based on liquid velocity heat dissipation theory, and not a specific model of heat transport in plant stems or tree trunks. Similar air flow sensors and hot-wire anemometer techniques are widely used in other applications. However, the Granier method does require knowledge of the physical dimensions of the sapwood to convert velocity to sap flow rate.

TDP sensor has thermocouples in the upper needle and the lower needle to measure the temperature difference between the two needles. The thermocouple output is in millivolts, and is measured by the data logger. This millivolt data is then converted to temperature difference using the formula below.

$$dT \text{ (in } ^\circ\text{C)} = \text{Thermocouple differential voltage (in mV)} * 25$$

Where dT is the differential temperature between the heated needle and the reference needle.

From the differential temperature dT, Granier (1,2) defined a dimensional parameter K as:

$$K = (dT_M - dT) / dT$$

dT is the measured difference in temperature between that of the heated needle, referenced to the lower non-heated needle, placed at a fixed distance below the heated one. The value of dT is found from the differential voltage measured between the upper and lower thermocouple. The parameter dT_M is the value of dT when there is no sap flow (zero set value). Clearly, when dT = 0, K equals infinity and, if dT = dT_M, K = 0 (zero flow).

Granier found empirically that the average sap flow velocity V (cm/s) could be related to K by an exponential expression:

$$V = 0.0119 * K^{1.231} \quad \text{cm/s}$$

To convert the velocity to sap flow rate, one uses:

$$F_s = A_s * V * 3600 \text{ (s/h)} \quad \text{cm}^3/\text{h}$$

where F_s (cm³/h) is the sap flow (cm³/h), and A_s is the cross-sectional area of sap conducting wood (cm²). Typical midday values for V are from 10 to 80 cm/h, as reported by Granier (1,3).

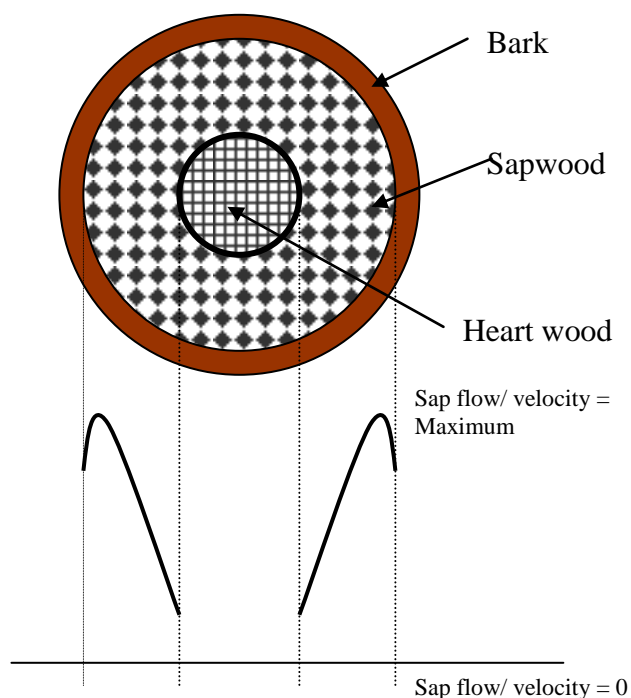
CR1000 program FLGS-TDP.CR1, calculated temperature difference, dT based on the above expressions and converts the latter into sap velocity. This sap velocity is then converted to sap flow seen by the sensor.

3.2 Sapwood Area

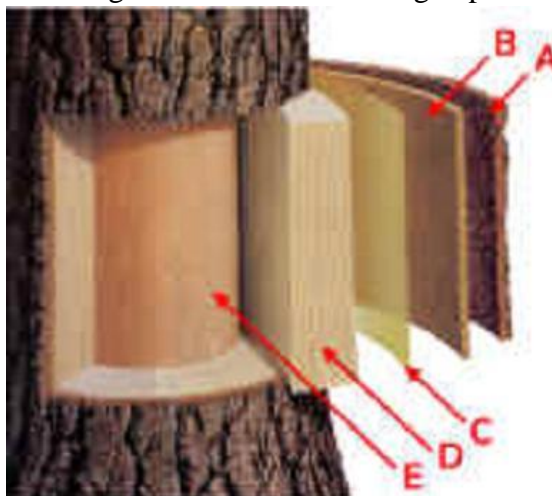
As seen from the above calculations accuracy of the sap velocity measured by TDP sensors depend on the following factors,

- Position of thermocouples with respect to sapwood area
- Uniformity of sap flux density profile (non-uniform profile requires more sensors)
- Weather shielding to avoid effects of thermal gradients on the measurements

The figure shows profile of sap flow or sap velocity with in the sapwood area for a typical plant. The width of sapwood area varies widely among species, hence the heartwood area. Once sap velocity in cm/s is obtained from the thermocouple measurements, it can then be converted to sap flow quantity in grams or liters etc, or rate of sap flow in grams/hour or liters/hour. Simply multiply sap velocity by the sapwood area or the active area (when looking at the cross section at the point of installation) to obtain quantity or rate of sap flow. Hence, accuracy of the computed sap flow depends on the accuracy in estimation/ determination of the sap wood area value used. In reality it is extremely hard to obtain an accurate determination of the sap wood area with out physically cutting the stem/ branch off and performing a die test. Hence this is done at the conclusion of the measurements. Following picture shows different layers in the cross-section of a typical stem. In many cases the boundary between the layers is not as well defined as the illustration. This poses a challenge in accurately determining sapwood area. Following methods of estimating sapwood area are currently in use.



- (A) Outer Bark
- (B) Inner Bark
- (C) Cambium Layer
- (D) Sapwood
- (E) Heartwood



- Die-test (destructive method)
- Empirical method
- Incremental corer method

Die-test: Die-test the most accurate method of estimating the sapwood area. In this test the test plant/ branch is cut-off and the freshly cut sample is kept in a bucket of coloring die such as methyl-violet. With time xylem vessels in the cut sample absorb and transport colorant as if it is water in-take from the roots. After few hours or when the die bucket is empty, cut and slice the sample stem at about 6” from the starting point and make slices of about 2-3” discs. Observe the cross section, the colorant (blue) is absorbed from the bucket and travels only in the xylem vessels (sapwood area). Thus the colored portion is a measure of sap wood area. Measure colored area at the point where sensors were installed. This gives sapwood area for computing sap flow.

Empirical Method: Empirical method is applied where it is not possible to destroy the plant on which measurements are being taken and plants of same species, ages are available in the same region. In this case 20-30 plants are cut-off from the ground and die-test is performed as before. Measure area of the colored portion at approximately the same height on each sample. Based on these measurements, an empirical relation between circumference of the tree and its sapwood area at the same point can be obtained. Using this method Granier obtained an empirical relation between sapwood area and circumference at the same point for pine as,

$$S_A = -0.0039 + 0.59 S_T$$

Similar linear formula can be obtained for any species of plants/ trees. Constants in the relation may vary not only for species but also for the region and type of growth conditions they were subjected to.

Incremental borer Method: Incremental borer method is a relatively non-destructive method of estimating sapwood compared to die-test. In this method a special tool, incremental bore, which is very common in forest trade is used. Using incremental bore core the stem radially inwards and obtain a sample of a slice of the cross-section of the stem. This sample when fresh distinctively shows the various zones in the cross-section. Measure width of the sapwood region in the cored sample, apply this width and the diameter/ radius of the stem and calculate area of the annular region corresponding to the sapwood. In this method it is not necessary to destroy the sample tree, only a borehole is made in the stem, which can be sealed to heal and allow for the tissue re-growth. This method can be used to obtain an empirical relation between sapwood area and circumference using the method explained above.

3.3 References

- 1) Granier, A. (1985). Une nouvelle methode pour la mesure du flux de sève brute dans le tronc des arbres. *Ann. Sci. For.*, 42:81-88.
- 2) Granier, A. (1987). Evaluation of transpiration in a Douglas fir stand by means of sap flow measurements. *Tree Physiology*, 3:309-320.
- 3) Granier, A., R. Huc and S.T. Barigali (1996). Transpiration of natural rain forest and its dependence on climatic factors. *Agricultural and Forest Meteorology* 78:19-29.

4.0 TDP Sensor Installation

4.1 *Preparation of Probe Site*

Once sample trees are selected, an installation site is prepared on the surface of the trees. This is done by shaving off the corky bark and clearing room for a rectangular area roughly 4 cm wide and 10 cm tall. Only the outer bark of the plant is removed and damage to living tissues should be avoided. The site should be 1 to 2 meters above the ground to prevent thermal gradients created by cool sap as it emerges from the soil.



CAUTION

We recommend extra precaution be used for trees of value. The drill bits should be rinsed in 10% Clorox (chlorine bleach) solution before drilling. One should re-rinse between trees to prevent spread of disease from tree to tree.

Place the drilling jig flat on the prepared surface and drill pilot holes 30 mm deep using the small drill bit supplied, 0.059" diameter (size #53), and a suitable drill. Two drill bit sizes are provided. The smaller diameter drill bit is only 0.002" larger than the needles, and should be used first. Most trees, especially hardwoods, will not swell up inside the hole and this will be the drill bit most often used.

The larger drill bits, 0.063" -(size #54) is provided for softwoods, or other trees that may swell up the fibers inside the hole, preventing a smooth needle insertion. Be extremely careful that no force to insert the needle causes it to buckle, since this will cause it to crack and most likely break upon removal. If the sensor needles do not push in smoothly and are binding in the holes, carefully pry the needles out (see removal section) and then drill the hole out to the larger diameter, without using the drill jig.

For Tdp50 - Tdp100, drill bit sizes will be: .073" (size #49) pilot hole, hardwood tree
 .076" (size #50) larger bit, softwood tree

Holes will be drilled for length of probes: Tdp10 - 10mm deep
 Tdp30 - 30mm deep
 Tdp50 - 50mm deep
 Tdp80 - 80mm deep
 Tdp100 - 100mm deep

A lightweight portable drill is handy for drilling holes in the field. The holes are 40 mm apart but this is not critical as long as they are in a close vertical line. Remove any loose particles by reversing the drill and running the bit in and out of the hole a few times. Stop drilling and clean the bit if particles are wedged into the drill flutes.

Remove the drilling jig and use a syringe to rinse the installation site with hydrogen peroxide. A syringe with a 20-gage needle is supplied to flush the drill holes. This is to minimize the introduction of pathogens into the plant and to promote a quick healing response in the drilled holes. We recommend extra precaution be used for trees of value, so the drill bit should be rinsed in 10% Clorox (chlorine bleach) solution before drilling. One should re-rinse the drill bits between trees to prevent spread of disease from tree to tree.

A single probe may be used on trees 3-5" (to 125 mm) in diameter, but two or more probes are recommended for trees in the 5-8" (to 200 mm) diameter range. Very large trees, over 8" (200 mm) may require four or more. In closed canopies, where trees are more uniform in size and spacing, good results are reported with just one probe per tree, regardless of size. This recommendation is based on past experience (Granier, 1987) but is strongly influenced by the objectives of the study and on the plant species being tested.

Ambient temperature gradients can be reduced significantly by wrapping an insulating jacket of flexible porous foam at least 5 cm (2") thick and twice as long as the tree diameter around the trunk, centered on the midpoint between the two needles.



4.2 *Installing the TDP Probes*

Use care when handling the sensor wires, especially the constantan wire (inside a protective tube connecting both probes for differential temperature). The wires are thin and are damaged beyond repair if broken.

Insert the TDP needles with the heated needle (four wires including red and black) in the top hole and the reference needle in the bottom hole. Insert the needles about 10 mm at a time, pushing each needle alternately until almost all the way in, leaving 2-3 mm of shaft still visible. This leaves room for the tree to add bark growth and not damage the TDP needle. Also, be careful not to damage the wire that is common to both probes during this process. The insulation around the probe wires make them appear larger than they really are but these are actually very fine wires. Do not stress or pull the wires at the probe connections.



CAUTION

Do not bend or twist the probes to insert them. A bend in the probe will cause internal breakage.

Once the probes are in place the cables must be tied or taped to the tree for support and to remove stress from the probes. Duct tape or twine is useful for this purpose.

4.3 Thermal and Rain Insulation



Install plastic putty or pruning wax sealer around the needles, to surround them with a waterproofing seal. This will prevent water from touching the needle shaft, and causing a heat sink effect. Install foam quarter-spheres (or foam quarter eggs) on either side of the TDP needles to protect the sensor wiring from bending stresses, and to add thermal insulation around the needles. Tape these foam blocks to the tree.

Reflective bubble wrap or insulation is now wrapped around the tree, foam blocks, and the TDP probe installation. The reflective bubble shield may only be enough to form a tent or skirt around the tree where the measurements are taken. More shielding may be necessary to prevent the sun from shining on or below the area being measured. The sun can cause large local gradients on the stem, which can add or subtract from the temperature changes due to sap velocity. This wrap is also secured by reflective tape or twine. Securely sealing the top of the wrapping will certainly be prudent for preventing water running down the stem and touching the sensors.

Attach the TDP cables to the extension cables of the logger and the installation is complete. Ground the data logger to a heavy gauge copper rod buried at least four feet into the ground.



4.4 Probe Removal

CAUTION

When removing the probes, do not pull out by the base of the needle by hand or by pliers. A nail removing pry-bar (a short, 30-40 cm long pry bar is sufficient) lever should be addressed to the base of the needle, where the needle shaft (cannula) meets the hub, so that they can easily be withdrawn about 3-5 mm with a moderate force.

We recommend a short lever, and not a claw hammer, because hammers will easily bend these needles. After loosening each needle in the set, withdraw the needles by adding a 5 mm (1/8" to 1/4") wooden fulcrum between the tree and the pry bar. With a moderate (1 to 5 lb.) force withdraw each needle an additional 5 mm, then increase the thickness of the fulcrum another 5 mm. The lever should only have contact with the smaller section of the hub. Attempting extraction by pulling at the shaft of the needle may cause damage.

Continue this process, adding a thicker fulcrum, so that the pulling force is always perpendicular to the tree, in a straight line with the needle. This process will avoid any bending moments on the needle itself. By pulling each needle in turn, it is possible to remove each needle in the set without stretching the wires entering the hub of the needle.

5.0 GENERAL SYSTEM SET UP - OPTIONS

Section 6 gives the installation instructions that are required for FLGS-TDP operation. Sec 6.1 and 6.2 covers the system mounting and general field setup. Sensor cable wiring details are explained in 6.1.1. Section 6.3 covers Solar panel options, power requirements calculation, AC power and multiple voltage regulators. Section 6.4 details the sensor voltage control settings. Refer to Chapter 7 and Chapter 9 for detailed information that applies to logger software setup and connecting to the logger.

5.1 *Field Installation*

The typical system is shipped with all cables attached and ready to use, except the battery connector or solar power. The following steps are important to any system monitoring TDP sensors.

1. Check the power switch on both AVR D's to see if it is in the off position.
2. Mount the enclosure to a 1.5" diameter pole with the pole mounting hardware provided in the spares kit, or to a vertical surface with "U" mounting bolts and nuts.
3. Attach the positive battery lead red wire to the (+) battery terminal. Then connect the ground, black terminal to the (-) battery. For safety reasons and to prevent the unit from turning on during shipment, the positive lead is wrapped in tape.
4. **Attach the green wire to an earth ground.** Greenhouse and environmental chambers have earth ground in the wall sockets, so you can plug the banana lead into the ground receptacle (3rd wire). **Under no circumstances should the AC power line neutral be used instead of the earth ground. This could easily be confused with the hot wire and lead to a hazardous shock. If you are indoors, and cannot confirm a solid earth ground it is better to have no connection for now.**

Field installations require that the ground wire be firmly attached to a copper-grounding rod. Iron or copper water pipes will also serve as a good grounding point.

Hardware stores and electrical shops also stock ground rods for lightning protection on antenna installations as well. The copper rod should be driven into the earth at least four feet.

5. Plug in the AC battery charger into a 120 VAC outlet, if the system is within 6 ft. of a 120 VAC outlet. If not, plug in the AC Charger into an extension cord.
6. Put the battery and charger into separate battery boxes. Wiring plugs or plug contacts should not be left exposed to rain or irrigation water.

5.1.1 Sensor Connection To Logger

FLGS-TDP system is supplied with required number of pigtailed assembled to the unit, connected to the multiplexer inside the enclosure. Each pigtail cable is labeled identifying the type of TDP sensor that can be connected to and sensor number to which the program parameters can be entered. For example a pigtail cable labeled TDP10/30/50 can be connected to either a TDP10 sensor or a TDP30 sensor or a TDP50 sensor. A pigtail cable labeled TDP80 can be connected to a TDP80 sensor and a pigtail cable labeled TDP100 can be connected to TDP100 sensor only. TDP sensor has a quick-turn male connector on its end and pigtail cable has a corresponding female connector on its end. Connect TDP sensor to the corresponding pigtail cable. And the system is ready to collect voltage measurements from the sensor.

In addition each FLGS-TDP system is provided with a test report including a wiring chart, and test data. Refer to the wiring chart for the type of TDP sensor that can be connected to each sensor pigtail cable. Sensor pigtail cables are numbered #1, #2 Against each sensor# or a range of sensors is a TDP sensor type printed, saying for example that the pigtail number #1 can connect to TDP80 etc.

Below is an example-wiring chart in which sensor pigtail numbers labeled #9 through #16 can be used for connecting to TDP10/30/50 sensors. In addition these sensor are getting excitation voltage from heater voltage channel Htr_V(2).

Sensor# (range)	Heater Channel	Sensor Type
#1 - #8	Htr_V(1)	TDP10/30/50
#9 - #16	Htr_V(2)	TDP10/30/50
#17- #20	Htr_V(3)	TDP80
#21- #22	Htr_V(4)	TDP100

5.2 System Set Up

Before starting the system, perform or confirm the following basic steps:

1. Identify the plants on which sensors are to be installed and the position of installation on the stem or branch.
2. If possible determine sapwood area using one of the methods explained in the previous chapters.
3. Make the stem diameter measurement at the midpoint of the sensor installation. Record this measurement which will be used to determine sapwood area (in case of analytical method) later for sap flow calculation.
4. Complete the sensor installation described in the previous sections. Cables should be attached to the sensors during this step, and electrical tape should be wrapped around the connector interface when using the system outdoors. Make a record of the cable number corresponding to the sensor/plant.
5. Install FLGS-TDP system on a tower or a ½" diameter pole.
6. Attach the 9-pin RS232 connector to the personal computer or laptop COM1 connector.
7. Plug the AC adapter into a 120 VAC outlet. The backup battery begins charging at this time, and the Logger is waiting for instruction to begin running.
8. Refer to the software (PC400) chapter launch the software and start communication with the FLGS-TDP system.

Allow the battery to become fully charged, and keep the battery charged fully from now on. The battery serves as a back up should power outages occur, and is not intended to last for more than 4 hours operation.

5.3 Solar Power - Batteries - Charger - Expansion Options

5.3.1 Solar Panel Requirements

A 60 Amp hour battery can be easily discharged overnight by a few large gages. A reference sheet is included in Sec 5.3.2 that shows how to properly calculate the solar panel size needed and the backup battery capacity required. The FLGS-TDP software disk includes the SolarTDP.xls spreadsheet to perform the calculations. 1) The details of mounting the solar panel to a pole are contained in the instruction sheet shipped with the panels. Field applications with no line power available are handled with an external 12-volt regulated solar panel, connected to a large deep-cycle battery. Each logger module must have its own power source, which is distributed to the number sensors attached. More than one battery may be connected in parallel to extend the operation life in cloudy weather in the larger trunk sensor application. The regulated output of the solar panels usually have the ring connectors attached, and are ready to be wired to a battery. More than one solar panel may be connected in parallel to provide enough current to run the large trunk gauges.

2.) Use caution not to touch black and red leads together, and attach Solar panel red lead battery (+) to the battery (+). Next attach the solar panel battery (-), black lead and the battery (-). The AVR regulator is normally installed into enclosures for systems.

3.) Attach the green wire to an earth ground stake or water pipe.

Field installations require that the ground wire be firmly attached to a copper-grounding rod. Steel or copper water pipes will also serve as a good grounding point. Hardware stores and TV/Radio electrical shops also stock ground rods for lightning protection on antenna installations as well. The copper rod should be driven into the earth at least four feet. Then clamp the green earth ground lead from the logger enclosure to the grounding rod clamp.

4) For operation with trunk gages, the user supplied 60 Ahr battery, must be preserved by use of the power down mode. Refer to the programming section on how to enact this option to save power at night.

The size of the solar panel must be large enough to replace the number of amp-hours drawn by the gauges and recording equipment within the worst-case sunlight hours available at the site of installation. A power budget guide and solar radiation chart for the worst-case equivalent solar hours is provided in Section 5.3.2. The spreadsheet file is included in the disk. These charts enable one to prepare a power budget for any given sensor requirement. The work sheet may be downloaded from the Dynamax FTP website also. Access is by a web browser to [ftp.dynamax.com/SolarPower](ftp://ftp.dynamax.com/SolarPower). Download this Excel file, SolarTDP.XLS (Office '97 version or higher), if you would like to have the solar panel requirements automatically calculated. The battery(s) required will also be calculated. The process is to enter the quantity of sensors in each category, and then enter the "Equivalent Sun Hours", ESH value for your area. The spreadsheet calculates the totals, and the array current required. By looking at the array current required, one must then figure out the number of solar panels that will exceed the required array current. Contact Dynamax or your distributor if further assistance is desired to size the solar panels for your geographic location and sensor application.

5.3.2 Solar power Budget Sheet

(Bold entries by customer)

Solar Panel Calculations						See insulation Chart	
Power Each Sensor						ESH Examples	
Sensor	Watts	Qty	Total W	Volts	Amps		
TDP-10	0.15	0	0.00	2.5	0.00	Canada	2.0 - 2.5
TDP-30	0.20	4	0.80	3.0	0.27	USA	3.5 - 5.0
TDP-50	0.38	0	0.00	5.0	0.00	India	7.0
TDP-80	0.50	0	0.00	7.5	0.00	Brazil	4.0
TDP-100	0.60	0	0.00	9.0	0.00	Africa	4.5 - 7.0
	Total	4	0.80	-	0.27	Australia	2.5 - 5.0
						NZ	2.5
Sum all sensors			Total Amps		0.27Amp	Solar Panel Current Out	
Safety Factor 20%			X1.2		0.32Amp	MSX60 3.56	
24 Hr Consumption			X24 Hr		7.68AHrs	MSX40 2.37	
						MSX20 1.19	
						MSX10 0.59	
Enter Equivalent Sun Hours (ESH)				5	1.54Array Current Required (24 H Oper.)		
Battery Backup		10					
Battery Amperage		50					
				Solar Panel Type Required 1.54			
Quantity of 80 AHr Batteries Needed				2	Quantity of Solar Panels Required 0.6		

Figure 6.2 - Multiple regulator diagram

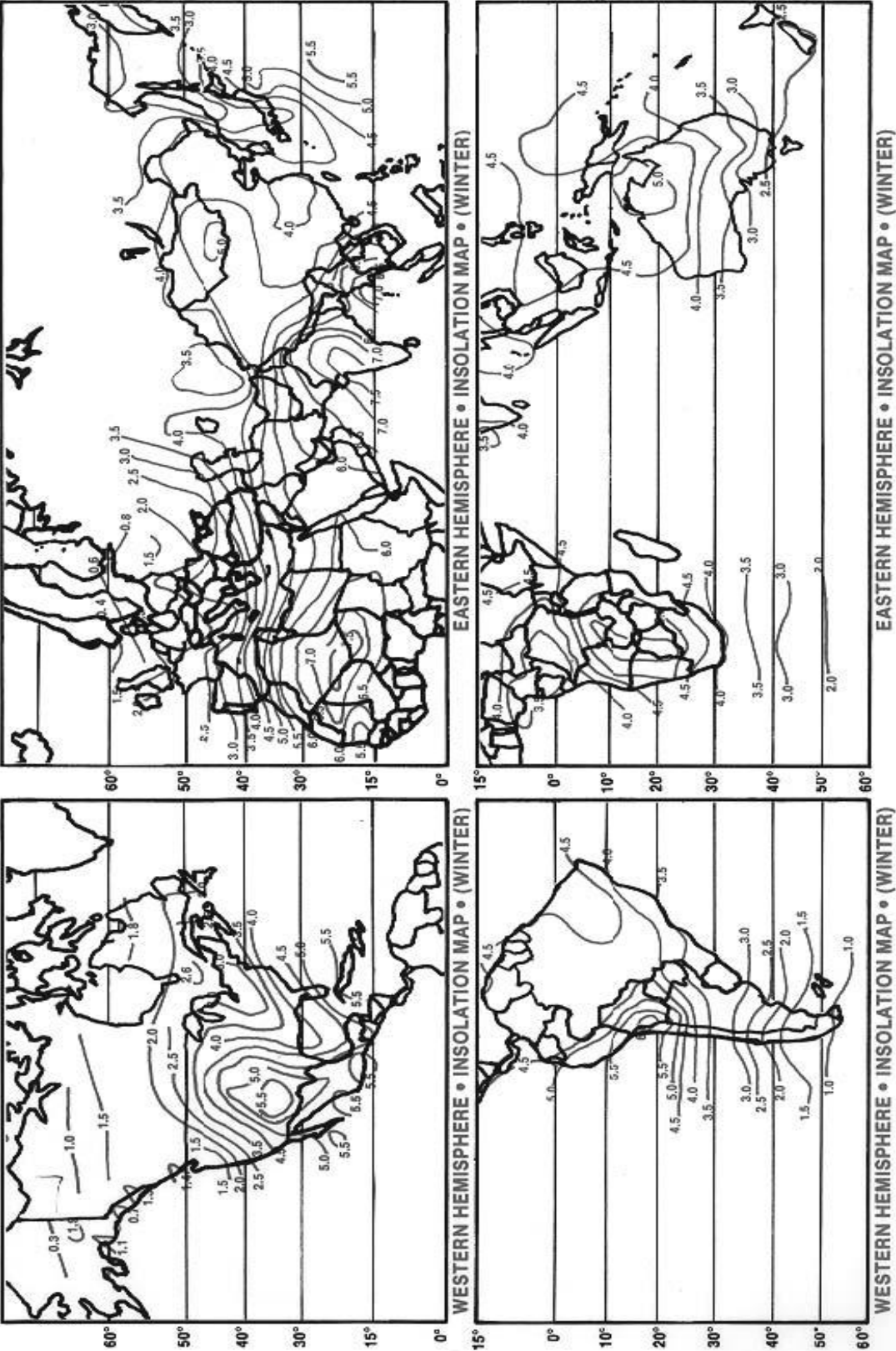
Keep in mind that the ESH is for worst-case winter solar conditions, and your summer only experiments in the growing season may have significantly more "sun hours".

To compute the array current by hand one may use the spreadsheet, and perform the calculations described. Additional solar panels and batteries are usually required to keep a full charge on lead acid marine batteries. Add up the total amp hours for the sensors first, then compute the hours and safety margin required. Then the 24-hour Amp-hrs calculation is divided by the equivalent solar hours in the users location to produce the total array current. The total current then specifies the number of panels and the sizes recommended. At the end of the budget sheet, the battery requirements are computed. Note that, the specified batteries need to be deep - cycle, marine type batteries. It is normal to take the commercial amperage hours and derate the stated capacity on the specification by 40%, to account for the voltage limit required to maintain the data logger operation, typically no less than 10 volts.

5.3.3 Worldwide Solar Distribution Chart -Worst Case Winter Data Esh

CAUTION: Winter insolation values do not always represent the worst case on especially true in equatorial zones that may experience low insolation during rain that experience micro-climates. Please consult your Solarex sales representative analysis before finalizing your system design.

WORLDWIDE INSOLATION AVAILABILITY MAPS
These maps indicate worst case (wintertime) solar radiation based on a Solar Array tilted toward the sun at an angle equal to the latitude of the location + 15°.

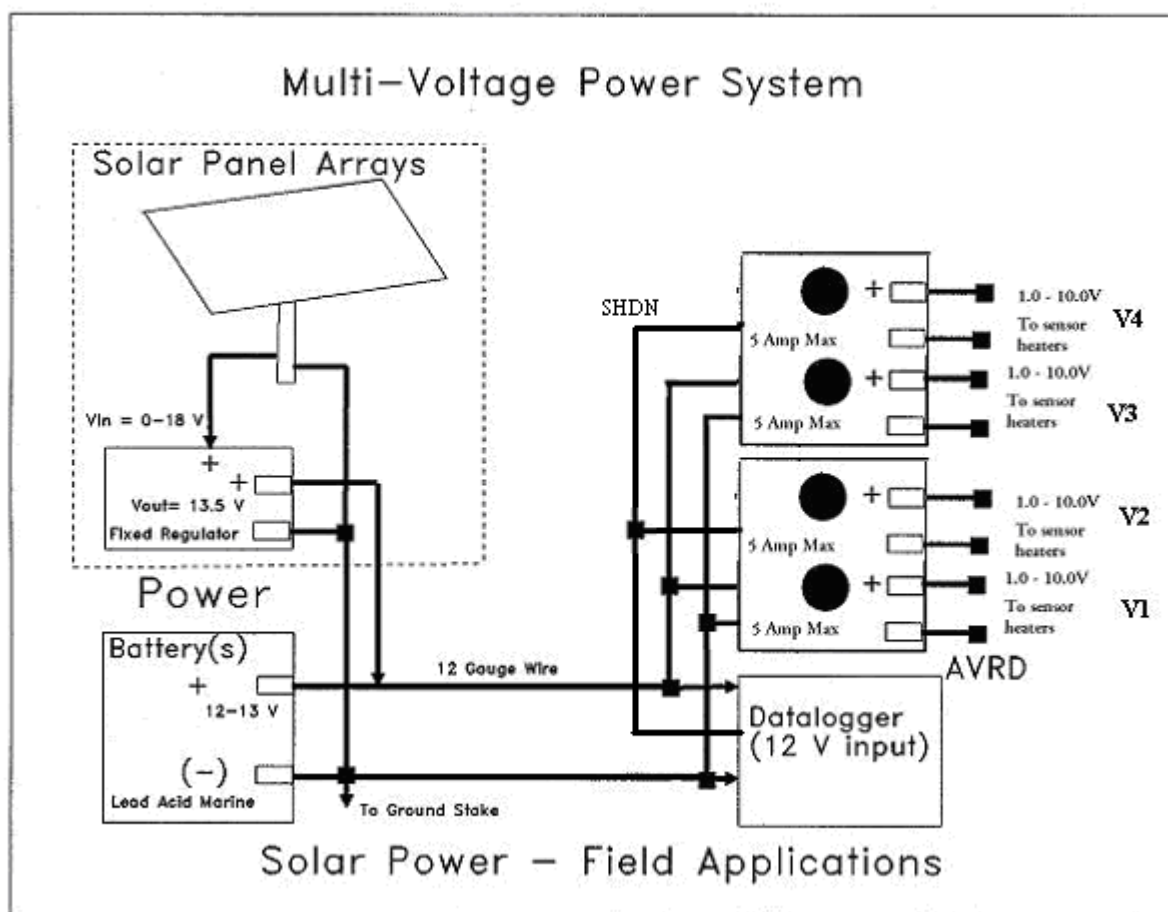


5.4 120 VAC Power

The pair of power leads coming from the logger enclosure conduit exit are firmly attached with the battery leads and the battery charger terminals (Red to +12), black to (-). Plug in the charger 3-prong socket to a suitably grounded receptacle; note the charging light when everything is attached. Keep the backup battery fully charged before and after operation on the logger system.

The AC charger specification should include a safety protection to 45C from overcharge, shorts, and reverse charge. The AC charger specification should have a safety ground on its wall socket. **This ground is isolated from the output, and is not an earth ground for the logger and sensors. It is very important that the logger and sensors should be attached to a single earth ground by the green wire. There must not be any extra wires connecting Earth to the AC power Ground, since these are not the same potential, and can cause severe ground noise (ground loops) and logger malfunctions.**

If the system is to be shut down for extended periods, let the battery charge 6 hours, turn off the charger and remove the battery leads. Insulate the battery leads with tape to prevent a short, and remove the wires completely.



5.5 Setting The Sensor Input Voltage

WARNING - DO NOT POWER UP THE AVR D WITHOUT UNDERSTANDING THE VOLTAGE INPUT REQUIREMENTS OF THE SENSORS.

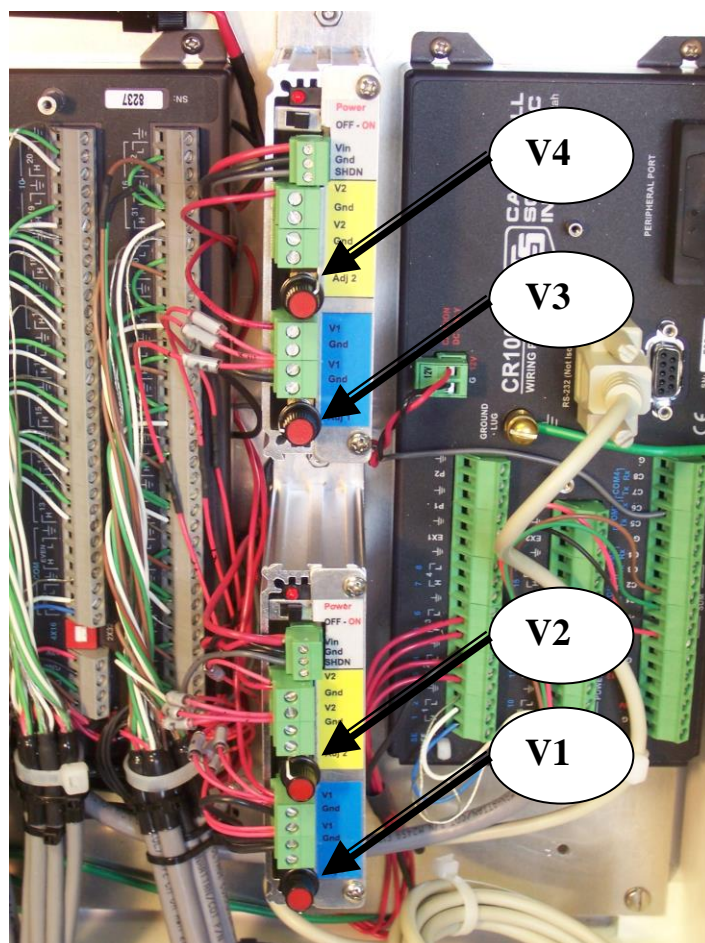
1. The sensor voltage requirements are listed in the TDP Specifications Chapter 2.
2. The system is shipped with both voltage regulator knobs set at about 2 volts (or zero volts which is the minimum), which is fully counterclockwise. The adjustable voltage regulator is also turned off when shipped. After the sensors are installed, connected and the power is attached, slide the AVR D power switch to ON position and the RED led lights up.
3. The potentiometer which sets the voltage is a 15 turn knob adjustor on the top of the AVR D. Clockwise rotation increases the voltage about 0.6 Volt per revolution. Counter clockwise rotation decreases the voltage about 0.6 Volt per revolution.
4. With the AVR D, four controls are available for different type of TDP sensors connected to the FLGS-TDP at the same time. TDP10 sensor requires a lower voltage of 2V for heater and the TDP100 sensors requires a heater voltage of 8V. Having four different voltage outputs that can be independently set enables the system to measure data from a combination of TDP sensors.
5. After choosing a target from the specification, there are two means to set the voltage.

a.) Use a volt meter attached between the AVR D output's Vout and Gnd, to measure applied voltage if necessary. Turn on the AVR D and adjust the voltage to the minimum required by the sensors specification Section 3.2.

Since the datalogger is actually a precision digital voltmeter, it is just as well to follow the procedure below:

b.) Use the test program FLGS-TDP_Tst.CR1, download this to the CR1000 datalogger, and observe the voltage as the logger scans each value is updated in the monitor window. If you are not certain, it is best to have the adjusting knobs turned counterclockwise all the way before proceeding. Turn on the AVR D power switch. Exact steps are:

- 1.) Connect the PC and logger with the 9-pin RS232 cable.
- 2.) Enter commands in the PC400 (or LoggerNet) software by downloading the FLGS-TDP_Tst.CR1 program file, i.e., launch PC400 (or Logger Net) software then press the Connect button on the Connection to logger utility panel.
- 3.) Then Associate and Send the file in the

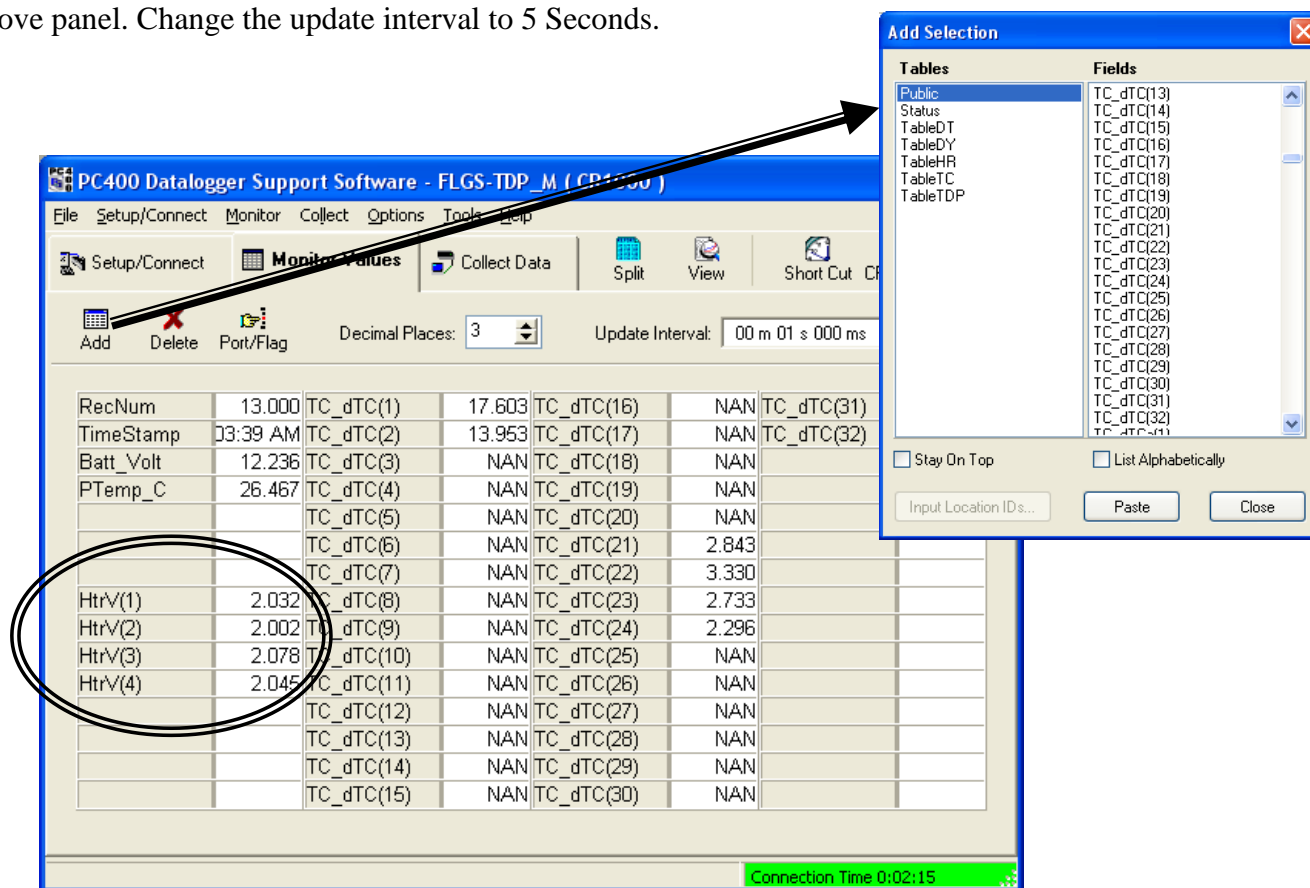


FLGS-TDP directory named FLGS-TDP_Tst.CR1. 4.) Press the Monitor tab/ Numeric button to observe the readings. Then use Setup or Add button on the Monitor/numeric screen to select the HtrV channels of interest. The dTC channels can be selected also. This is a routine maintenance and troubleshooting mode. All users should be familiar with the display of the sensor voltages.

5.) Observe the voltage settings on the right of the screen, and slowly turn the adjustable voltage regulator knobs until reaching the correct settings for the application and sensors attached. Be patient on the changes since five seconds elapse before the voltage is scanned and then displayed on the PC. Recall that one turn clockwise on the AVR D is an increase of about one 0.6 Volt.

Note: if a reading of -99999 or NAN appears it means a sensor's wire is loose or not connected.

This is an example of how to select the channels of interest for display by pressing the Setup button on the above panel. Change the update interval to 5 Seconds.



When connecting a mix of gages on the FLGS-TDP, TDP100 gages need a higher voltage than the typical voltage for a TDP-30. The sensor specifications in Section 3 explain the settings needed for various sensors. Two to 10 volts can be used at any given time, for TDP10 up to TDP100 sensors. The regulation of the standard system assumes two ranges of voltage are needed. Each FLGS-TDP system is assembled with two AVR D units. Each AVR D unit has two output voltages that can be adjusted independently as shown in the figure above. Sensor heater wires (Red) are connected to the terminal strips labeled V1 (#1) through V4 (#4). Each sensor heater wire red is labeled with the sensor number it is identifying, same number as the pigtail label. Each cable lead is labeled with the sensor number. To move heater wire from one AVR D output to another simple, remove the Red wire with corresponding label from its current terminal on the AVR D units and connect to the desired output location.

6.0 SOFTWARE INSTALLATION

FLGS-TDP is a completely integrated weather station capable of reading TDP sap velocity sensors. Sensor readings are then stored in data logger's memory. In addition removable storage modules are available for expanding the available data memory. Data from the logger is available for down load using data logger support software. This sensor data is then processed using custom spreadsheet supplied with the software to obtain sap flow in g/hour on an hourly basis or in the user-defined interval. FLGS-TDP station is integrated with CR1000 data logger. Hence can be operated using any of the following data logger support software,

- PC400
- LoggerNet

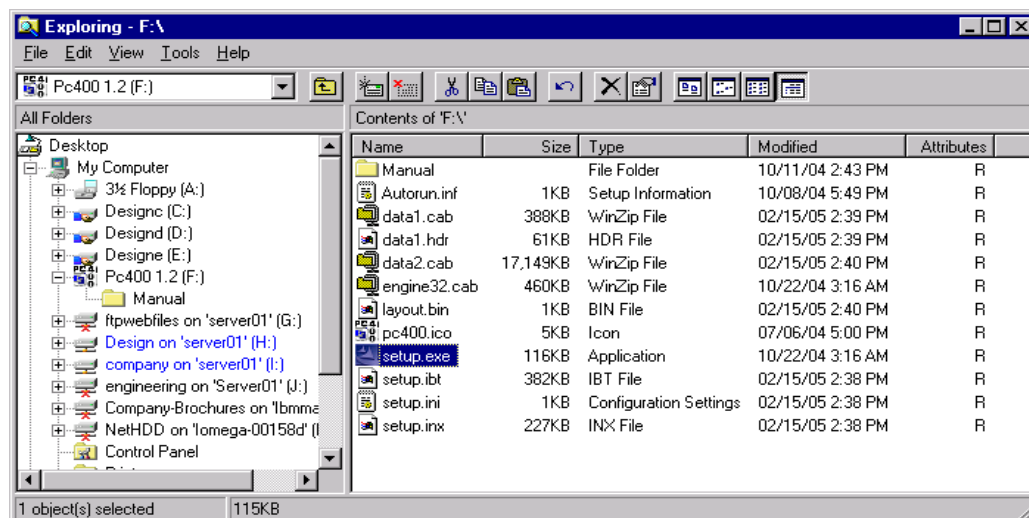
For Procedure to connect, program download data using PC400 and LoggerNet refer to chapter 7 and 8 respectively. In this manual we describe working with FLGS-TDP logger using PC400. As described above full capabilities of the FLGS-TDP system can be achieved by using two sets of software programs,

1. **Data logger support software** - PC400
2. **Sapflow computation spread sheet:** Excel spread sheet to calculate sapflow for dT values collected from the data logger. This spreadsheet has custom formulas to compute auto zero on the sensor data and then use zero values to compute sapflow.
3. Data logger program Flgs-tdp.cr1 to load in to CR1000 datalogger for reading TDP sensors, compute weather data from electrical measurements and store to logger memory.
4. In addition custom weather station configurations may require a modified Flgs-tdp.dld program designed for the customizations.

FLGS-TDP software is supplied in a disk with FLGS-TDP data logger. Where as PC400 or any other data logger support software is an optional purchase. This chapter explains the procedure to identify these software diskettes and install on Windows based computer.

6.1 PC400 Installation

PC400 Logger utilities software is provided in a CD-ROM. Insert the CD into the CD-ROM. It should automatically present the installation panels. If it does not then open windows explorer (My Computer) to view the following list of files on the install CD.



Double click on setup.exe to launch the installation. The installation panels will guide you through the process. Please note, to install PC400 software in one of the following directories,

C:\CampbellSci\Program Files\PC400 (Default install directory) or

D:\CampbellSci\Program Files\ PC400 or

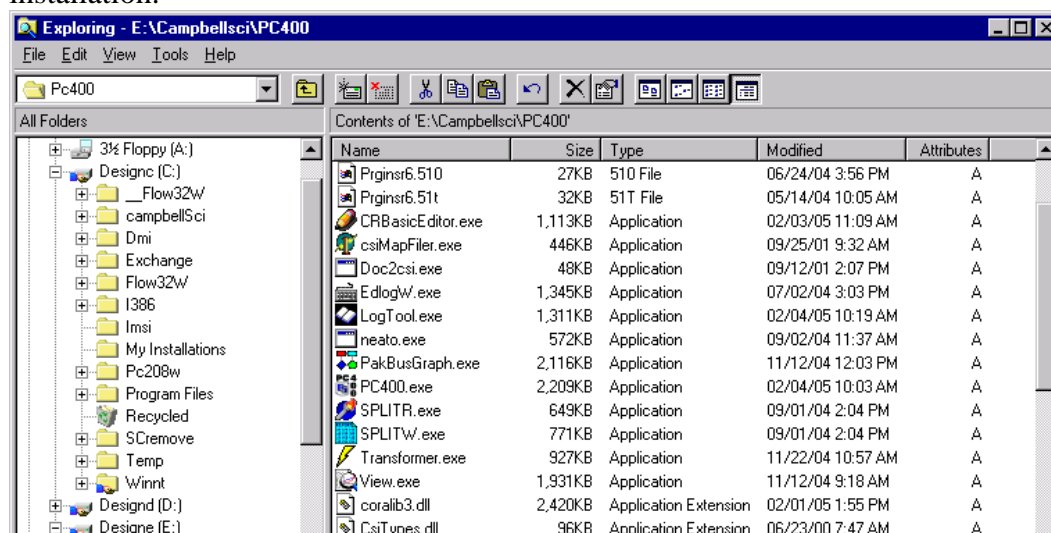
E:\CampbellSci\Program Files\ PC400 or

C:\CampbellSci\ PC400 or

D:\CampbellSci\ PC400 or

E:\CampbellSci\ PC400

If not installed in the above directories Flow32w (if using on the same computer) will not function in conjunction with PC400 option. Following is an abbreviated listing of PC400 hard-drive directory after installation.



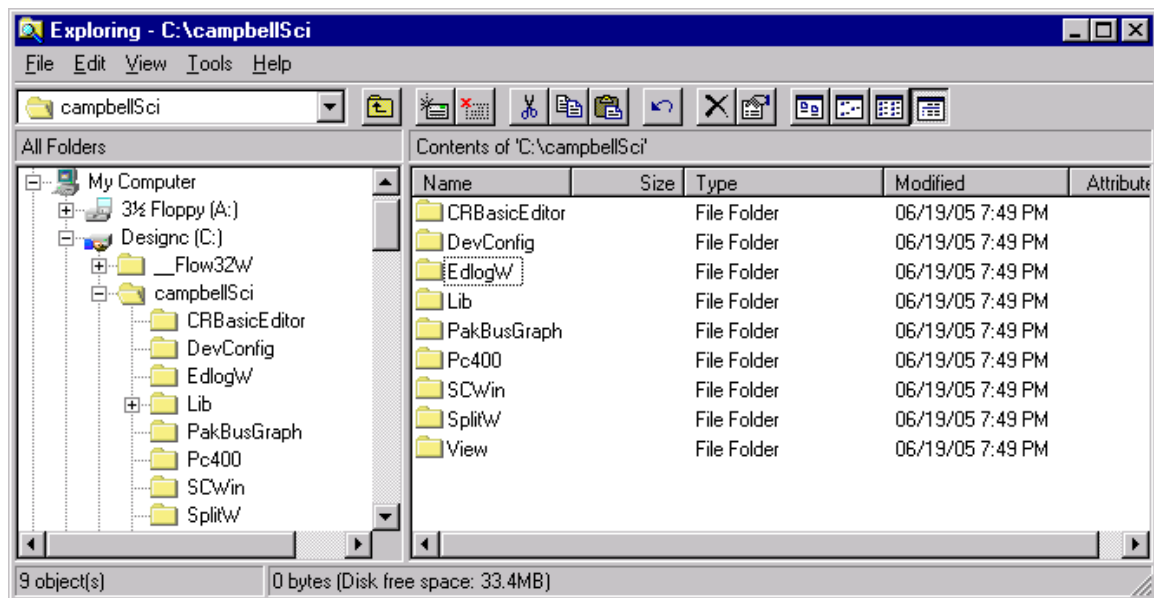
Refer to next page for working directory and following page for SMS installation.

6.1.1 Working Directory Location

PC400 install wizard prompts for working directory location. By default working directory is

C:\CampbellSci\PC400

Specifying a different path location on the hard-drive during installation can change this to required location. Location of working directory will not affect the operation of PC400 or Flow32w software. This directory stores temporary files. Following is a typical list of working directory when working directory and PC400 executables are stored in different locations.



6.2 FLGS-TDP software installation

To install the FLGS-TDP software to your PC,

1. First create a subdirectory called **FLGS-TDP** in your PC's hard drive.
For example, C:\FLGS-TDP
2. Place FLGS-TDP software CD in CDROM drives open to view the contents.
3. Copy all the contents of CD to the new FLGS-TDP folder in the hard drive. i.e. C:\FLGS-TDP\
4. Make sure the new directory on hard drive contains all the files from the CD.
5. Remove the CD and save it for future use.

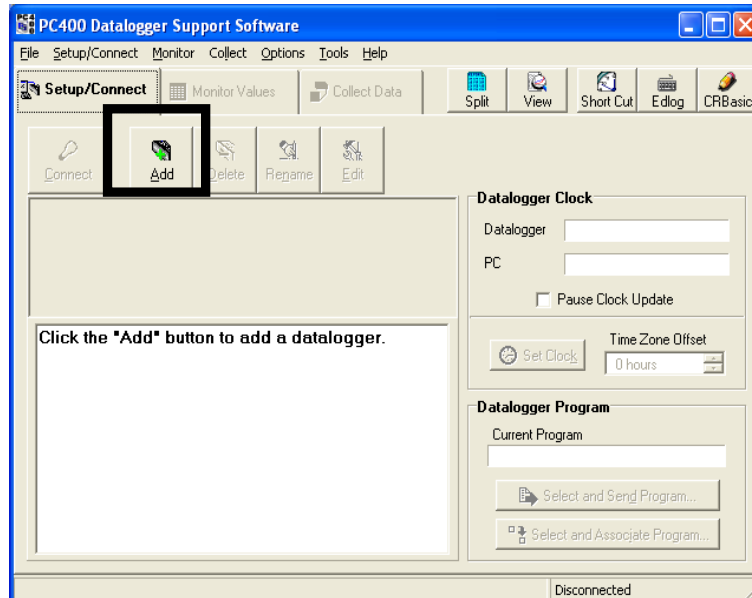
7.0 USING PC400

NOTE: This chapter explains operation/ data retrieval of CR1000 using PC400. In addition advanced network applications require LoggerNet for communication scheduling and automatic data collection. Refer to chapter 8 for using LoggerNet.

7.1 Launch Pc400

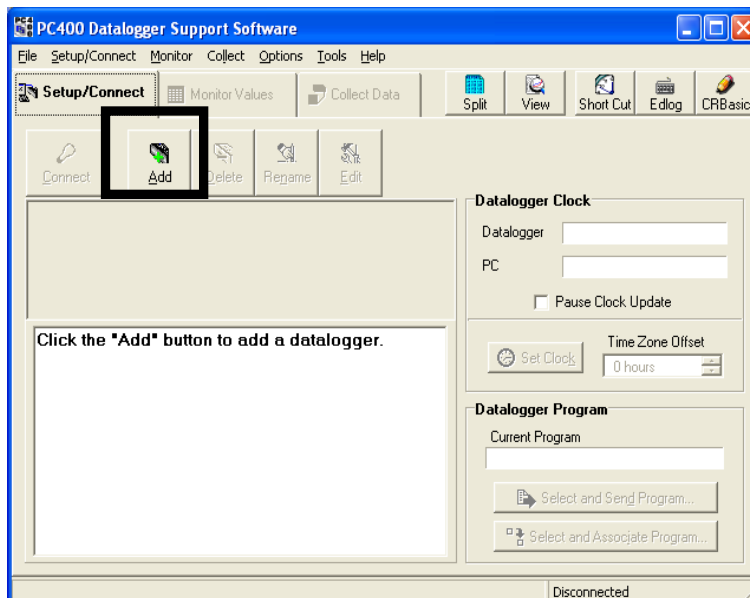
Launch PC400 software from the desktop icon or from the start menu. This opens the main PC400 window along with tool bars for PC400 components.

To setup/ modify CR1000 parameters click on Setup Logger command. This will launch PC400 tool bar and SETUP screen, shown in the next page.



7.2 Setup, Program Logger And Communications

1. If this first time using software or to add a new logger station to the software setup click on **Add** button. **PC400 offers a easy to use step-by-step EZSetup wizard** that will guide through adding stations and connecting to logger features. If the station is already added in the list, proceed with connect to logger in the next section.



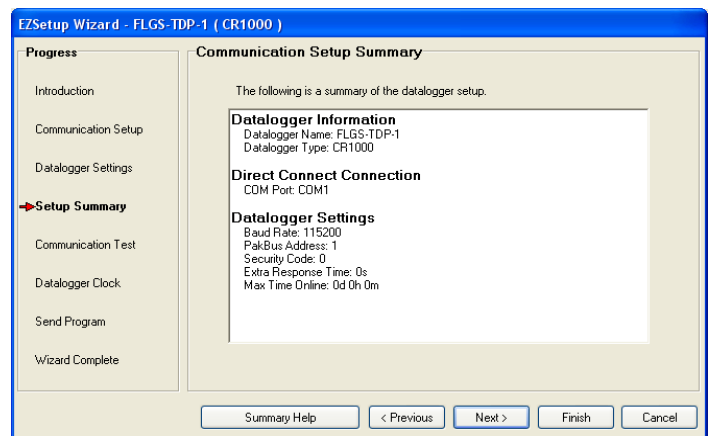
2. EzSetup wizard is shown in the screen below. Click **Next** to start the wizard or **Cancel** to manually setup station parameters at a later time.

3. Select Data logger type **CR1000**, use scroll bar to scroll down and select the logger type if necessary.
4. Type data logger name in the text field, for example **FLGS-TDP-1** as shown in the figure.
5. Click **next** to proceed with setup process.
6. Select communication type,
Direct connect using RS232 cable or using any of the modem connections for remote communication. In this case we show a setup wizard using Direct Connect only. Following wizard may be different depending on the modem selection. Click **Next** to proceed with setup wizard.
7. Select COM port from the list and click **Next**.
8. Select Data logger settings shown below. Set data logger baud rate to 9600. Other parameters Security code, Extra response time, Next time Online are optional defaults can be used.

Click **Next** to continue with setup.

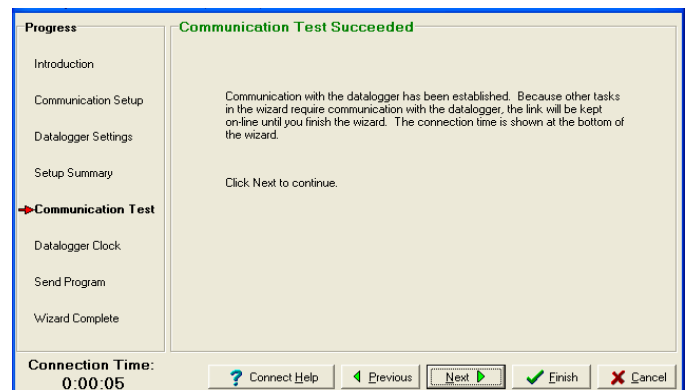
9. Next window shows the setup summary entered in the previous steps for review.

If setup summary is as desired click **Next** to continue with connection wizard. Click **Previous** to make any changes to the data logger or communication setup.

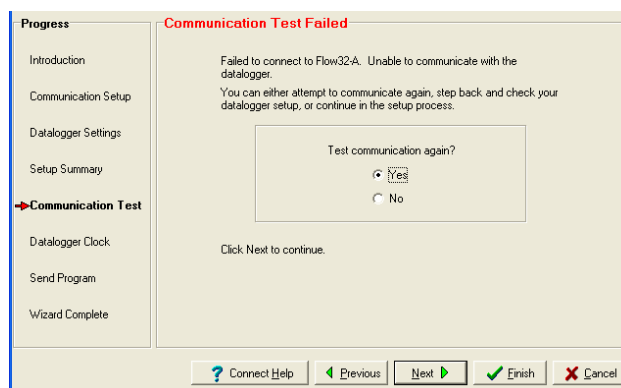


10. At this point if data logger is connected to PC Com port user may proceed with communication test by selecting **Yes** for the radio button clicking **Next**. Or click **Finish** to close setup wizard, add the new station (FLGS-TDP-1) to the station list for connection and data retrieval in future.
11. If **Test Communication** is selected in the previous window, PC400 software tries to connect to the specified logger on the COM port assigned in the setup wizard. Displays the following dialog box while attempting to connect to logger.

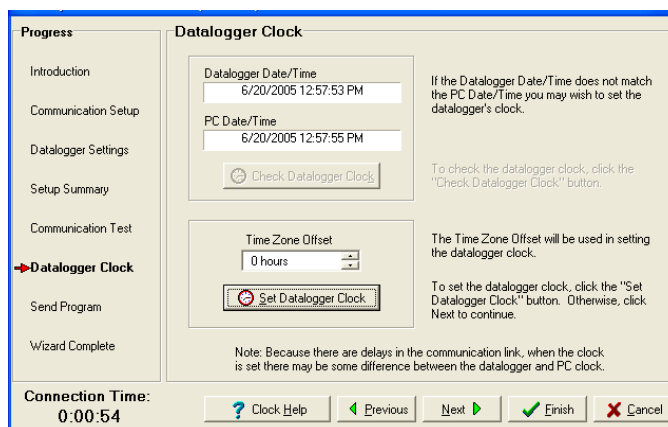
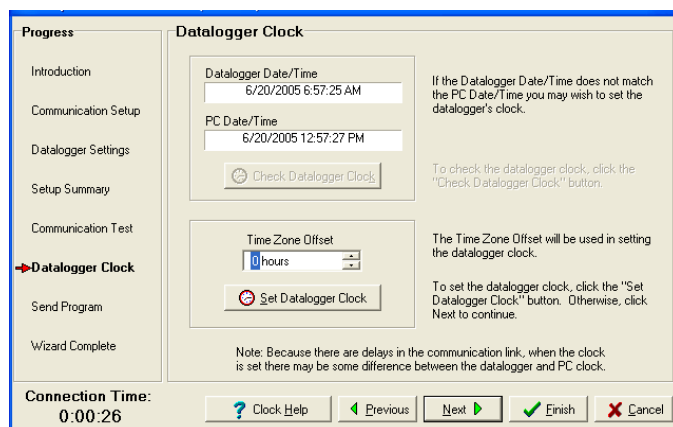
If the communication test is successful **Communication test successful** window will be displayed as shown below. Click Next to continue with setup wizard.



12. If the Communication test is unsuccessful software responds with **Communication test Failed** message and reverts back to the communication test selection window. At this point make sure FLGS-TDP systems communication cable is connected to PC and logger is powered and retry the communication test.



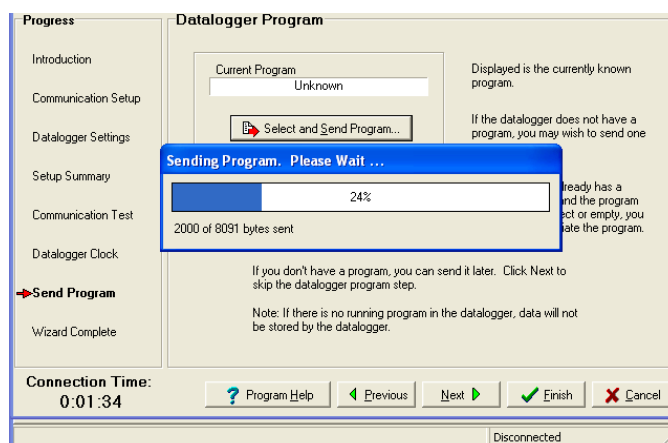
13. **Datalogger clock** window is displayed as shown in the figure. If Datalogger Date/Time is different from the PC Date/Time, select time zone offset between data logger and PC and click **Set Datalogger Clock** command button. Click **Next** to continue.



14. In the **Datalogger Program** window click command button **Select and Send Program** to select *.cr1 program (FLGS-TDP.cr1) using windows file selector and send to the data logger. Alternatively, you may click on command button **Select** and associate program for sending to data logger at a later time.

Warning: By sending new data logger program (cr1 file) to the data logger any data currently stored in the logger will be erased.

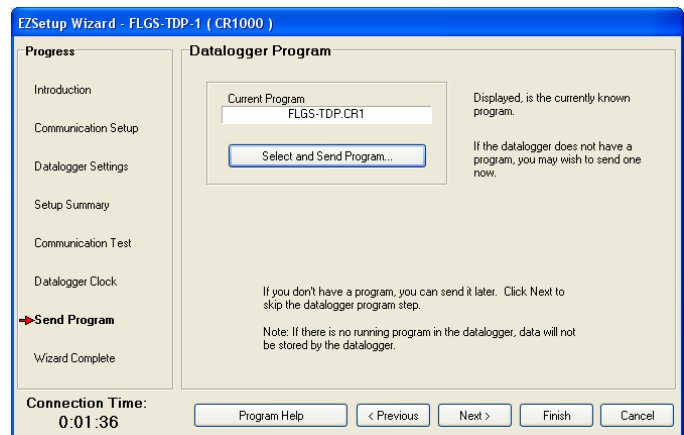
Note: Please refer to section Customizing the Program and Programming the logger, where details of what variables can be customized and allowed values are explained.



15. New data file weather sent to the logger or associated in the software is displayed in the software window as shown below.

16. Click **Next** to continue.

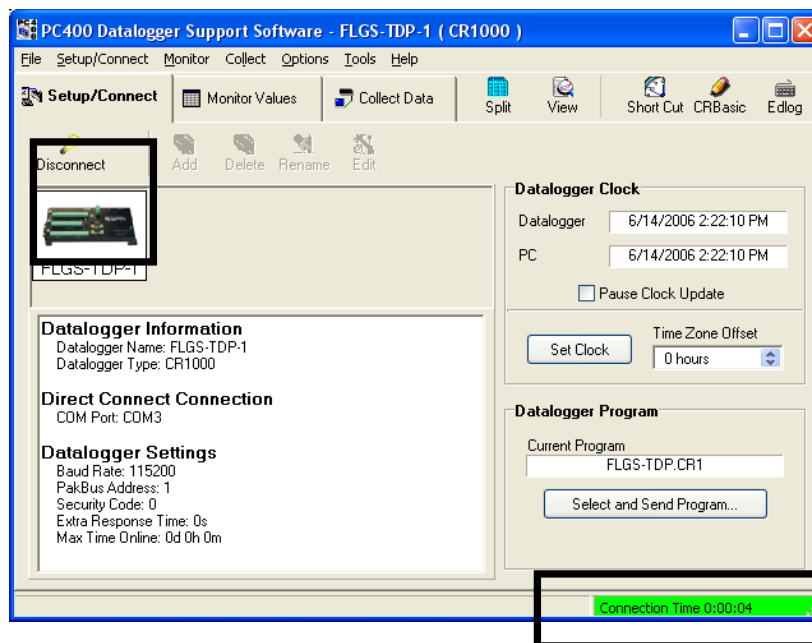
17. This completes all the steps in EzSetup wizard.



18. Click **Finish** to close the EzSetup wizard and view PC400 main window as shown below.

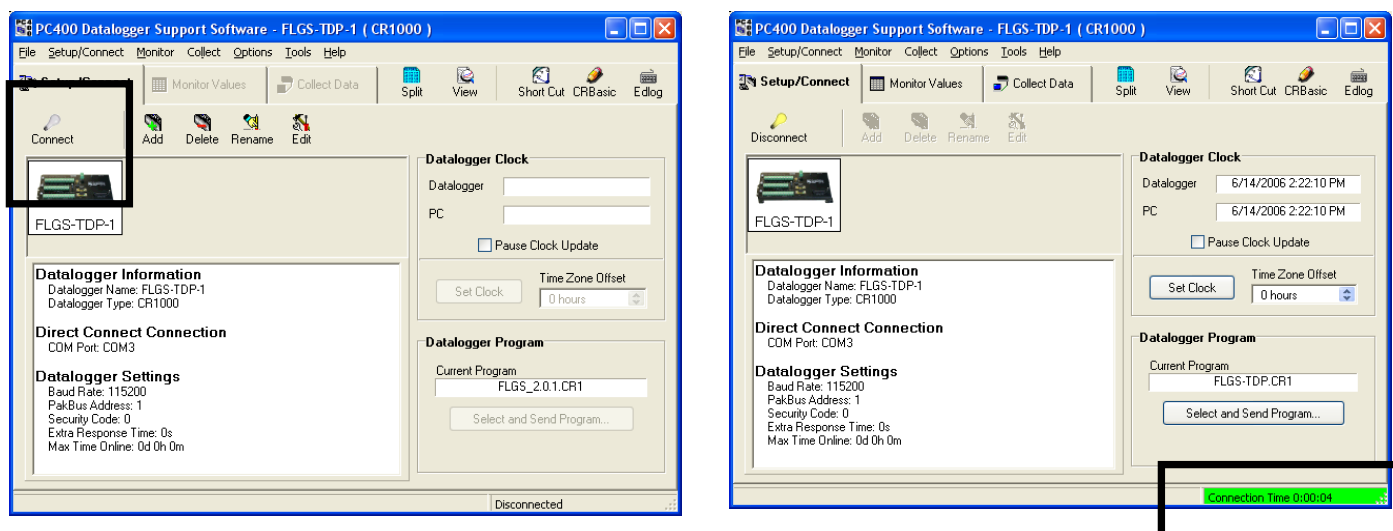
19. In the PC400 **Setup/Connect Tab** notice “Disconnect button is displayed” as shown in the figure below and on the bottom right corner displays Connection time, implying software is currently connected to the data logger. Also data logger clock and datalogger program can be set from this window.

20. Connection to a data logger already setup in the software is described in the next section.



7.3 Connect To Logger

PC400 saves data logger setting once added in the software for future connections. A list of stations with name assigned is displayed in the **Setup/ Connect** tab of PC400 software as shown in the figure. A summary of the previously assigned settings in the software is displayed on in this window as shown below.



- In order to connect to a logger for setting up program or data retrieval simply select the logger and click on **Connect** button.
- If the connection is successful Connect button changes to “**Disconnect**” and Connection time is displayed at the bottom right corner indicating software is currently connected to the data logger.
- If datalogger clock and PC clock are different select **Offset** and click **Set Clock** to update datalogger clock.
- To send and new program to the logger click command button **Select and Send Program**, click **Select and Send Program** to associate a new program to this logger but not sent to logger.
- As soon as a connection is established to the logger, verify that the data logger clock and PC clock displayed on the PC400> Setup/Connect tab are same. If not, click the button **Set Clock** to set the data logger clock to current. If the computer in use set for a different time zone, use Time Zone Offset accordingly before applying Set Clock command.

7.4 Programming the Logger

If a program is readily available this program can be sent to the logger using **Select and Send** command. Once the program is transferred, the logger tries to compile. If any errors are encountered in the compilation process, these errors will be relayed to the user. Upon completion of the compile process, the logger starts executing the program. So, programming the logger involves two steps as described in the following sub-sections.

7.4.1 Modifying the program

A standard program FLGS-TDP.cr1 is supplied with all CR1000 based FLGS-TDP systems. This program reads 32 TDP30 sensors ever minute, average readings and calculate sap velocity/ sap flow every hour. These settings can be easily modified according to the user requirements. This section explains procedure to open the standard program in CR Basic Editor and the procedure to customize the program.

Data logger program must be modified before sending to the logger. Hence, it is not necessary to have the data logger connection established at this point. Launch PC400 software, click on **CR Basic** icon on the top right. This opens a blank editor window. In the editor window click Open icon or File>Open from the menu. In the resulting file selection dialog box navigate to the FLGS software installation directory and open the standard file FLGS-TDP.cr1 as shown below.

```

'CR1000
'CR1000 Series Datalogger
'Dynamax Inc
'10808 Fallstone Rd, Ste 350, Houston, TX 77099
'Phone: 281-564-5100
'Fax: 281-564-5200
'www.Dynamax.com

'Program: FLGS - TDP using CR1000
''for testing the initial code
'date: 15-Nov, 2005

'Program author: Sai Gonuguntla, Dynamax, Inc
'Revision Notes
'Version 1.7    11/15/05
'  Initial program with simple string to array File: FLGS_TRP7_CL.CR1
'Version 1.8    12/07/05
'  Revised program more structured and easy to modify parameters
'version 2.0.1  6/9/06
'  starting from 1.8.1

'////////////////////// CONSTANTS ////////////////////////
'
'BEGIN: User constants
'  User can change the following constants only
'//////////////////////

Const INT_SCAN=60  ' Scan every seconds
Const INT_AVG=60   ' Average every minutes average and LOG interval are same
Const NUM_TDP = 32 ' Number of TDP sensors
Const NUM_TC = 32  ' Number of Thermocouples/ measurement points among all the TDP sensors
' A TDP10/30/50 each has 1, a TDP80 sensor has 2 & a TDP100 sensor has 3 thermocouples/ measurement
' So total number of Thermocouples(NUM_TC) must be determined depending on the number and type of
' For example a system with 4 TDP30 sensors and 2 TDP80 sensors and 2 TDP100 sensors
' will have in all 14 thermocouples/ measurement points    i.e. NUM_TC = 14
Const DTMN = 0.2  ' Minimum differential below which the measurement from sensor is ignored

[Version]C:\Campbellsci\lib\Compilers\CR1Comp.exe VERSION:CR1000.Std.07 DATE:051130
D:\D.DESIGN\p.FLGS_TDP\PROGRAMS\PROGRAMSFROMDESIGN\FLGS_2.0\FLGS-TDP.CR1 -- Compiled in SequentialMode.
Line: 25 Col: 36      1027 lines written to D:\D.DESIGN\p.FLGS_TDP\PROGRAMS\PROGRAMSFROMDESIGN\FLGS_2.0\FLGS-TDP.CR1      Insert

```

Navigate down in the program where the constants start and user modified constants are located. This can be identified with the following comments.

```

'////////////////////
'      BEGIN: User constants
'      User can change the following constants only
'////////////////////

```

A screen shot of the user constants in the editor window is shown below.

```

'//////////////////// CONSTANTS //////////////////////
'
'      BEGIN: User constants
'      User can change the following constants only
'////////////////////

Const INT_SCAN=60    ' Scan every seconds
Const INT_AVG=60     ' Average every minutes average and LOG interval are same
Const NUM_TDP = 32   ' Number of TDP sensors
Const NUM_TC = 32    ' Number of Thermocouples/ measurement points among all the TDP sensors
                     ' A TDP10/30/50 each has 1, a TDP80 sensor has 2 & a TDP100 sensor has 3 thermocouples/ measurement
                     ' So total number of Thermocouples(NUM_TC) must be determined depending on the number and type of
                     ' For example a system with 4 TDP30 sensors and 2 TDP80 sensors and 2 TDP100 sensors
                     ' will have in all 14 thermocouples/ measurement points      i.e. NUM_TC = 14
Const DTMIN = 0.2    ' Minimum differential below which the measurement from sensor is ignored
Const WARMUP_MIN = 60 ' Warmup time in min before the measurements are considered valid

Const FIELDINDEX = 1.0 ' This is the index value either Area INdex/ LAI used to scale plant sapflow to field
Const FLAG_INDEX_EN=0 ' Enable scaling of sapflow to the field
Const FLAG_VOTE_EN=0  ' Enable voting algorithm

Const PS_ENABLE = 1   ' Enable power save at night ' Note power save is not performed on a day when auto zero is done
Const PS_START=1260   ' Power save start (Heater off) min-since mid night
                     ' time at which to start the power save, 1260 corresponds to 21:00 hours or 9:00 PM
Const PS_STOP=300     ' Power save end (Heater on) hour-since mid night
                     ' time at which to stop power save mode and turn heaters ON, 300 corresponds to 5AM

Const ZERO_ENABLE=1   ' Enable auto calibration/ auto zero
CONST ZERO_STARTHOUR=2 ' Top of the Hour at which to start auto zero algorithm
CONST ZERO_STOPHOUR=5 ' Top of the Hour at which to stop performing auto zero and compute new zero (dTM) value.
CONST ZERO_DAYINT=3   ' Number of days between successive auto-zero

'////////////////////
'      END User modified constants
'////////////////////

[Version]C:\Campbellsci\lib\Compilers\CR1Comp.exe VERSION:CR1000.Std.07 DATE:051130
D:\D.DESIGN\p.FLGS_TDP\PROGRAMS\PROGRAMSFROMDESIGN\FLGS_2.0\FLGS-TDP.CR1 -- Compiled in SequentialMode.

Line: 49 Col: 1      1027 lines written to D:\D.DESIGN\p.FLGS_TDP\PROGRAMS\PROGRAMSFROMDESIGN\FLGS_2.0\FLGS-TDP.CR1      Insert

```

The following is a tabular listing of the constants and values permitted for each constant.

Constant Name	Units	Value		Range	Remarks
		Default	Maintenance		
INT_SCAN	Sec	60	5	0 – 60	Interval between sensor measurements
INT_AVG	Minutes	60	1	0 – 60	Log/ storage interval
NUM_TDP	Number	32	32	0 – 32	Numberof TDP sensors
NUM_TC	Number	32	32	0 – 32	Number of thermocouple/ measurements among all the TDP sensors
DTMIN	Deg C	0.2	0.2	0 – 3	DT below which data is ignored
WARMUP_MIN	Minutes	60	1	0 – 120	Sensor warmup time
FIELDINDEX	Sq. cm	1	1	Area sq.cm	Average field index (stem area/ sapwood area/ LAI)
FLAG_INDEX_EN		0	0	0 or 1	scaling flag (1-Enable)
FLAG_VOTE_EN		0	0	0 or 1	voting flag (1-Enable)
PS_ENABLE		1	0	0 or 1	Power save flag (1-Enable)
PS_START	Number	1260	1260	0 – 1440	Power save start time
PS_STOP	Number	300	300	0 – 1440	Power save stop time
ZERO_ENABLE		1	0	0 or 1	Auto-zero flag (1-Enable)
ZERO_STARTHOUR	Hour	2	2	0 – 24	Auto zero start hour
ZERO_STOPHOUR	Hour	5	5	0 – 24	Auto zero stop hour
ZERO_DAYINT	Number	3	3	0 – 10	Interval between auto zero performing days.

Referring to the table above modify the user constants as required. Save the file with a different name so that the original file is not modified.

In addition to the above mentioned list of parameters the user must enter TDP sensor parameters such as TDP Type, Sap wood area, initial dTM, for each one of the NUM_TDP number of TDP sensors. This part of the code can be found starting from line number 400 in the program. A screen shot of the is shown below.

Syntax of a TDP sensor definition in FLGS-TDP is

InputTDP# = "TDP Type, Index Area, dTM1, SA1, dTM2, SA2, dTM3, SA3"

InputTDP#:

Where # is a three digit decimal number referring to the sequence number of the TDP sensor not the Thermocouple sequence number.

TDPTYPE:

Value identifying the type of TDP sensor. Below is the list TDP sensor types and their value Ids.

TDP sensor type	Sensor ID
TDP10	10.0

TDP30	30.0
TDP50	50.0
TDP80	80.0
TDP100	100.0

Similar Ids are used for the thermocouple or the measurement channel/ point in the TDP sensor for multi-thermocouple type TDP sensors. Here is a comprehensive list of sensors or channel Ids. This list is used only with in the program and not necessary of the user.

TDP10	TDP10 sensor/ single thermocouple in TDP10	10.0
TDP30	TDP30 sensor/ single thermocouple in TDP10	30.0
TDP50	TDP50 sensor/ single thermocouple in TDP10	50.0
TDP80	TDP80 sensor	80.0
TDP80A	Thermocouple channel A in TDP80	80.0
TDP80B	Thermocouple channel B in TDP80	80.1
TDP100	TDP100 sensor	100.0
TDP100A	Thermocouple channel A in TDP100	100.0
TDP100B	Thermocouple channel B in TDP100	100.1
TDP100C	Thermocouple channel C in TDP100	100.2

Based on the above syntaxes and Ids, here is an example of the sensor definition in FLGS-TDP program.

InputTDP001 = "10.0,1.00,12.00,27.00,0.00,0.00,0.00,0.00"

This means first TDP sensors connected to the multiplexer is a

Sensor sequence number is 1

TDP sensor of type TDP10

index area of 1.0 sqcm.

dTM of the sensor/channel 12.0 degC

Sap wood area pertaining to this sensor installation is 27.00 sqcm.

Please note number after 27.00 in the definition is not relevant to the sensor definition.

InputTDP004 = "80.0,1.00,12.00,27.00,14.00,23.00,0.00,0.00"

This means 4th sensor connected to multiplexer (not the sensor on channel 4 of the multiplexer) is of type TDP80 with the following settings

Sensor sequence number is 4

TDP sensor of type TDP80

index area of 1.0 sqcm.

dTM of the measurement channel A is 12.0 degC

Sap wood area pertaining to measurement channel A in the sensor is 27.00 sqcm.

dTM of the measurement channel B is 14.0 degC

Sap wood area pertaining to measurement channel B in the sensor is 23.00 sqcm.

Please note that last two numbers in the definition are 0 and they are irrelevant to the TDP80 sensor.

InputTDP005 = "100.0,1.00,12.00,27.00,13.00,21.00,15.00,25.00"

This means 5th sensor connected to multiplexer (not the sensor on channel 4 of the multiplexer) is of type TDP100 with the following settings

Sensor sequence number is 5

TDP sensor of type TDP100

index area of 1.0 sqcm.

dTM of the measurement channel A is 12.0 degC

Sap wood area pertaining to measurement channel A in the sensor is 27.00 sqcm.

dTM of the measurement channel B is 13.0 degC

Sap wood area pertaining to measurement channel B in the sensor is 21.00 sqcm.

dTM of the measurement channel C is 15.0 degC

Sap wood area pertaining to measurement channel C in the sensor is 25.00 sqcm.

```

CRBasic Editor - [D:\D.DESIGN\PROGRAMS\PROGRAMSFROMDESIGN\FLGS_2.0\FLGS-TDP.CR1 for the CR1000]
File Edit Search Compile Template Instruction Options Goto Window Help
' Syntax for TDP sensors
' InputTDP# = "TDP Type, Index Area, dTM1, SA1, dTM2, SA2, dTM3, SA3"
InputTDP001 = "10.0,1.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP002 = "30.0,1.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP003 = "50.0,1.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP004 = "80.0,1.00,12.00,27.00,14.00,23.00,0.00,0.00"
InputTDP005 = "100.0,1.00,12.00,27.00,13.00,21.00,15.00,25.00"
InputTDP006 = "30.0,1.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP007 = "0.0,0.00,0.00,27.00,0.00,0.00,0.00,0.00"
InputTDP008 = "0.0,0.00,0.00,27.00,0.00,0.00,0.00,0.00"
InputTDP009 = "0.0,0.00,0.00,27.00,0.00,0.00,0.00,0.00"
InputTDP010 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP011 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP012 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP013 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP014 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP015 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP016 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP017 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP018 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP019 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP020 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP021 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP022 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP023 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP024 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP025 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP026 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP027 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP028 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP029 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP030 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP031 = "0.0,0.00,12.00,27.00,0.00,0.00,0.00,0.00"
InputTDP032 = "0.0,0.00,11.00,26.00,0.00,0.00,0.00,0.00"

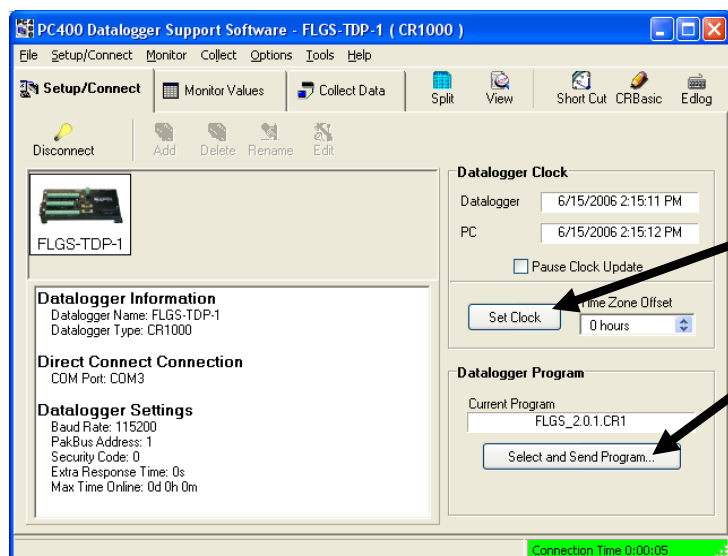
iTC=1
StartCh = 1
for iTDP=1 to NUM_TDP step 1

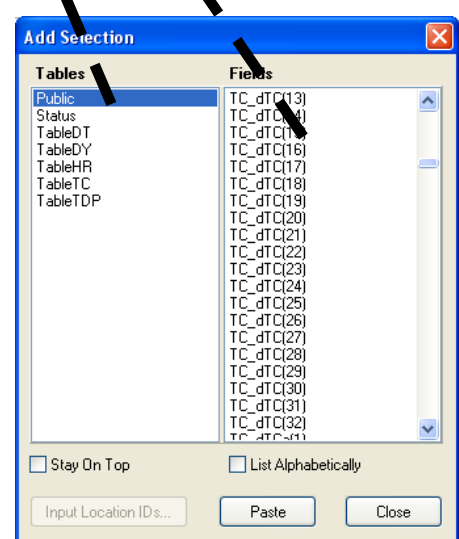
```

Line: 440 Col: 1 | D:\D.DESIGN\PROGRAMS\PROGRAMSFROMDESIGN\FLGS_2.0\FLGS-TDP.CR1 loaded. | Overwrite

7.4.2 Programming the Logger

Launch PC400 software, Select the respective logger, and click **Connect** icon. Wait for the logger to establish communication. On the **Setup/ Connect** tab, check for data logger clock and set if necessary. Click **select and send program** command button, from the resulting file selection dialog box select the required file. Click command button Open to send the file. The software prompts a warning saying that the “Data from the logger will be lost” as shown below. Click **Yes** to proceed.





7.6 Advanced PC400 Features

In addition to basic options explained above for FLGS-TDP logger and custom sap velocity loggers operations an advanced user can explore a myriad of other features offered by PC400 data logger support software's explained else where in the manual or in different booklet.

7.6.1 SHORT CUT/ SCWIN

Short Cut for Windows (SCWIN) is an application for generating programs for Campbell Scientific's dataloggers and preconfigured weather stations. SCWIN guides you through four steps to program a datalogger to measure your sensors and select the data to be stored in the datalogger's final storage. Once a program is completed, SCWIN generates a wiring diagram for connecting your sensors to the datalogger.

7.6.2 Program Logger/ EdLog

EdLog is programming editor and compiler for array based dataloggers such as CR10X etc. Refer to CR10X manual and PC400 manual for description and usage of Edlog feature.

7.6.3 Program Logger/ CRBasic

CRBasic is programming editor and compiler for table based dataloggers such as CR1000 etc.

7.6.4 Other Features (Not applicable to FLGS-TDP system)

Other PC400 software features such as

Split
EdLog,

are not applicable to FLGS-TDP systems with CR1000 logger.

8.0 DATA RETRIEVAL AND PROCESSING

Three types of data retrieval are available:

1. On command, after connecting the PC to the logger.
2. Graphics retrieval from charts saved in the graphics mode.

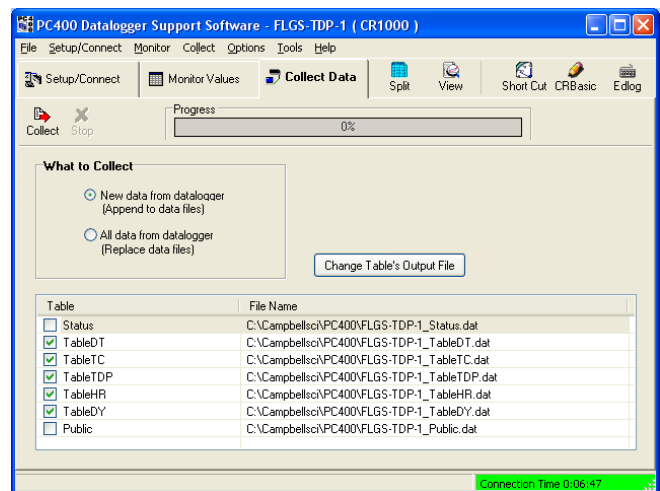
To initiate communications to the logger, refer to previous chapters covering the hardware setup and the communications path options. In the following section possible steps to retrieve the data and the data format is explained, and then we show how to interpret data collected and produce reports. Advanced post processing of data is explained in the next chapter.

8.1 Collect Data For Offline Processing

An active communication path to the data logger is required and communication established in the software to collect data. In labs, nearby field tests or environmental chambers, the logger can be within RS232 cable connection range (100 ft), or within the range of a broadband radio link up to 40 miles (using Dynamax's RFMX modem) or cellular wireless connection using Dynamax's GSM modem. In addition to data collection real-time monitoring of data can be performed from a remote station explained in the previous sections. Following steps explain data retrieval manually at will.

2. With software connected to the data logger select **Collect Data** tab in PC400 software to display data retrieval options and controls.
3. From the list of tables select the table(s) to collect data from change the output location or file name if necessary by double clicking on the file name next to the Table name or by clicking on the Change Table's Output File command button.
4. Select **what to collect** options,
New data from logger option collects data from the last retrieval and appends to specified file name.
All data from logger collect and dump all the data present in the logger and overwrite the specified file name.
5. Before proceeding make sure desired file names and properties as explained above are assigned.
6. Select the tables to collect by enabling the check box as shown above. Following is the typical list of required files to collect at every data collection event.
 - a. TableTC
 - b. TableTDP
 - c. TableHR
 - d. TableDY

Rest of tables displayed in the list are either system or program related tables, these are not required for end user as they are not data related.



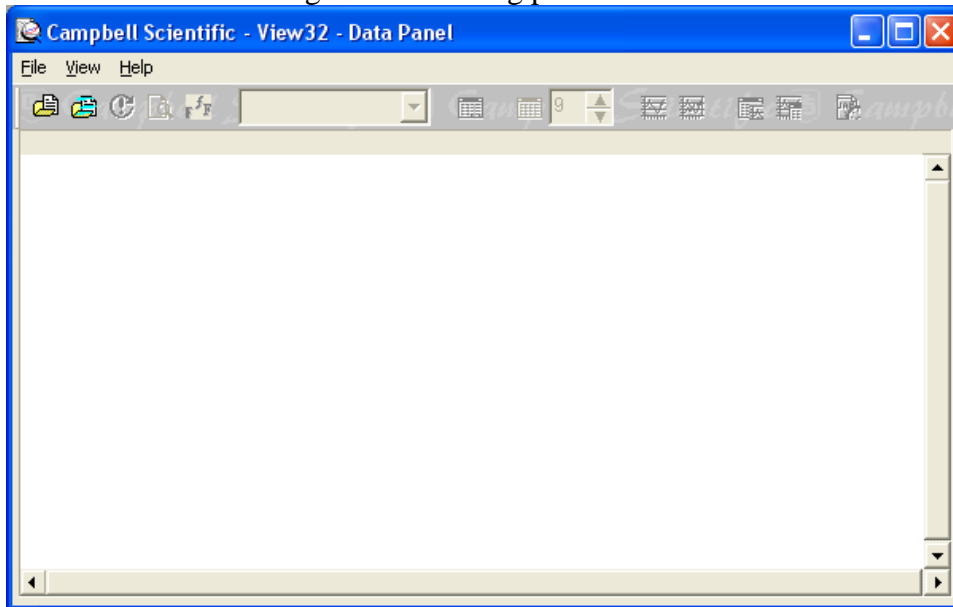
7. Click **Collect** button to start data collection and save to file. Wait for software to complete retrieval and respond with “Collection Complete” message. Click on **stop** command button to stop data collection at any time.
8. Now the data is collected and saved to data file(s) for further processing and analysis. The data are saved in comma separated format .csv, hence can be opened directly in any spread sheet application. Use file name with extension .csv to open these files by double clicking on the file name in windows explorer, otherwise spreadsheet opening wizard can be helpful. Each data file has a header row that displays variables in each column and units if available.

Table Name	Description	Variables
Status	Data loggers status table	
Public	Programs public table, contains all the public variables at any given time	
TableDT	Table of differential temperatures between the logging events	DT(1) – DT(32)
TableTC	Table containing differential temperature and sap flow calculation variables for all the thermocouples, battery voltage, panel temperature, heater voltages	JDAY JHM dTC(1) – dTC(32) dTM(1) – dTM(32) Vel(1) – Vel(32) Flow(1) – Flow(32) Status(1) – Status(32) HtrV(1) – HtrV(4) Batt_Volt PTemp_C
TableTDP	Table containing calculated sap flow data and indexed sap flow data along with statuses for all the TDP sensors	JDAY JHM TDP_Flow(1) – TDP_Flow(32) TDP_FlowIx(1) – TDP_FlowIx(32) TDP_Status(1) – TDP_Status(32)
TableHR	Table containing accumulated total hourly sap flow from all the sensors	JDAY JHM Hr_Flow
TableDY	Table containing accumulated total daily sap flow from all the sensors	JDAY DY_Flow

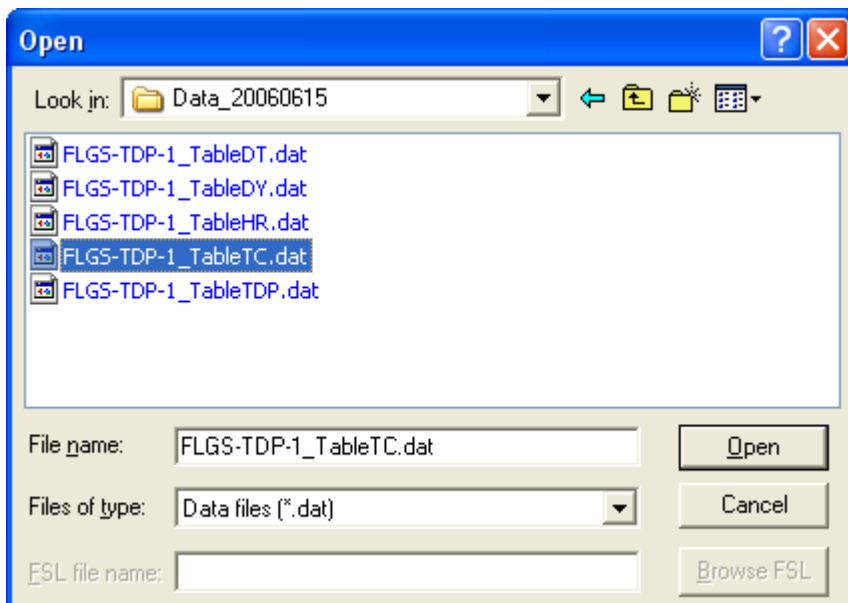
PC400 supports only manual data collection. For advanced data retrieval options such as Automatic data retrieval and scheduled data collection choose LoggerNet.

8.2 Graphics Mode Display - File Data

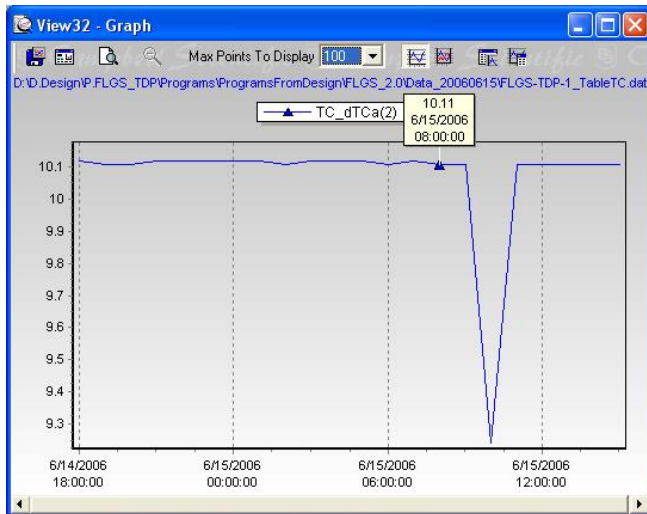
1. In order to view data that has been collected by the data logger in the previous section, PC400 View utility is a great tool for a quick look at the data. Detailed charts are probably best done with another Windows application or the Recalculate option in the next chapter. Click on the View button on the PC400 main toolbar to get the following panel.



2. Click on File and browse down to Open file selection dialog. Select file name with .dat or .csv extension. FSL file is not necessary for CR1000 output files as the header information is saved in the same table output file.



7. Once the necessary column(s) are highlighted, click on Show Graph (1 Y-axis) or Show Graph (2 Y-axes) tool bar button. This launched a graph displaying selected column values in Y-axes. X axes is always the first column, i.e. time stamp. Examples of graphs with one Y-axis and with two Y-axes are shown below.



9.0 RECALCULATE SAP FLOW USING EXCEL

The purpose of the SPLIT utility is to make data easily understood, and to format the data retrieved from the FLGS-TDP so that it can be printed, viewed on the PC monitor, or sent to files for subsequent graphing or analysis. This section explains how to load preprogrammed parameter files, and to extract the data saved to the FLGS-TDP.DAT files with the PC400 of LoggerNet.

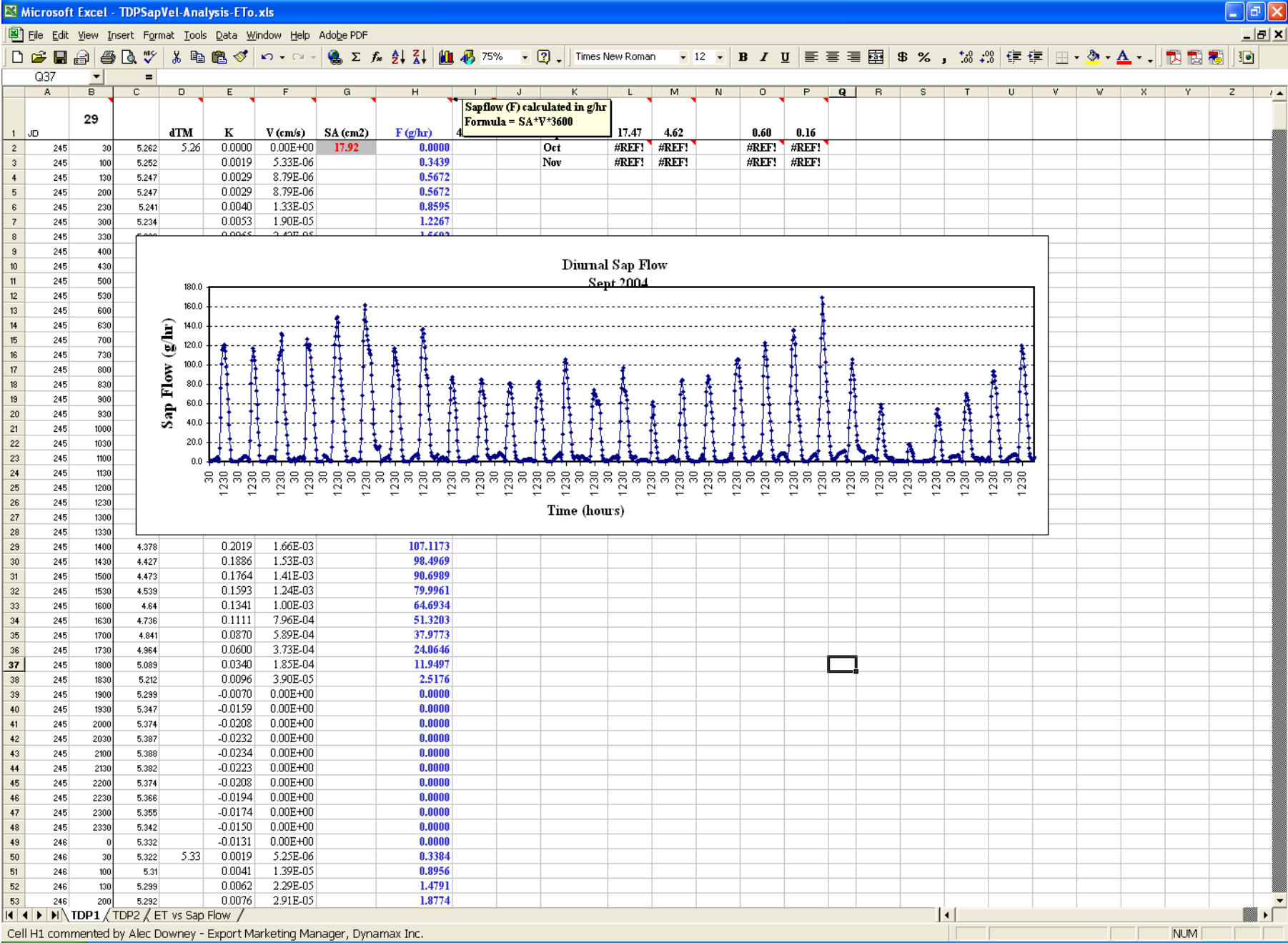
The process of calculating sapflow from dT data collected from the logger is simplified by the excel spread sheet TDPSapVel-Analysis-ETo.xls. The user simply opens the spreadsheet, copy dt for a particular gage along with time and date to the spreadsheet. The spreadsheet calculates the sapflow.

Note: TDPSapVel-Analysis-ETo.xls spreadsheet is designed for data every half hour (30 minutes).

If data interval is different from 30 minutes custom modification of the formulae is required in the spreadsheet.

Follow the steps below to use excel spread sheet and recalculate sap flow.

1. Open TDPSapVel-Analysis-ETo.xls spread sheet provided with software.
2. Open data file collected form logger in excel using wizard so that columns are preserved.
3. Copy the Julian day and time columns from .dat file to the spreadsheet.
4. Select the dT column of the desired sensors
5. Copy and paste below the header dT in the spread sheet.
6. Formulae embedded in the spreadsheet perform auto zero on dT and calculate sapflow for this sensor. Calculated sapflow is displayed in the chart.
7. An example of this is shown in figure below.

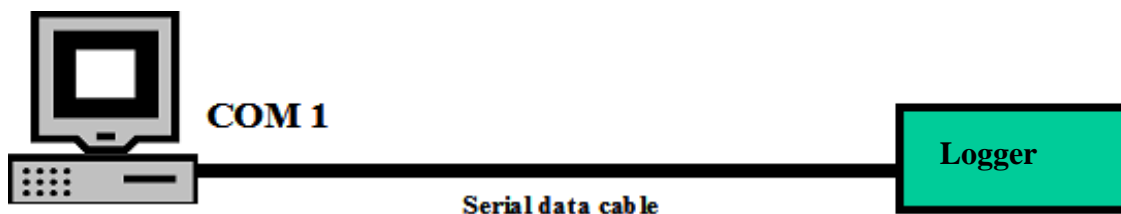


10.0 COMMUNICATIONS

FLGS-TDP (CR10x) data logger along with PC400 or LoggerNet has added communications and networking features for remote long distance and cable communications and scheduling. Below is a list of communication devices offered by Dynamax and are tested on CR10x based systems for signal strength and transmission range.

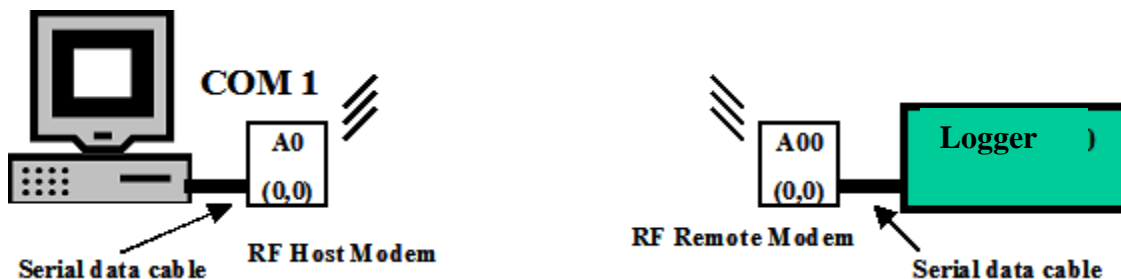
Serial data cable:

This is a basic serial communication interface using 9 conductor serial cable, is shown in the figure below. 6' serial cable is supplied with logger and can be extended up to 200' without losing any signal. If a longer cable is required contact Dynamax. For distances longer than 200' it is recommended to use either a short-haul modem or RF interface.



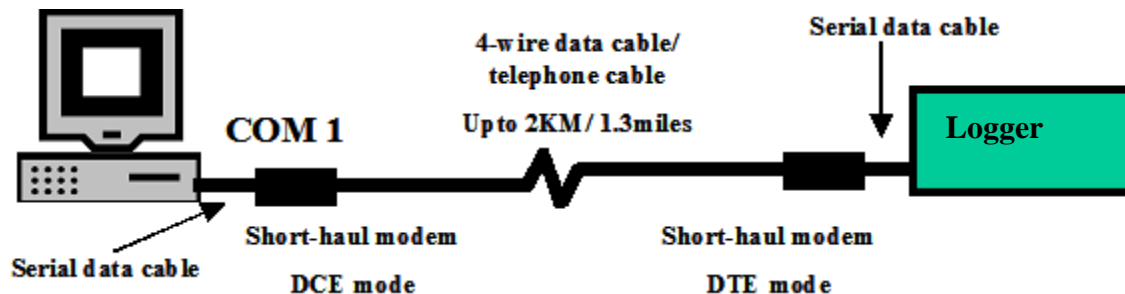
RF Radio Modem (RFMX):

Radio modem for wireless communications up to 40Miles (64KM) at baud rate 9600bps. Baud speed is programmable. LoggerNet and PC400 software is equipped with capability to program, and configure RFXM modems in point-to-point and point-to-multi-point modes. Refer to RFXM modem manual for setup and programming details. A simple communication setup between FLGS-TDP-Logger and PC using RF modems is shown below along with modem addresses.



Short-haul Modem (SHM):

Short haul modem is a bi-directional serial interface converter for RS232 and RS485. This communication setup facilitates Point-Point bi-directional communication up to 1.3 mile/ 2Km/ 6660ft. at a data transfer rate of 9600bps. This model makes use of Dynamax's SHM short-haul modem, 4-wire 24-gauge cable or standard telephone cable. Short-haul modems are configured using DIP switch in different modes. For details on short-haul modem refer to SHM manual.



Landline Phone modem (DNX9600):

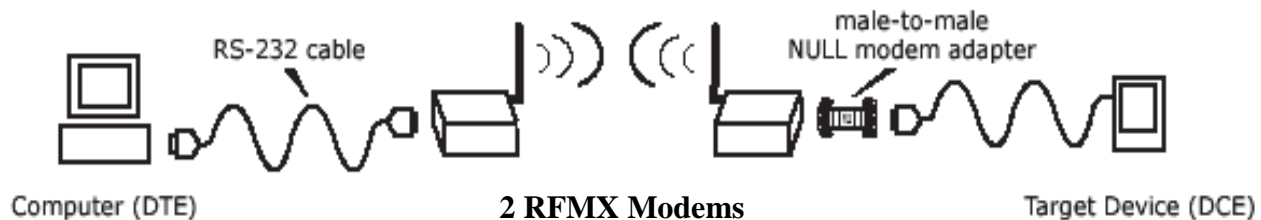
Data modem/ Land-line dialup modem. Where telephone service is available. DNX9600 is factory set to 9600 bps but can be changed using DIP switch settings or programming software.

Cellular Modem (GSM):

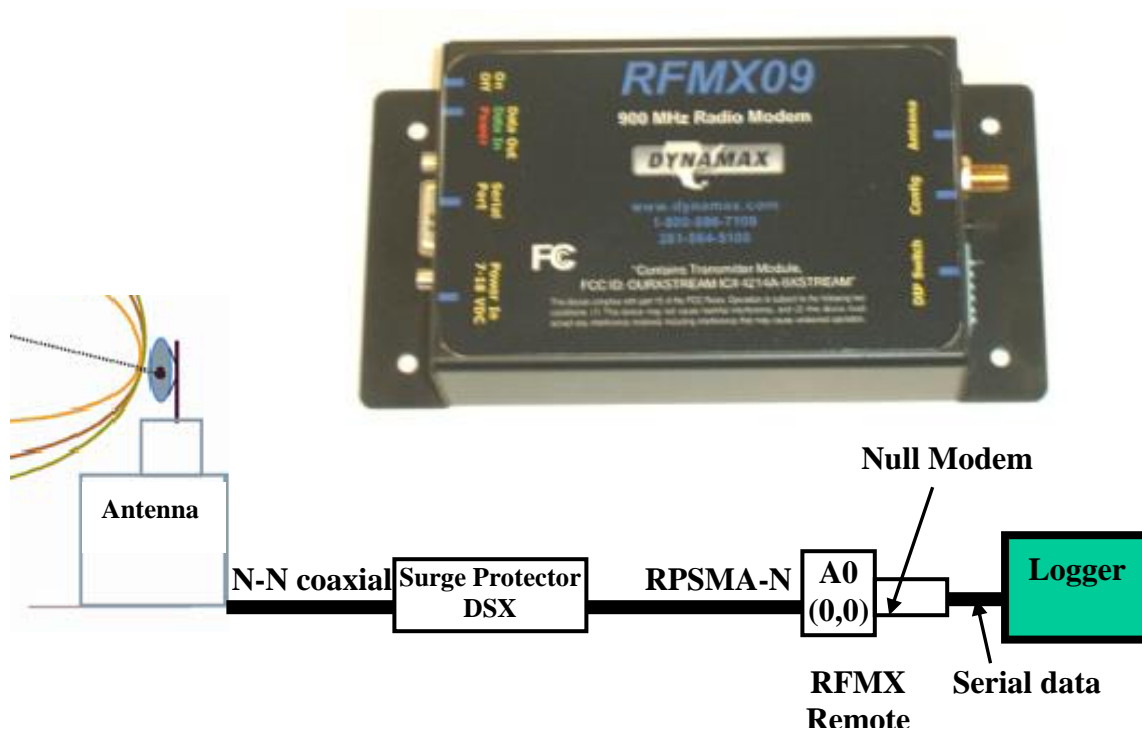
GSM is a Dual-band cellular modem for serial communications using GSM mode. As GSM is widely acceptable and providers available in most countries. Cellular modem is offered in all the 4 available GSM frequencies making it possible to use in any country. Devices with serial data rates up to 15200bps can be connected using GSM modem.

10.1 RF Modem (RFMX)

Typical wireless connection used for serial communications between DTE and DCE devices



RFMX 900 MHz RF modem with transmission range of up to 40 miles LOS using a directional antenna is shown in figure below. Basic hardware setup using half-wave dipole antenna is shown above. RFMX modems with dipole antenna has a transmission range of up to 7 miles LOS. This chapter describes installation of RFMX modems along with hardware, required power, supplies, network topologies, etc. Also is included a list of compatible hardware for use with RF modems such as Surge protectors, high-gain Antennas, omni-directional antennas, coaxial cables and connectors, adapters etc. Refer to the list of hardware required for entire list.



10.1.1 Specifications

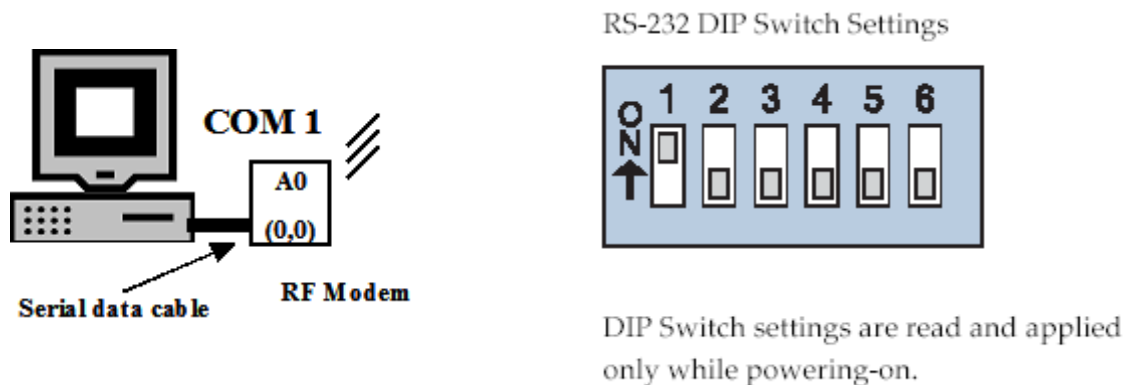
Communication	Frequency	902 – 928 MHz
	Channel capacity	7 hopping sequences sharing 25 frequencies
	RF baud rate	10,000 bps
	Network Topology	Point-to-point, Point-to-multi-point Multi-drop
	Serial Interface	RS-232
	Serial Baud Rate	1200 – 115200 (programmable)
Performance	Indoor	Upto 1500' (457m)
	Outdoor	7miles/ 11Km LOS (dipole) 40 miles/ 64Km LOS (Yagi/ High-gain antenna)
	Transmit power output	140mW (21.5dBm)
	Receiver sensitivity	-110dBm
Power	Supply voltage	7 – 18 VDC
	Transmit current	200mA
	Receive current	7mA
	Power down current	<1mA
Physical properties	Enclosure size	2.75" x 5.50" x 1.124"
	Weight	7.1 oz (200g)
	Operating temperature	-40° to +85° C
Certifications	FCC Part 15.247	
	Industry Canada	

10.1.2 List of Hardware

Radio-Surge Protector cables	Length
LMR400 N(M)-RPSMA(M) coax	3'
RPSMA(M) - RPSMA(F)	3'
RPSMA(M) - RPSMA(F)	10'
RPSMA(M) - RPSMA(F)	20'
Surge Protector	DSX-POL N(F)
Antenna cables (Coaxial)	Length
LMR400 N(M)-N(M)	10'
LMR400 N(M)-N(M)	20'
LMR400 N(M)-N(M)	30'
Antenna	dB gain
Dipole/Half-wave comes with radio 2.1dB	2.1
High directional Yagi antenna	6, 9, 11
Omni directional antenna	3, 5, 7

** Refer to RFMX data sheet for detailed specifications and various antenna and accessory configurations available.

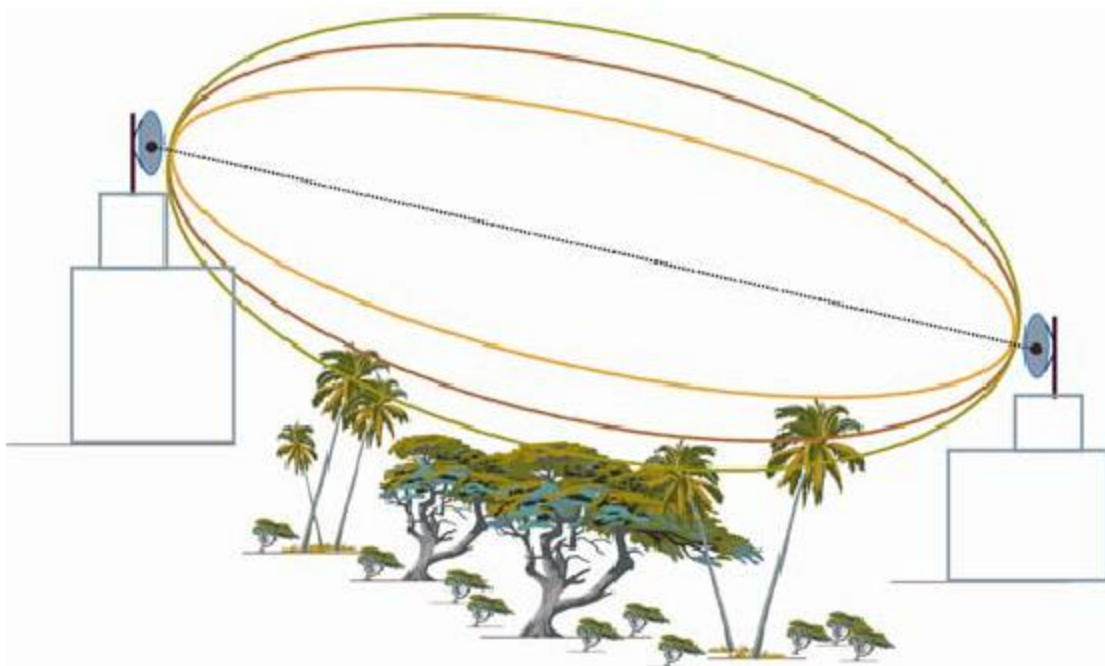
10.1.3 Programming



RFMX modems are programmable using LoggerNet software. Set DIP switches as shown in the figure above for RS232 mode. Connect RF modem directly to the PC using serial cable as shown above. Refer to RFXM manual for detailed programming and communication protocol.

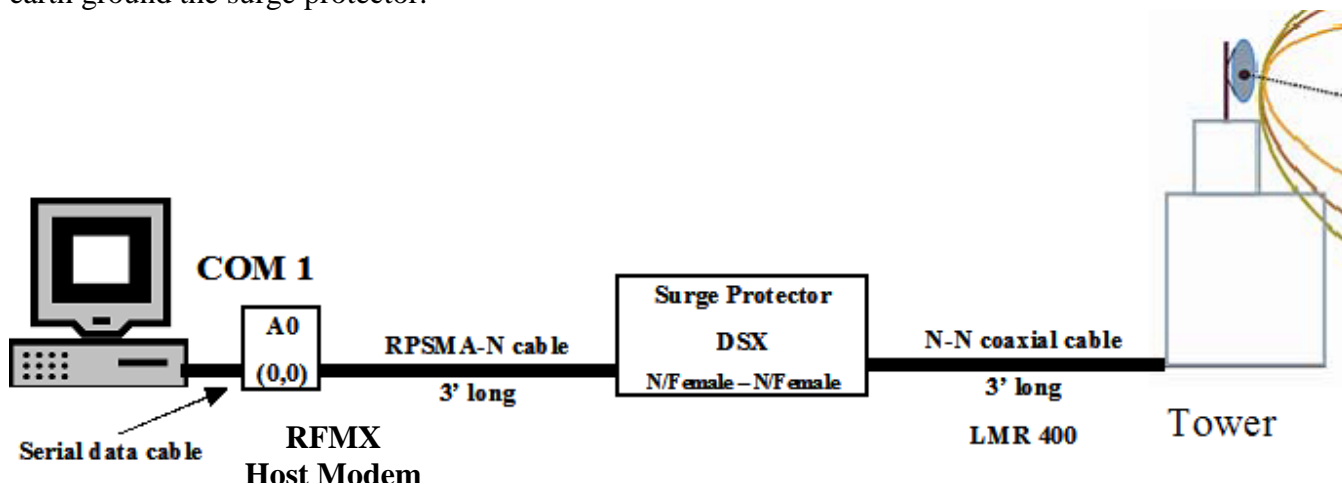
10.1.4 Antenna/ Tower

Line of sight between host and remote modem is essential to get maximum signal strength and maximum transmission range. This distance can be improved by using mounting antenna on a high tower such that common obstructions like trees, buildings are not causing an obstruction in to interface between the two points. An example of this is shown in the figure below.



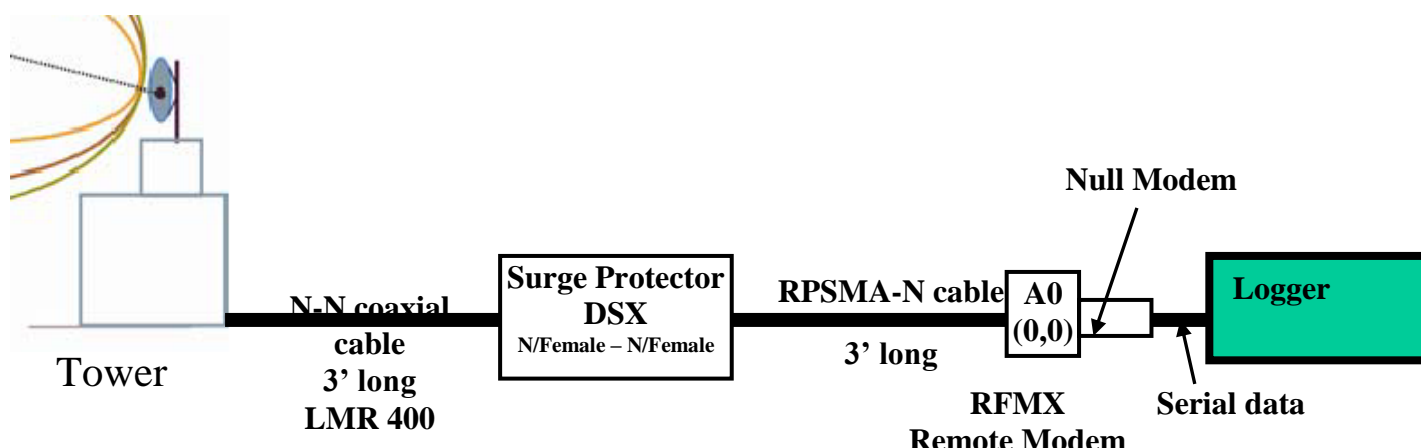
10.1.5 Host Modem Installation

Configuration for Host station is shown in figure below. RF modem is connected to PC using serial cable and to transmitting antenna via surge protector to shield equipment from lightning surges. Make sure to earth ground the surge protector.



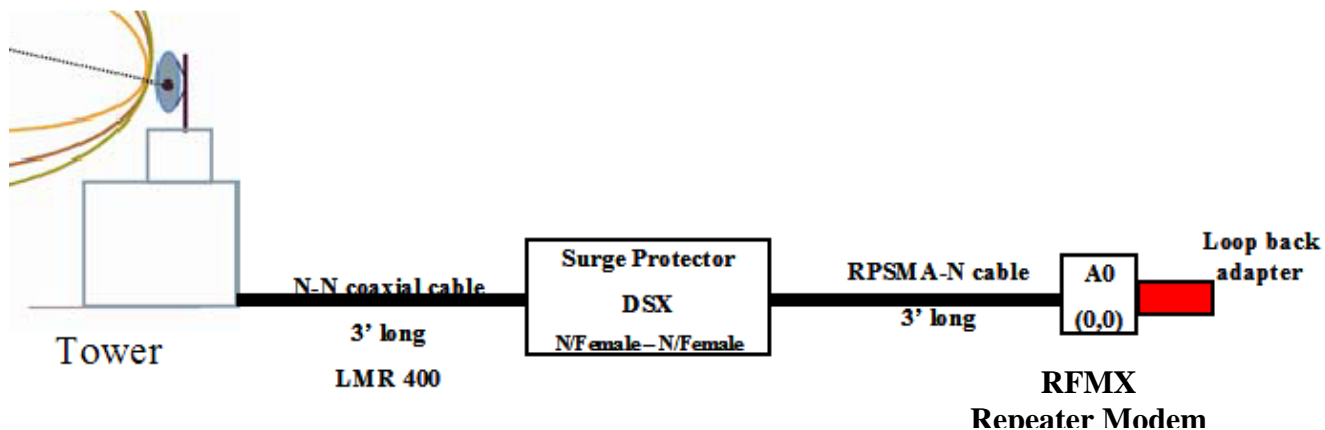
10.1.6 Remote Station Installation

Hardware setup for remote FLGS-TDP -Logger station is shown in figure below. Program RF modem from LoggerNet / PC400 software before connecting to remote station.

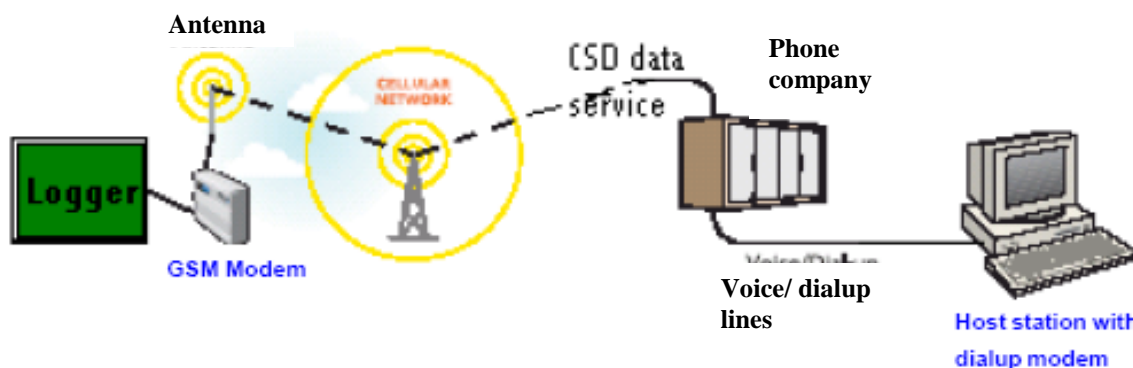


10.1.7 Use of Repeater

For extreme terrain conditions, and transmission over long distances achievable using host and remote antennas it is possible to use a repeater tower along with a omni-directional antenna as shown in the figure below. This is simple **store and forward method of repeater configuration**. This configuration uses a loop back adapter supplied with RF modem. The repeater will buffer incoming data and retransmit it when there is a break in data reception.

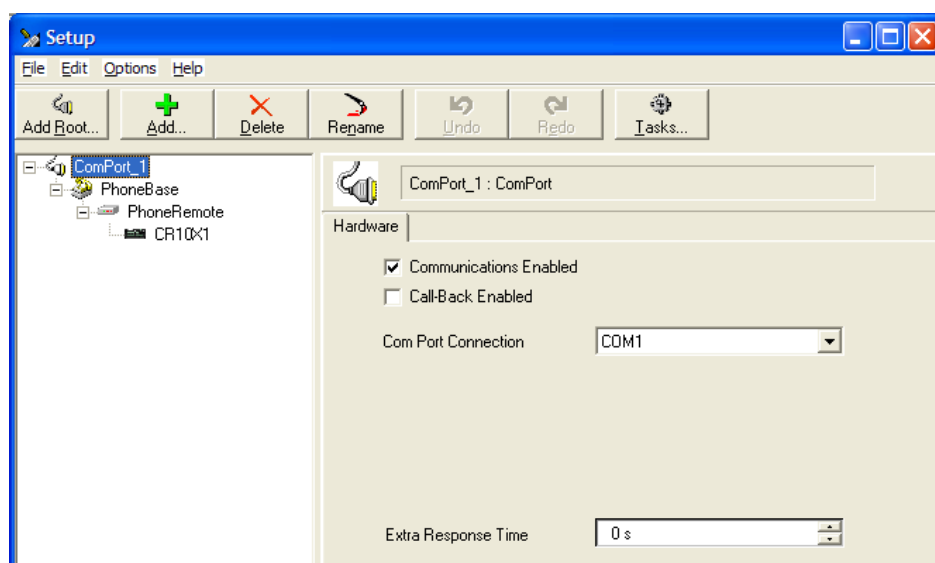


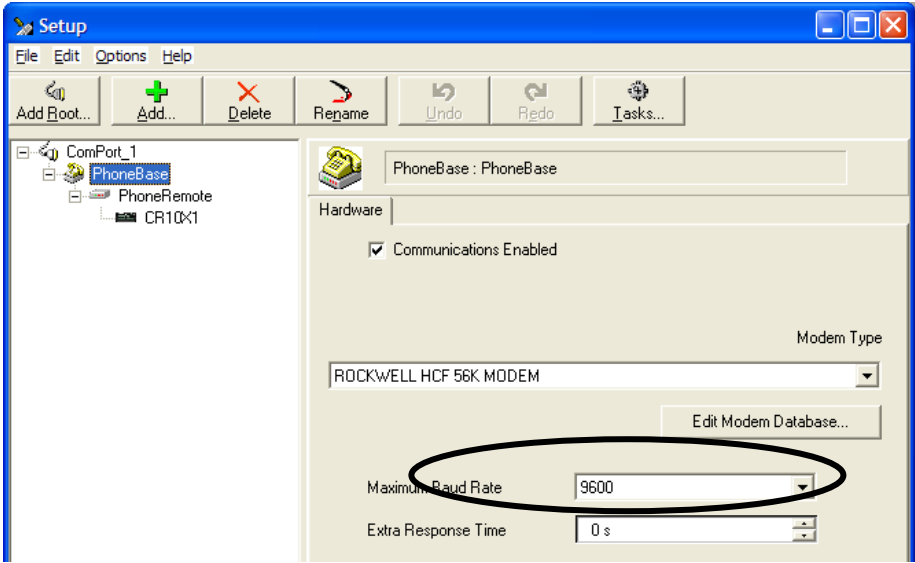
10.2 Dual band cellular wireless Modem (GSM)



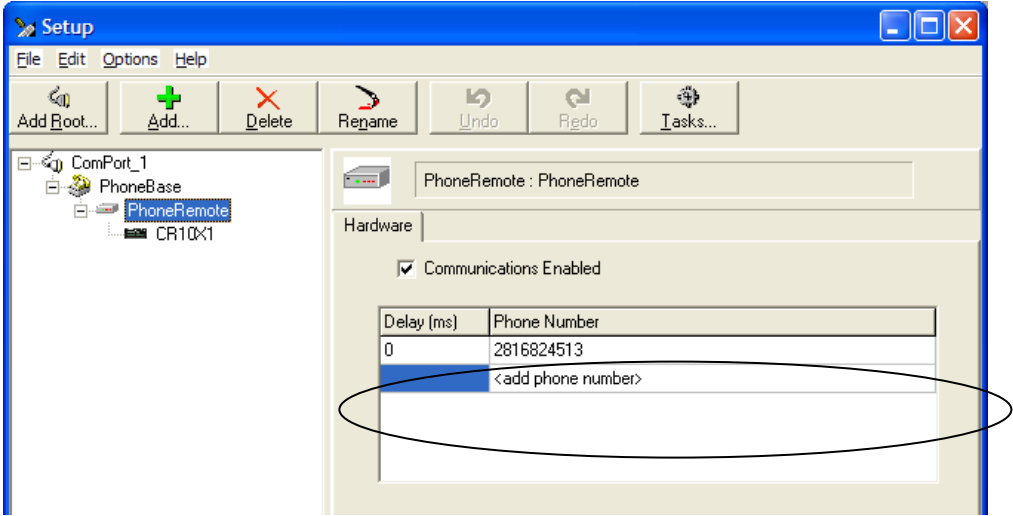
Dynamet weather station is compatible with cellular modem (GSM-F1/2) for remote communications using GSM wireless network. Communication can be established using PC400 or LoggerNet. Follow the screen captures to setup GSM modem communication to Dynamet - CR10x logger.

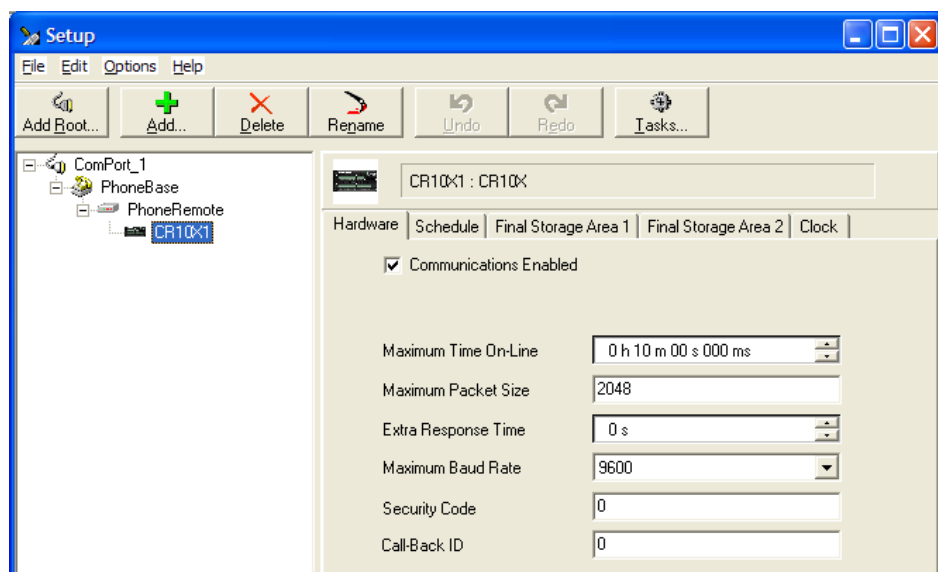
** base modem / modem connected to the PC-software Conexant HCF 56K modem is not in the modem pick list Select "Rockwell HCF 56K modem" instead





Enter data number corresponding to the remote modem – Phone modem/ GSM cellular modem





Connecting to the Logger:

1. Click on Connect tool bar to open **Connect to datalogger** window.
2. Select CR10x station with GSM modem.
3. Click on **connect** button to start dialing out to GSM modem and datalogger network.

10.3 Short-haul Modem (SHM)

The Short-haul modem is a compact interface device that can be used to transmit and receive serial data over relatively long distances that are not achievable using RS232 interface. The modem unit plugs directly in to the COM port on an asynchronous device.

SHM is a non-powered line driver with a 1500VAC lightning surge protection and noise rejection. The unit shown in the figure is switch selectable and operates using 4 wires on screw terminals or RJ11 connector. For using with FLGS-TDP -Logger modem is connected in point-point 4-wire Full-duplex mode where only software handshake is applicable.



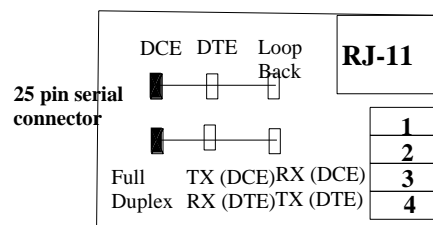
SHM Non-Powered RS-232 Line Driver

Communication modes

Full duplex/simplex switch selectable
Loop back

Features

No External Power Required
DCE/DTE Switch Selectable
Long Distance Transfer Via Economical TP Cable
Compact Size



IC 150

10.3.1 Specifications

Function		Specification
Connectors		RS-232 DB-25 Female, RJ-11 Jack 4 Screw Terminal
Switches	SW1	DCE, DTE, Loop Back Select
	SW2	Full Duplex, Simplex Select
Cable Length		3.5 Km (Max.) @ 4800 bps 2 Km (Max.) @ 9600 bps 800 m (Max.) @ 19200 bps
Interface		RS-232
Data Transfer Speed		110 ~ 38400 bps
Power Consumption		No external Power source Required
Housing		Plastic
Weight		60 g
Dimensions (L x W x H)		54 x 74.5 x 18.5 mm

10.3.2 Hardware Configuration

Installing a serial interface using SHM, short-haul modem uses a 4-wire cable. A 4-wire cable with RJ-11 connectors on either end reduces the installation time.

Connect the transmission cable as show in the figure using screw terminals or directly to RJ-11 sockets.

Configure the selection switches SW1 and SW2 on host modem connected to PC and the remote modem connected to FLGS-TDP -Logger as shown in the table below.

Connect 25-9 pin serial adapter to the serial port connector on each modem.

Connect host modem to COM port on PC and remote modem to Communication cable on FLGS-TDP-Logger. No power connections are required.

Turn power ON to FLGS-TDP-Logger and Launch FLGS-TDP-Logger software on PC.

Refer to chapters 9, 10 and 11 for software setup using LoggerNet or PC400.

Comm. Device	Device type	Sw1	Sw2
PC (Host)	DTE	Full-Duplex	DCE
FLGS-TDP-Logger (Remote)	DCE	Full-Duplex	DTE

10.3.3 Troubleshooting

If experiencing difficulty getting communication using serial interface,

Check whether the COM port to each modem is connected, and COM port assigned in the FLGS-TDP-Logger software's station setup are the same.

Verify the switch selections on host and remote modem.

Check continuity on the cable/wires.

10.4 Modes of Communication

PC400 and LoggerNet components in FLGS-TDP software support various remote communication devices. Refer to section 1.6 for list of all the new features and upgrades. Following communication modes are possible using FLGS-TDP logger,

- **Point-to-point configuration** of multiple FLGS-TDP-Logger stations
- **Point-to-multi-point** configuration of multiple FLGS-TDP-Logger stations
- **Communication scheduling and automatic data collection**
- **Simultaneous monitoring and control of multiple stations from single PC** when each station connected to a different COM port.

FLGS-TDP along with LoggerNet supports the following communication interfaces,

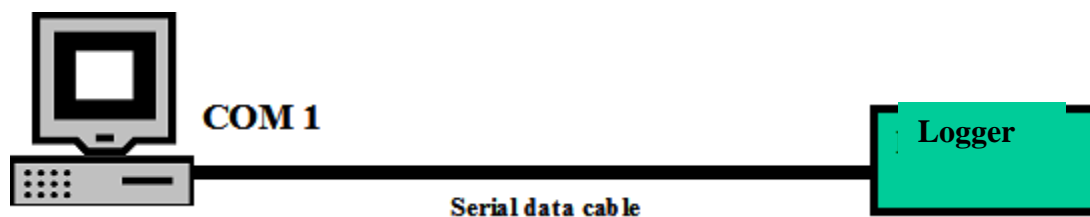
- Standard serial communication using Serial data cable
- RF communication using Dynamax's RFMX modems
- Short-haul modem communication using Dynamax's SHM.
- GSM cellular communication modem

For additional modes of communication not mentioned above may be used with FLGS-TDP to communicate with Logger but would require manual configuration specific to the communication device.

10.4.1 Modes of Configuration

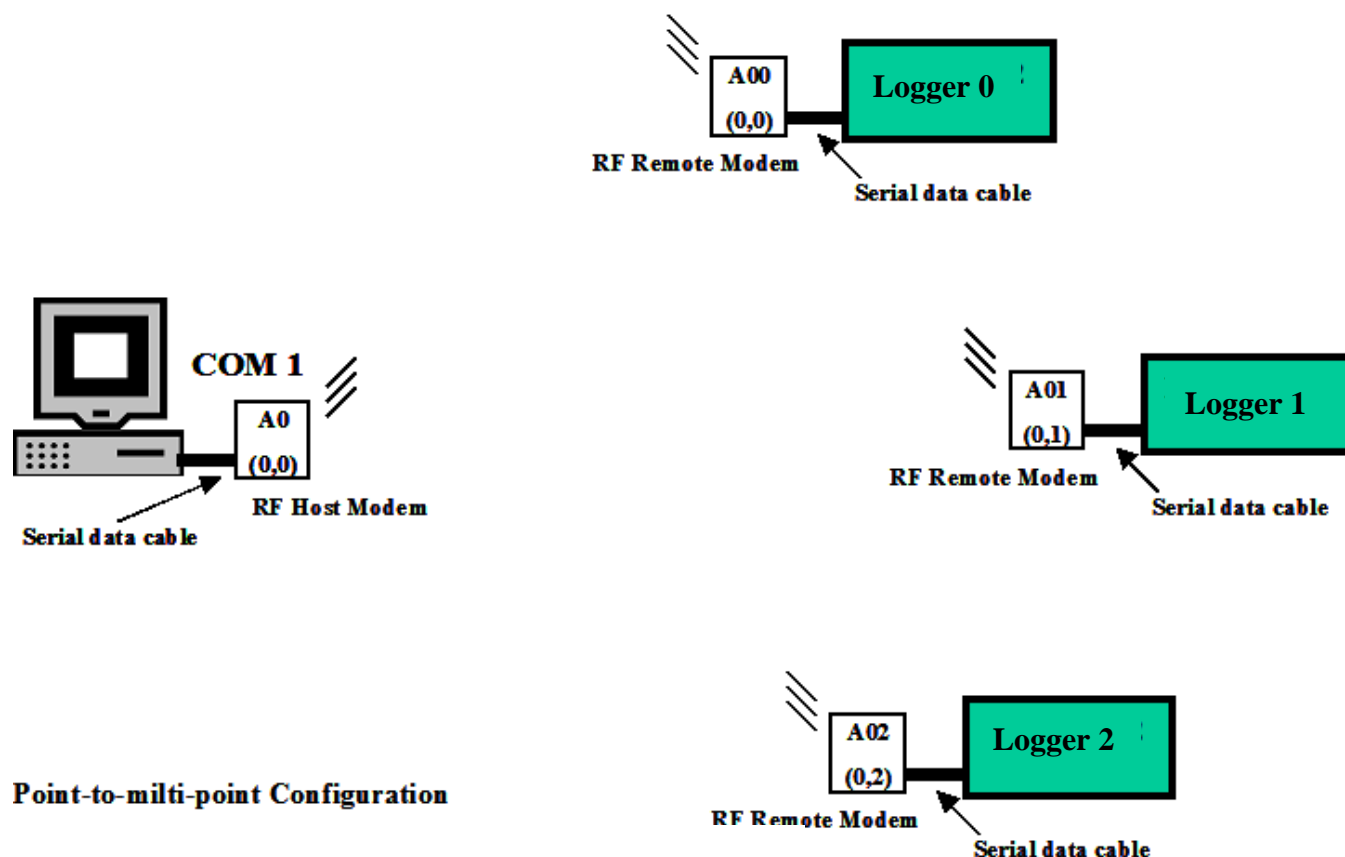
Point-to-point

Point-to-point is a simple configuration in which two devices located at two different places are interfaces to communicate with each other by using cable, modem etc. Simple point-to-point configuration between FLGS-TDP-Logger and COM1 on PC is shown in figure below. Cable interface in this figure can be replaced with RF or serial interface converter.



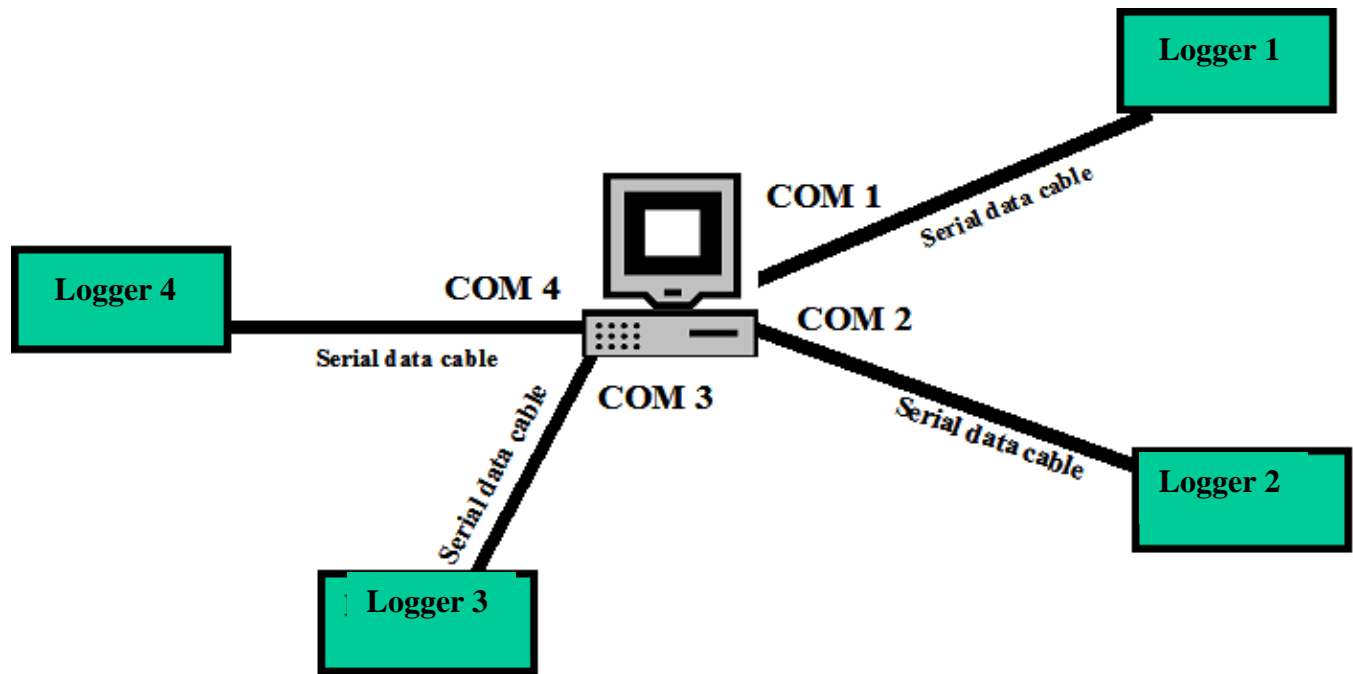
Point-to-multi-point

Point-to-multi-point configuration is one in which two or more devices located at different places are interfaced to communicate with single control station or PC. An example of point-to-multi-point configuration is shown in figure below. Data loggers Logger 0, Logger 1 and Logger 2 are setup to communicate with PC on COM1. PC400 and LoggerNet can program host modem to communicate with only one of the remote stations at any given time.



Multi-station Scheduling

A multi-station setup as shown in figure below is a configuration of more than one station connected to a single PC but each station connected on a different COM port. Main advantage of this type of configuration is in situations where it is required to simultaneously monitor and schedule more than one station from a single PC using FLGS-TDP/LoggerNet software. Once hardware (cabling and connections) are setup the setup is ready to monitor anytime. Communication interface in this network can be substituted with any of the available types as long as there is only one Logger station setup on each COM port.



Multi-station Configuration

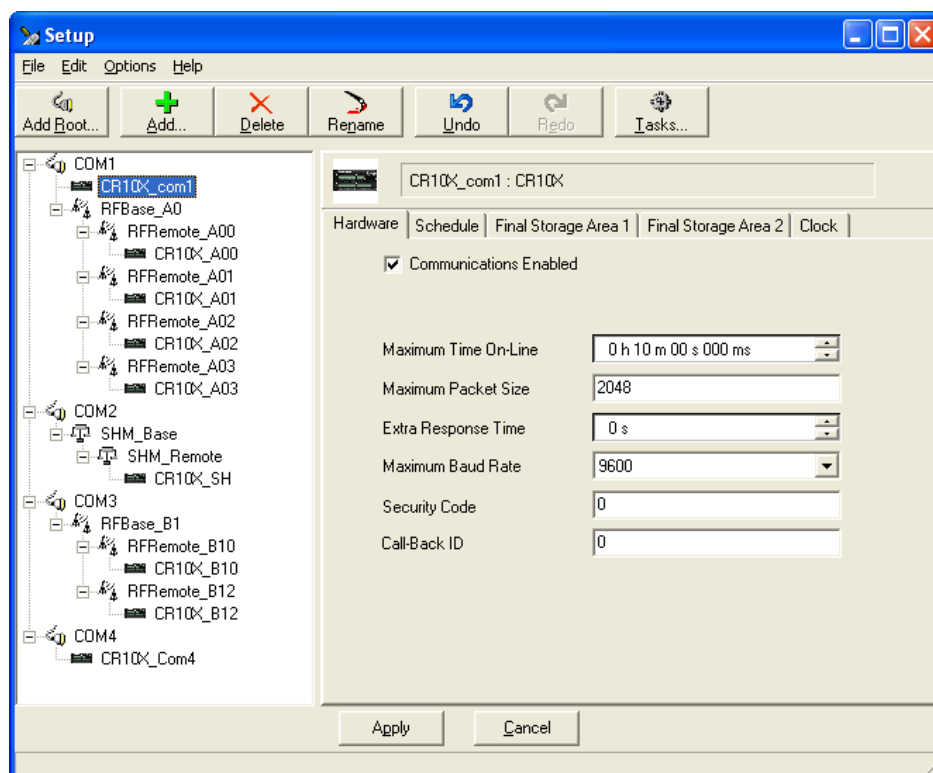
10.4.2 A sample large scale setup

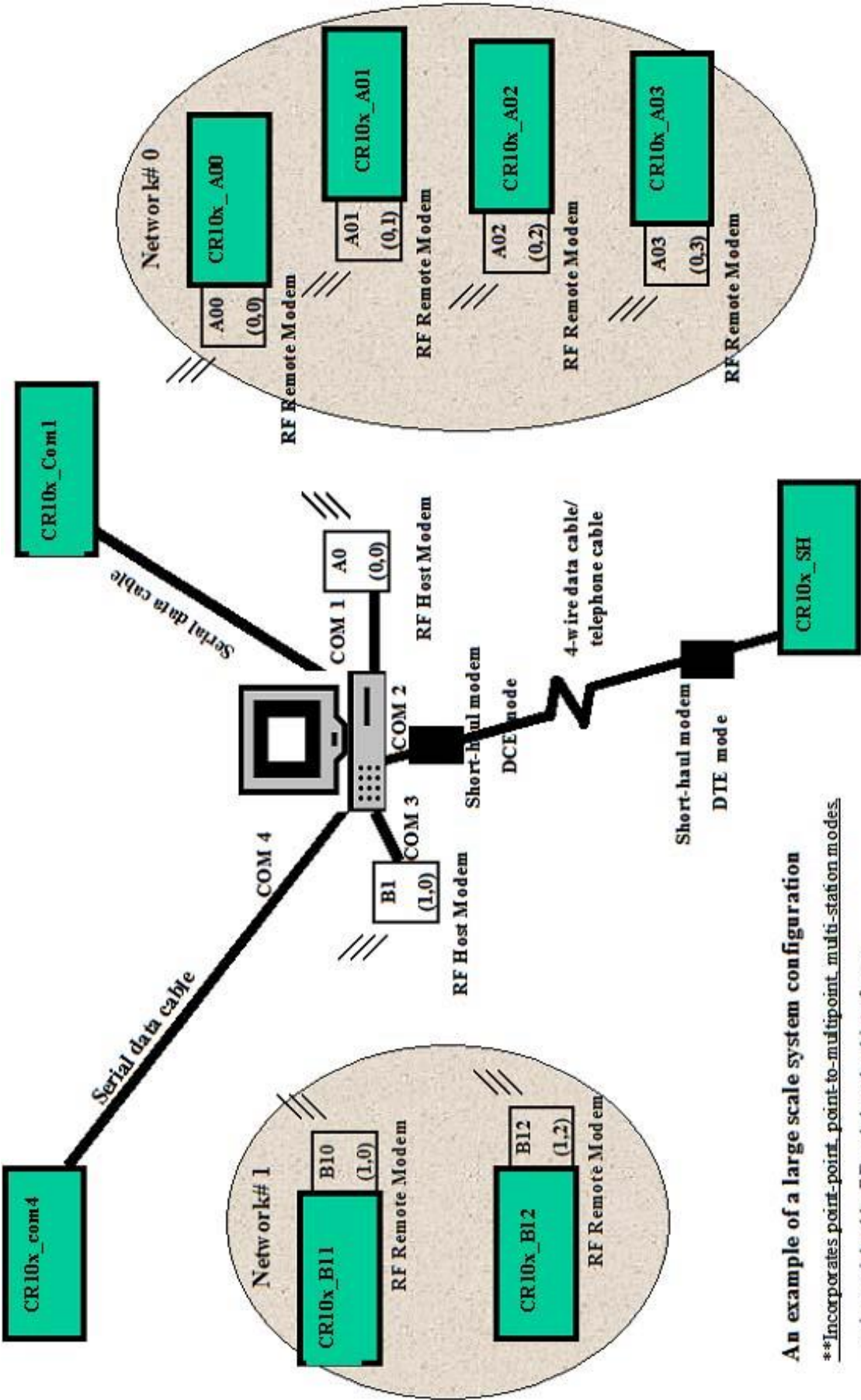
A large-scale/ hybrid network of FLGS-TDP-Logger stations can be characterized as a group of stations connected to more than one COM port on PC and using more than one type of communication interface. A sample large-scale setup is shown on the previous page.

This setup has 9 FLGS-TDP-Logger stations connected to 4 COM ports on a central workstation.

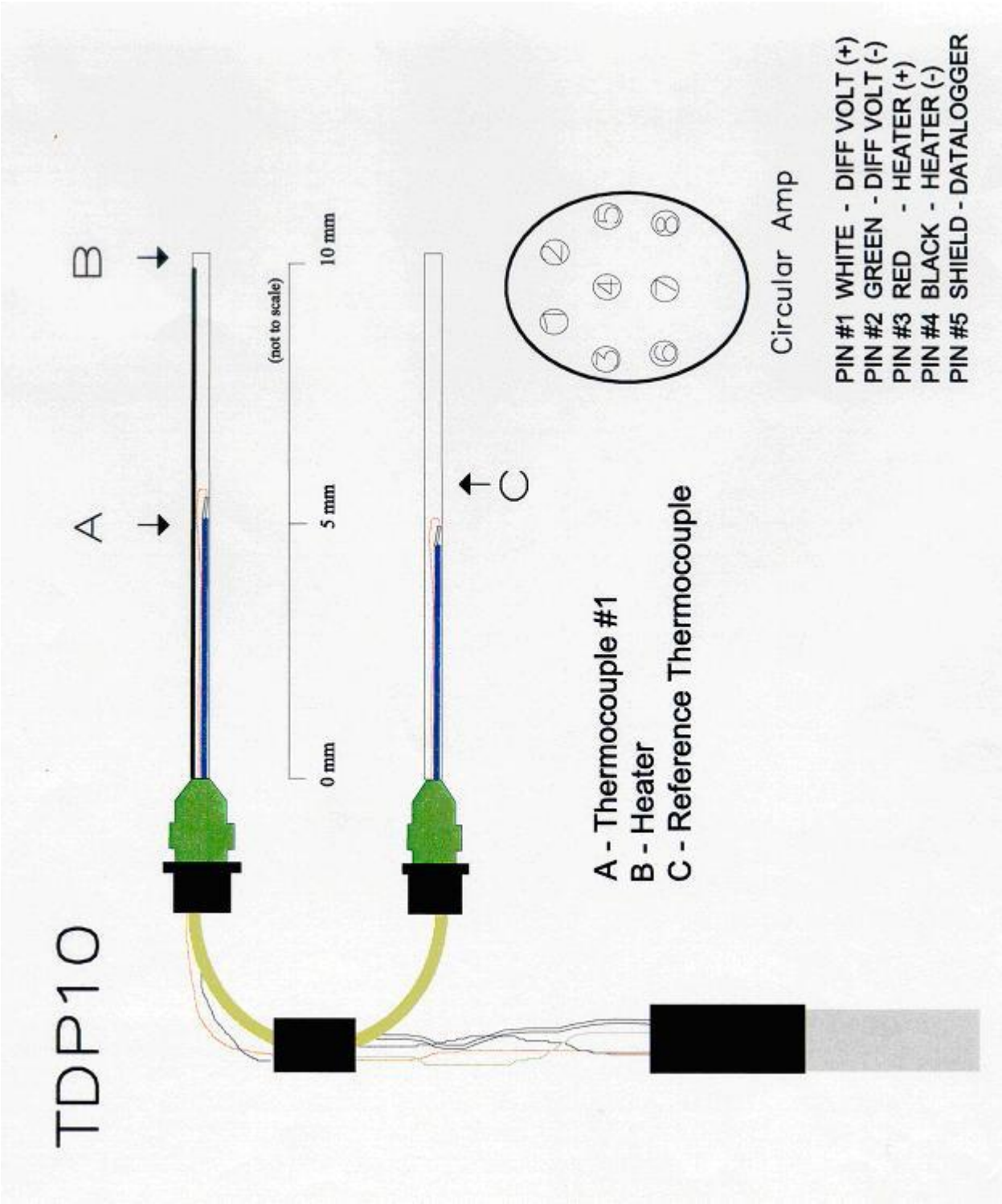
- CR10X_com4 is connected to Com4 respectively using standard serial (RS232) data cable. Distance in this case is limited to 200’.
- CR10X_SH is connected to Com2 using serial interface modem (short-haul modem). When using SHM modem, transmission distance (between PC and FLGS-TDP-Logger stations) is limited to 1.34miles(2KM).
- CR10X_B11 and CR10X_B12 are connected to RF Host modem B1 on COM3 via RF communication interface, using modems on each remote station. RF host modem B1 on Com3 can be programmed using LoggerNet to connect with either CR10X_B11 or CR10X_B12 at any given time.
- CR10X_com1 are connected to COM1 respectively using standard serial (RS232) data cable. Distance in this case is limited to 200’.
- CR10X_A00, CR10X_A01, CR10X_A02 and CR10X_A03 are connected to RF Host modem A0 on COM1 via RF communication interface, using modems on each remote station.
- Since we have more than one interface on COM1 (RF and serial cable), user has to manually connect the appropriate cable either serial cable on CR10x_com1 or serial cable to RF host modem. When serial cable from CR10x_com1 is connected to COM1 CR10x_com1 can be accessed from software. In order to connect with one of the stations is network#0, RF host modem A0 should be manually connected to COM1 and programmed net# and module# same as respective remote RF modem.

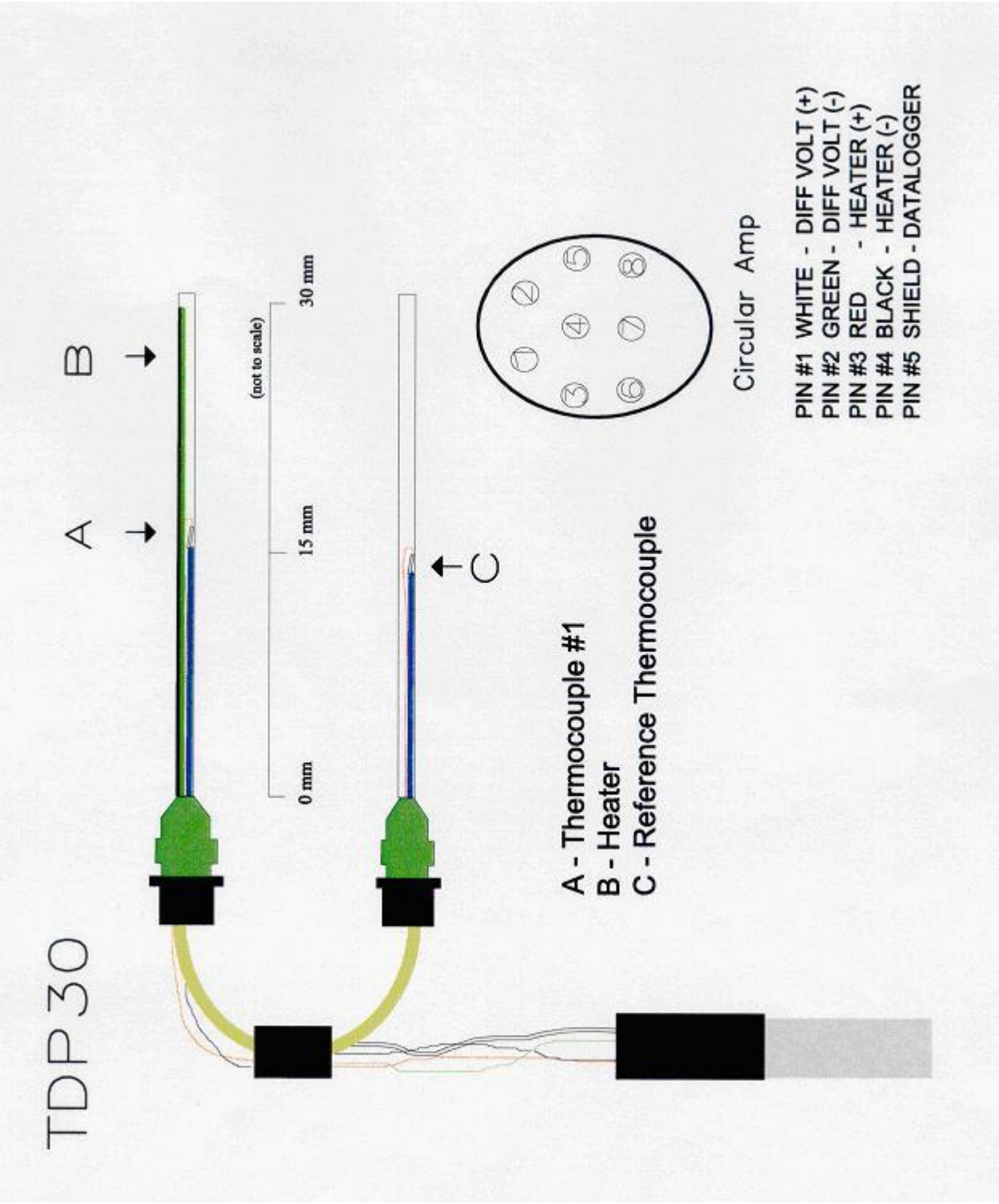
Configuration and setup of these stations in LoggerNet is shown in figure below. Automatic scheduling and data collection can be achieved by activating schedule tab for each CR10x station.

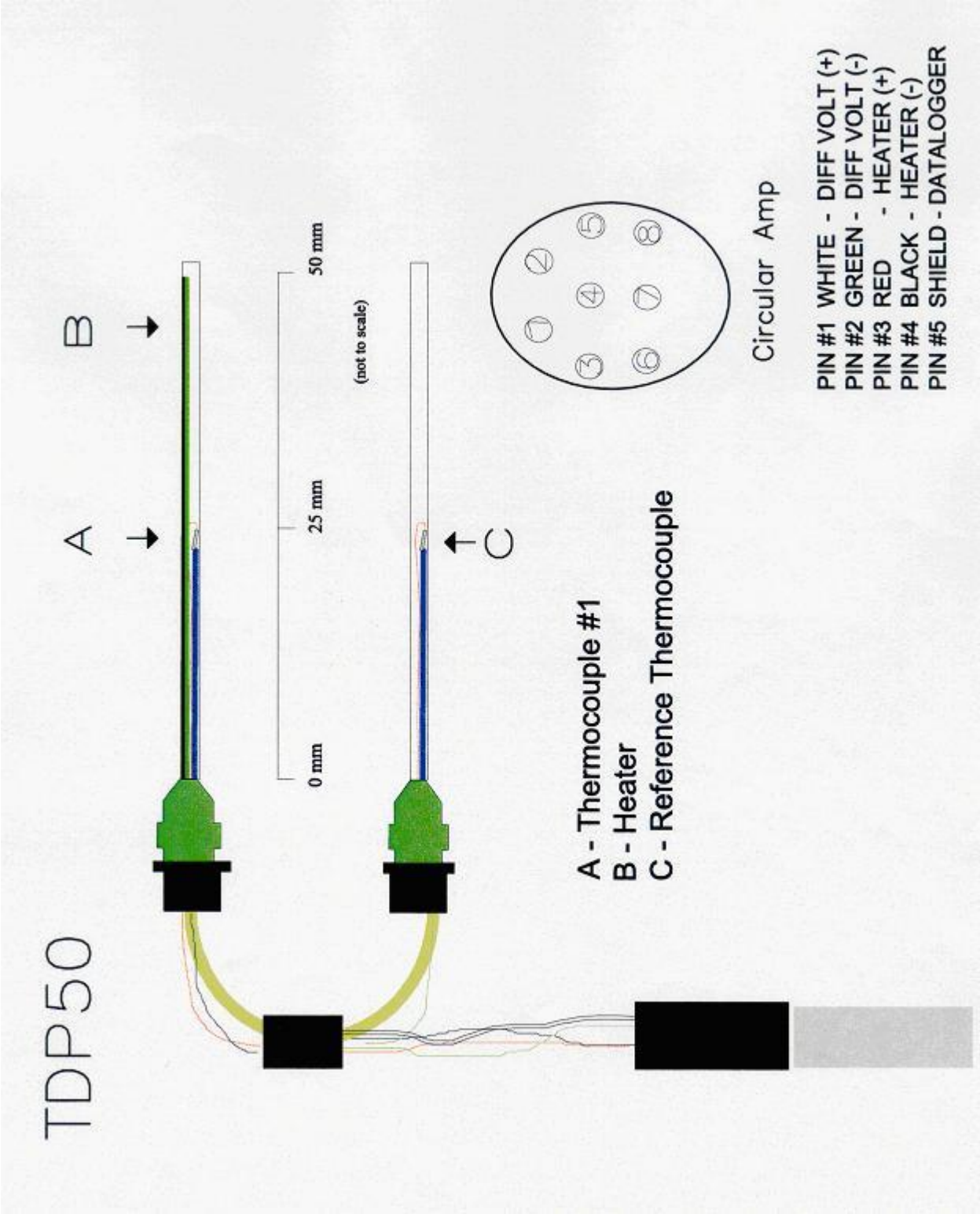


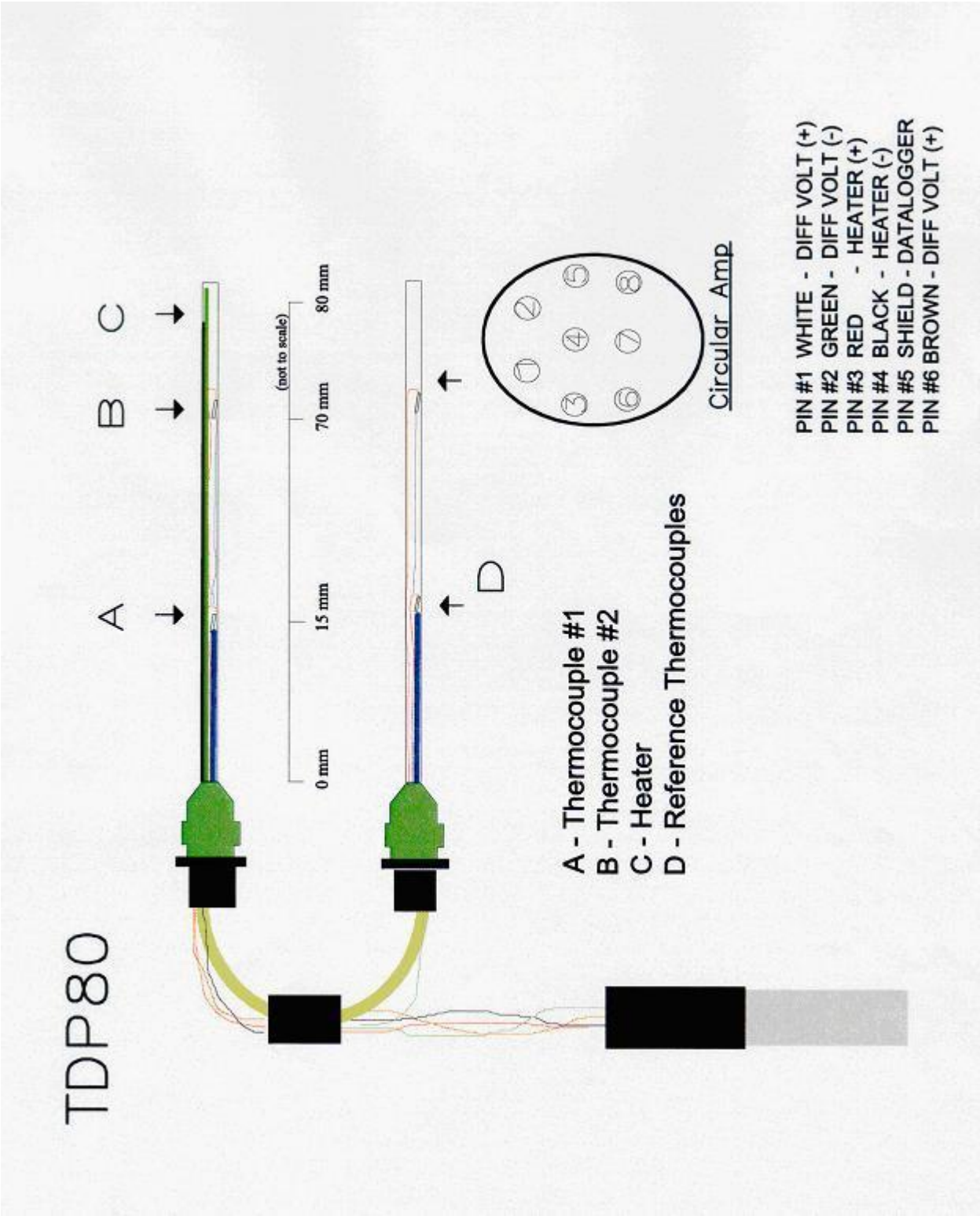


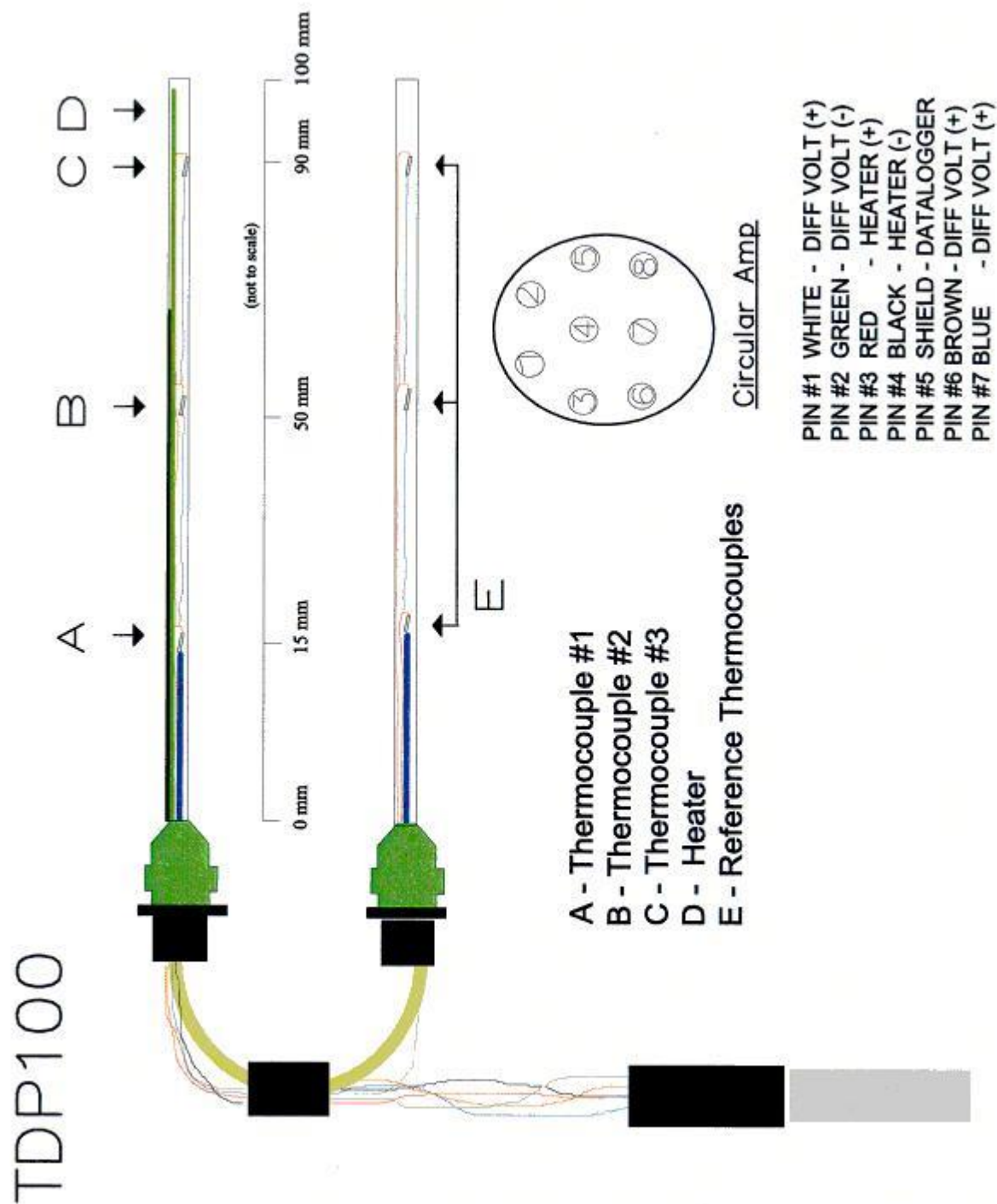
APPENDIX A: TDP SENSOR DRAWING/ CHANNELS





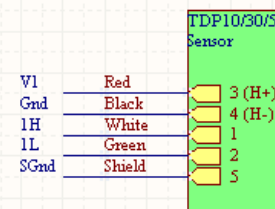




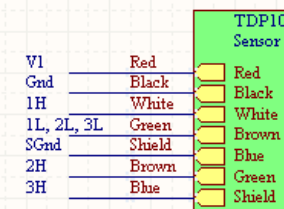


APPENDIX B: FLGS-TDP SYSTEM WIRING

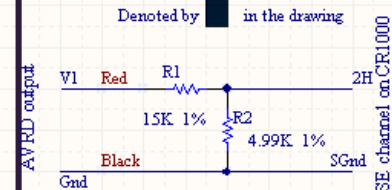
Example wiring: TDP10/30/50



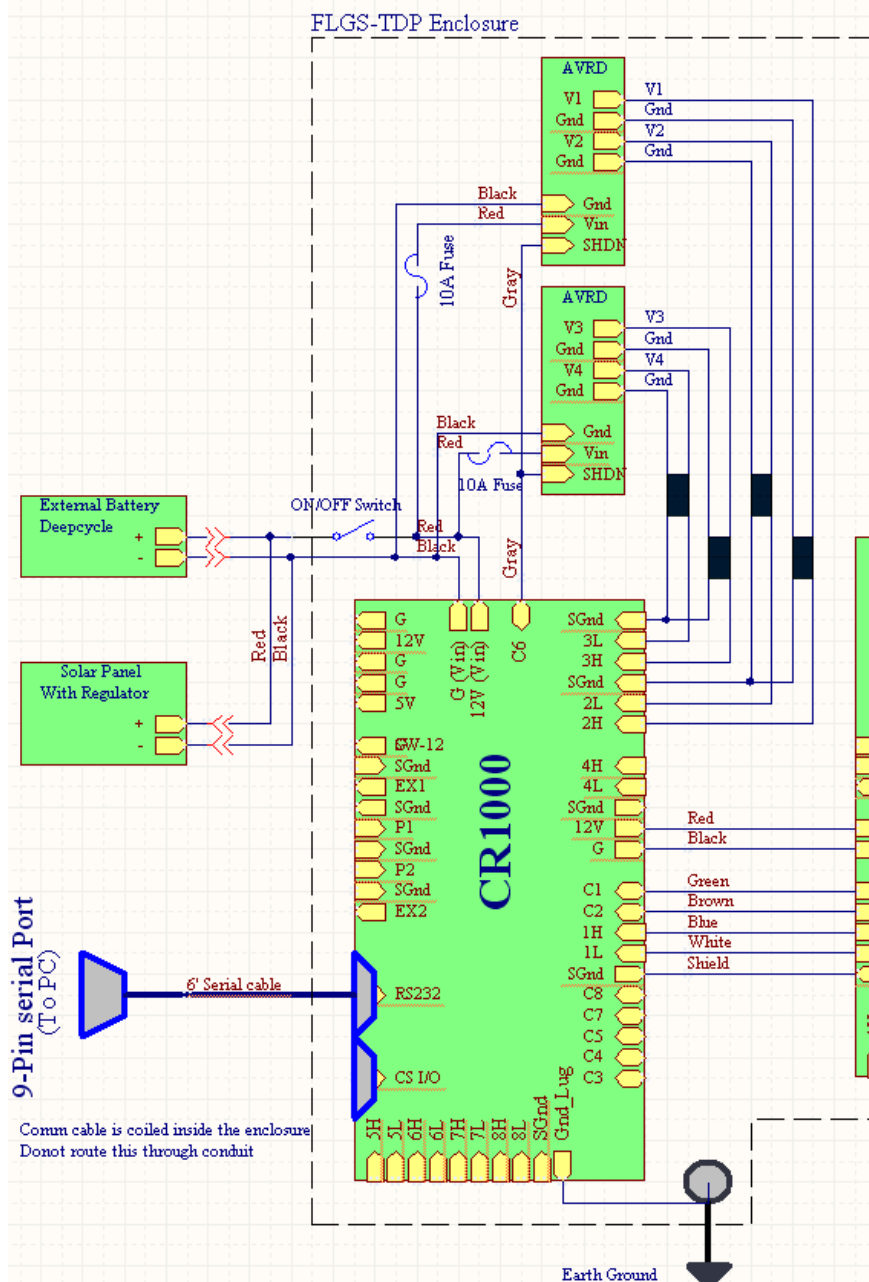
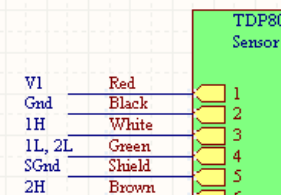
Example wiring: TDP100



Voltage Divider

Denoted by  in the drawing


Example wiring: TDP80


Comm cable is coiled inside the enclosure
Donot route this through conduit

Title		FLGS-TDP Panel & Sensor Wiring		Dynamax Inc, 10808 Fallstone Rd., Ste. 350 Houston, TX 77099, USA	
Size		FLGS-TDP Station		Revision	
A		Number		1.1	
Date:		8/30/2006		Sheet of 1	
File:		D:\D.Design\FLGS-TDP_Wiring3.SchDoc		Drawn By: Sai Gomuguntla	