Edition 22.1

Thermal Conditions Measuring System

ThermCondSys 5500

Operator's Manual

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1. GENERAL INTRODUCTION

The ThermCondSys 5500 is user friendly system for measuring, calculating and logging thermal comfort parameters at four levels at the same time in moderate, hot and cold environments. It has been developed to meet the growing need for indoor climate monitoring equipment such as:

- mobility (moving from place to place)
- easy fast configuration (connection)
- low power consumption and long logging time
- automatic sleeping mode and auto turning off
- wire-less communication between computer and devices.

ThermCondSys5500 offers simultaneous measurement following parameters depending on the system configuration of measuring modules.

Modules	Measured results	Calculated thermal comfort results
SensoTCMod 5503	t_a, t_{gc}, t_w, v_a,	$WBGT_{in}$, $WBGT_{out}$, SD, DR, Tu, t_r, t_{adb}, t_{eq}, t_{wc}
SensoTCMod 5506	t_a, t_{gc}, t_w, v_a, RH	$WBGT_{in}$, $WBGT_{out}$, SD, DR, Tu, t_r, t_o, t_{eq}, PMV, PPD, p_a, DEW, i, E_{req}, E_{max}, W_{req}, SW_{req}, t_{wc}, $IREQ_{min}$, $IREQ_{neut}$, ICL_{min}, ICL_{neut}, DLE_{min}, DLE_{neut},
SensoTCMod 5507	t_a, t_{gc}, t_w, v_a, RH, Pb	$WBGT_{in}$, $WBGT_{out}$, SD, DR, Tu, t_r, t_o, t_{eq}, PMV, PPD, p_a, x, ρ, DEW, i, E_{req}, E_{max}, W_{req}, SW_{req}, t_{wc}, $IREQ_{min}$, $IREQ_{neut}$, ICL_{min}, ICL_{neut}, DLE_{min}, DLE_{neut},

t_{gc}: corrected globe temperature
t_{nw}: natural wet temperature
t_a: air temperature
t_s: supplementary temperature
v_a: air speed
RH: relative humidity
P_b: barometric pressure
$WBGT_{in}$: wet bulb globe temperature
$WBGT_{out}$: wet bulb globe temperature in the presence of radiation
SD: standard deviation of air speed
DR: draught rating
Tu: turbulence intensity of air speed
t_r: mean radiant temperature
t_{adb}: adjusted dry-bulb temperature
t_o: operative temperature
t_{eq}: equivalent temperature

PMV: predicted mean vote
PPD: predicted percentage of dissatisfied
p_a: partial water vapour pressure in the air
x: humidity ratio
ρ: air density
DEW: dew point temperature
i: enthalpy for humid air
E_{req}: required evaporation rate
E_{max}: maximum evaporation rate
W_{req}: required skin wettedness
SW_{req}: required sweat rate
t_{wc} : wind chill temperature
IREQ: required clothing insulation (minimal and neutral)
ICL: required basic thermal insulation (minimal and neutral) according to ISO 9920
DLE: duration limited exposure (minimal and neutral)

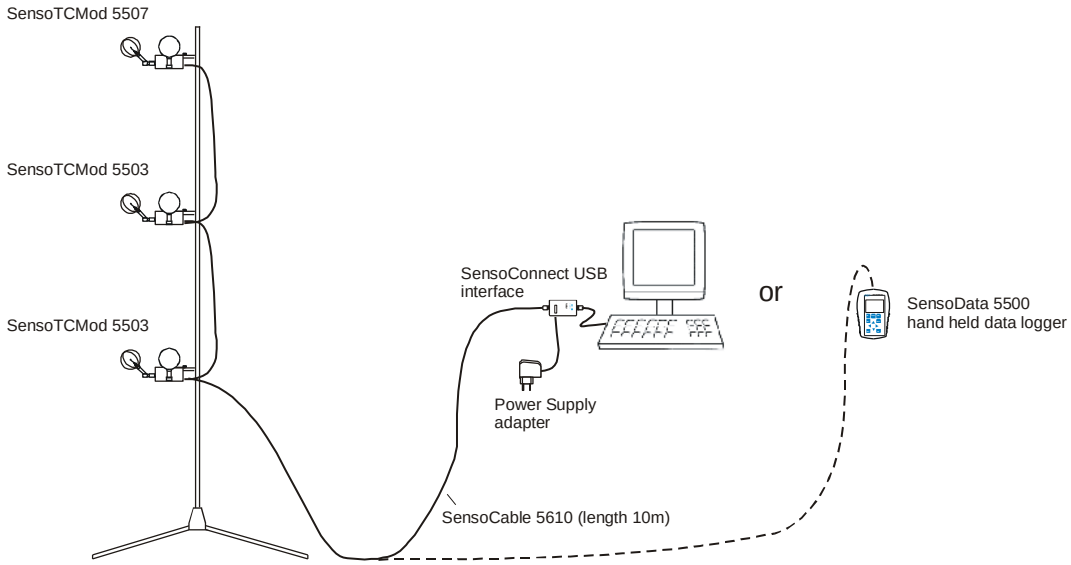
Because the humidity RH and barometric pressure P_b are the same on the each level you can use measuring configuration consisting of one SensoTCMod 5506 (SensoTCMod 5507) module and two or three SensoTCMod 5503 modules. ThermCondSys5000 is in compliant with following standards: ISO 7726, ISO 7730, ISO 13182, ISO 7243, ISO 7933, ISO 9920, ISO11079 and ASHRAE 55.

2. INSTALLATION OF THE MEASURING SYSTEM

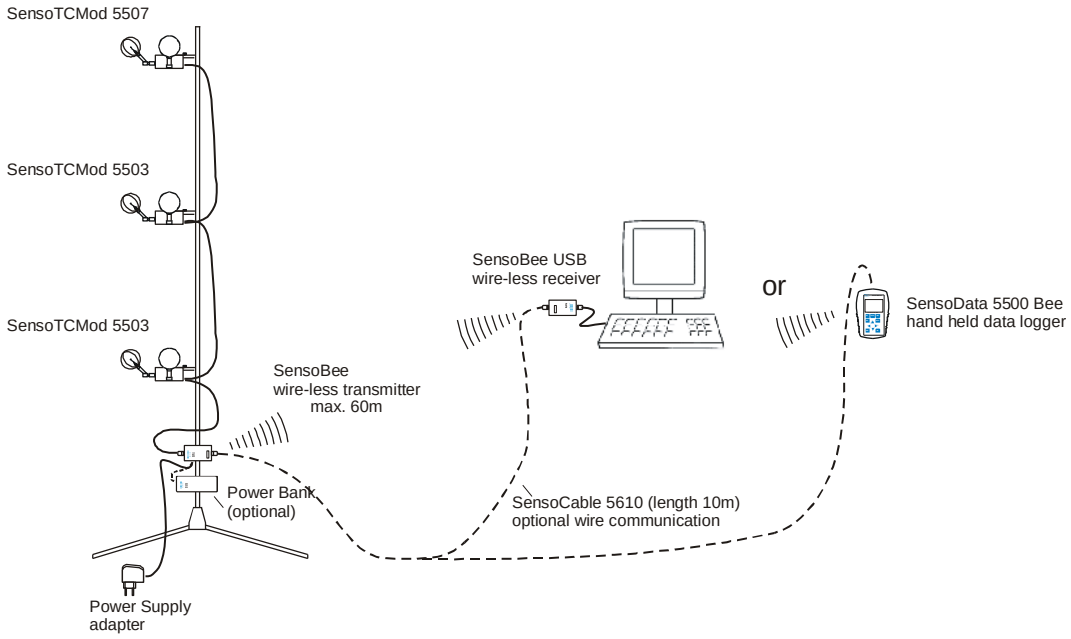
- Mount the measurement modules on a tripod.
- Connect measurement modules with cables (an example: SensoCable 5601).
- Connect one of the measurement module with SensoConnectUSB interface or SensoBee wire-less transmitter.
- Connect the power supply adaptor to the SensoConnectUSB interface (SensoBee wire-less transmitter) or turn on the power supply in the SensoBee transmitter (see Chapter 4C). The LED diode on the top of the measurement modules should blink first for a few seconds and next light up continuously. If the LED diode blinks permanently it means that the voltage of power supply is too small or batteries placed in the PowerBank are used up.
- Connect the SensoConnectUSB interface (SensoBeeUSB receiver) to the USB port in a computer. The LED diode on the casing should light up continuously (for SensoConnectUSB) or blink (for SensoBeeUSB).

3. EXAMPLES OF CONFIGURATION

A. Multipoint wire configuration



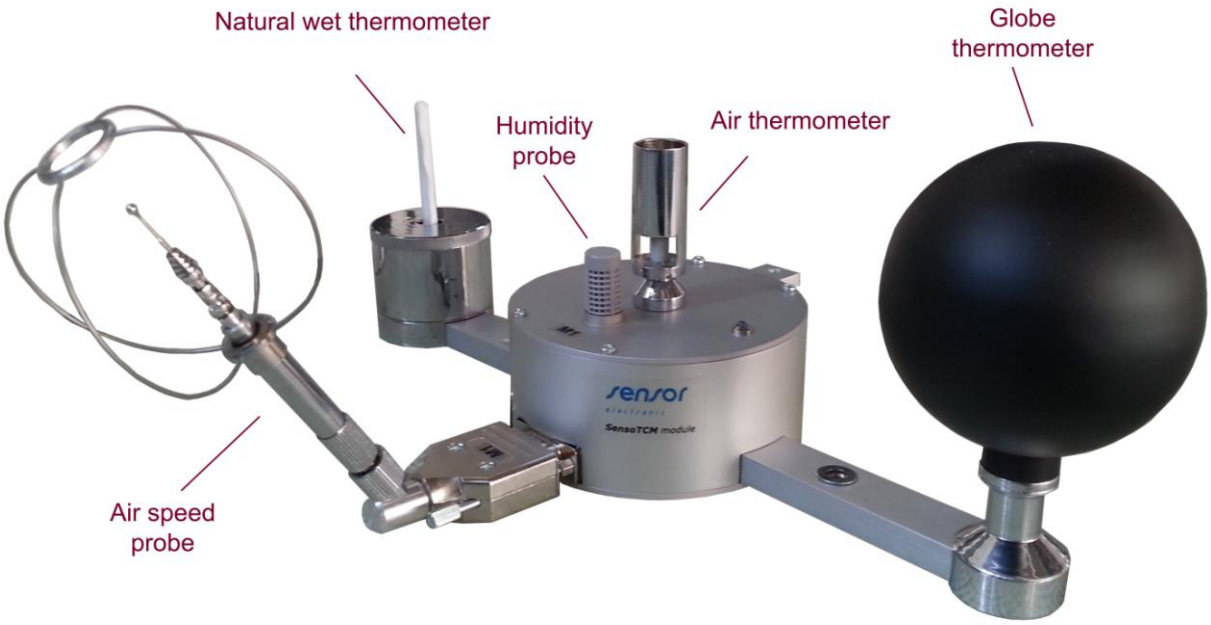
B. Multipoint wire-less configuration



4. SPECIFICATIONS

A. SensoTCMod module

Measuring modules of the thermal comfort are made in the form of cylinders with dimensions of 100x48mm. The SensoTCMod 5506 module includes following transducers: anemo, thermo, hygro. The SensoTCMod 5507 includes additionally barometric pressure sensor. The SensoTCMod 5503 module includes anemo and thermo transducers, but doesn't include baro and hygro transducer. Air temperature and relative humidity sensors are placed on the top of the cylinder. Natural wet temperature, globe temperature and air speeds sensors are placed on lateral horizontal supports. Air speed probe can be disconnected from the measuring module and may be transported, stored or calibrated separately. The measuring modules can be mounted on a special folding tripod, which enables mounting three or four units at the different heights.

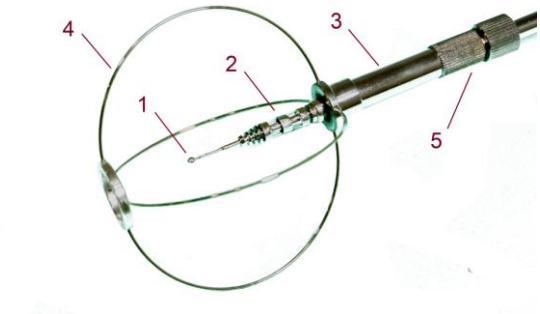


- **Air speed probe** includes the spherical omnidirectional air speed (1) and compensation temperature (2) sensors. Both the sensors are vacuum covered with special aluminium coating that increases their resistance to contamination and decreases the effect of thermal radiation on the accuracy of velocity measurement. The temperature sensor (2) can be additionally protected against radiation by moving shielding tube (3) (it may be necessary only if the airflow is measured very close to high temperature sources). Both sensors can be also protected against mechanical damage using openwork basket (4) made with wire circles. If such a protection isn't necessary it is possible to removed them from the shielding tube (3). Shielding tube (3) can be moved along the support of the probe and locked by the clamp screw (5).

Technical data:

- diameter of the speed sensor: 2 mm
- measurement speed range: 0.05…5 m/s
- resolution: 0.001...0.01 m/s
- accuracy: ±0.02 m/s ±2% of readings
- automatic temperature compensation: < than 0.1%/K
- temperature compensation: -20^{O}C…50^{O}C
- upper frequency f_{up} *): min. 1Hz, typ. 1.5 Hz

*) *The upper frequency is defined as the highest frequency up to which the standard deviation ratio remains in the limits of 0.9 to 1.1 in relation to the standard deviation of the frequency 0 Hz (see the ASHRAE Transaction Vol.1,1998, paper No SF-98-20-2).*



Preparation for measurements:

1. Check if the openwork basket (4) is on the shielding tube (3). If not, put openwork basket (4) on the shielding tube (3). Be particularly careful not to damage the speed sensor (1). To this purpose check if the shielding tube (3) is on the end of the probe completely covering the speed sensor and the clamp screw (5) is properly locked (it does not move). Put on the openwork basket (4) only then when the sensor (1) is covered by the shielding tube (3).
2. Connect the air speed probe to measurement modules. Loosen the clamp screw (5) and move the shielding tube (3) with the openwork basket (4) into the bottom uncovering the sensors (1) and (2).
3. Lock the clamp screw (5).
4. After the measurements move the shielding tube (3) back on the sensors (1) and (2).
5. The probe should be transported in the carrying case only with imposed openwork basket (4).

- **Air (t_a), globe (t_g) and natural wet (t_{nw}) thermometers** measure temperature using RTD sensors. Automatic correction of thermal drift provides high measurement stability. The use of insulating elements in design of probes (special wood and fiberglass) guarantees the appropriate thermal insulation and high measurement accuracy. In order to improve the accuracy each sensor is individually calibrated.

Technical Data:

- type and diameter of thermometer:	t_a: Pt-100 cylindrical Ø 2.6 mm
	t_g: black globe ε 0.95, Ø 70 mm, tickness 1.5 mm
	t_{nw}: Pt-100 cylindrical, length 30 mm, Ø 5 mm; support Ø 5 mm
- measurement range:	t_a: -20…60 ^{O}C
	t_g: -20…120 ^{O}C
	t_{nw}: 0…50 ^{O}C
- accuracy:	t_a: ±0.3 ^{O}C
	t_g: ±0.3 ^{O}C for range -20..50 ^{O}C i ±0.5 ^{O}C for range 50..120 ^{O}C
	t_{nw}: ±0.3 ^{O}C
- stabilization time of measurement:	15…20 min

- ***Barometric pressure*** probe is located inside the cylinder of the measuring module. The probe utilizes specialized piezoresistive micro-machined sensing element. Each probe is individually calibrated and thermally compensated. The calibration coefficients are programmed into EEPROM memory.

Technical Data:

- measurement range: 500…1500 hPa
- accuracy: ±3 hPa
- response time: 2s

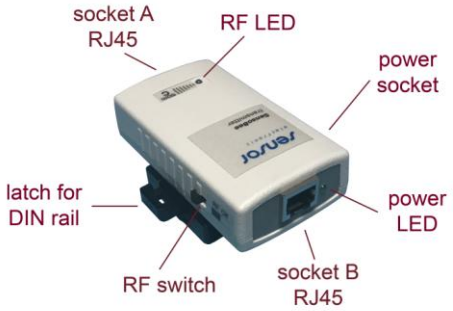
- ***Relative humidity*** probe (optional) is located outside on the top of cylinder of the measuring module. The probe includes a capacitive polymer sensing element for relative humidity and a bandgap temperature compensation sensor. Each probe is individually calibrated in a precision humidity chamber with a chilled mirror hygrometer as reference.

Technical Data:

- measurement range:	0…100 % RH
- accuracy:	typ. ±1,5% in range 10…90% RH, max ±3%
- long term stability:	<0.25% RH/rok
- response time:	<4s

B. SensoBee wire-less transmitter

The SensoBee transmitter contains an RF module for wire-less data transmission. The RF module operates under ZigBee (802.15.4) protocol accepted by ETSI/EC (Europe), FCC (U.S.A) and IC (Canada). The transmitter should be powered by an external power supply adapter or by PowerBank. RF switch should be in the position RF and RF led should flash. Measurement modules must be connected to the socket B. In the case of the absence or errors in the wire-less



transmission, the socket A enables optional wired connection of the transmitter with wire-less receiver. To do this, move RF switch to the Off position, the RF led is not lit. The transmitter is equipped with a latch for mounting it in a DIN rail.

Technical Data:

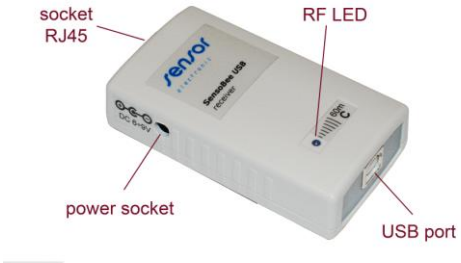
- indoor (urban) range: up to 60m
- outdoor line-of-sight range: up to 100m
- transmit power output: 100mW (20dB)
- operating frequency: 2.4GHz
- RF data rate: 250 kbps
- power supply: 5…9 VDC/1A

Remark:

Pay attention that the power supply adapter should have the voltage polarity on the plug compatible with power socket in the casing (+ out).

C. SensoBeeUSB wire-less receiver

The SensoBeeUSB wire-less receiver contains the RF module for wire-less data transmission. It enables wire-less data transmission between transducers (via SensoBee) and USB port of computer. The RF module operates under ZigBee (802.15.4) protocol accepted by ETSI/EC (Europe), FCC (U.S.A) and IC (Canada). The receiver is being powered from the USB port of computer (RF led flashes when connected to USB port), therefore it doesn't require the use of external power supply adapter.



The SensoBeeUSB can also be used for wired data transmission. In this case, you should:

- connect to the RJ45 socket one end of the connecting cable and the other end depending on the configuration, either directly to one of the measurement module or SensoBee wire-less transmitter
- RF switch in the SensoBee transmitter change from RF position to Off (disable RF module).

Power socket placed on the side of the casing is used to connect the power supply adapter in case of direct power connection to the measurement modules without using the SensoBee wire-less transmitter.

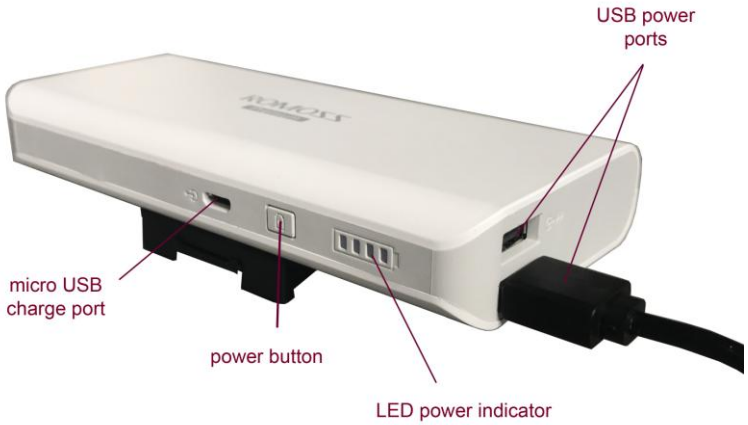
D. SensoConnect USB interface

The SensoConnect USB interface enables data transmission to a computer through the USB port. It is being powered from the USB port of computer, therefore doesn't require external power supply adapter. The power socket located on the side of the casing allows the user to connect an external power supply adapter used to power the measurement modules. The USB led indicates the connection interface to the computer.

5. ACCESSORIES

A. PowerBank

PowerBank is a high performance external battery pack with latch for DIN rail. The latch allows for easy installation of the device on a tripod along with other parts of the measuring system. Includes a charging cable (USB to micro USB) and spiral power cable (USB-plug DC) with a length of 30-100 cm.



Technical Data:

- Power port: 2 x USB DC 5V/1A
- Real capacity*): 7000mA or 1400mA
- Minimum supply current: 135mA
- Charging port: micro USB 5V/2.1A max
- Charging time: >15 h
- Long time efficiency: 300 cycles of full charge and discharge cycles will leave 85% of nominal capacity)

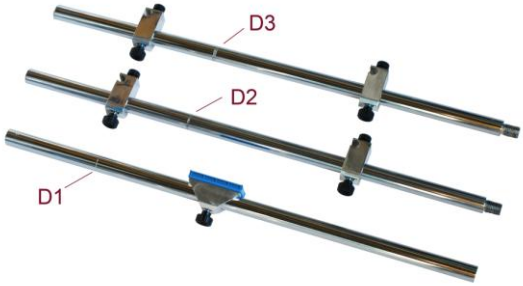
*) Capacity due to reduced efficiency when converting from battery voltage 3.6 V to output voltage 5V (theoretical capacity of the battery is 10000mAh or 20000mAh)

Remarks:

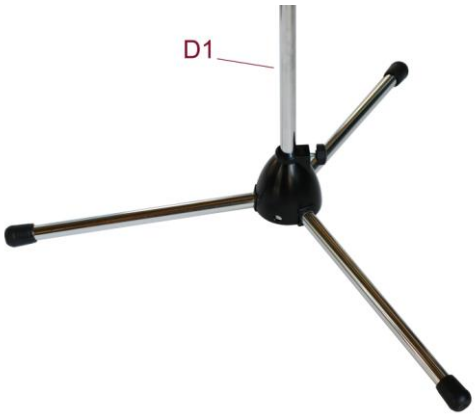
1. Turn off the PowerBank by disconnecting the power cable when you are finished working. Otherwise, this may lead to rapid discharge of the battery.
2. Charge and discharge the device once every 3 months, if it is not used for a longer period of time.
3. Due to the minimal supply current, PowerBank may automatically turn off after a few seconds in the case of smaller receivers power supply current consumption (for example: a single SensoAnemo transducer). Proper operation is achieved when are powered at least two SensoAnemo transducers and SensoBee wire-less transmitter.
4. See picture next to how to connect the PowereBank with SensoBee wire-less transmitter.

B. Folds-out tripod

Measurement system can be equipped with a fold-out tripod adapted to mount several measuring transducers with accessories. The tripod consists of the following parts presented in the photos below.

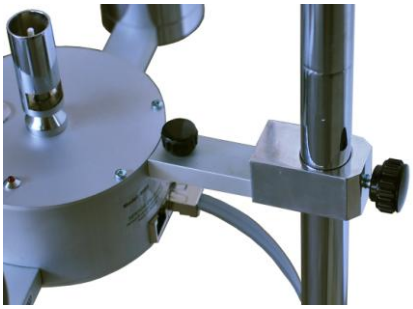


The way of assembling of the tripod is shown in the photos below. Attention should be paid to the pipes D1 ... D3 turn in the order corresponding to the incisions, ie. D1 pipe (single) to the D2 (dual), and D2 to D3 pipe (triple). D1 pipe should be inserted to the base of the tripod and locked by the knob. Then place the grips for fastening the measuring transducers and DIN grips for the accessories and lock them using the knobs.



C. Grip for the modules

The grip enables attaching on the tripod the measuring module at the any height from the floor.



D. DIN rail-mounted grip

The DIN rail-mounted grip enables attaching the devices equipped with rail clamps, so as: SensoBee wire-less transmitter, SensoBox adapter, SensoHygBar transducer or SensoData 5500 datalogger.

6. SOFTWARE AND DRIVER INSTALATION

1. Insert the CD-ROM in your CD drive, choose setup.exe in folder ThermCondSys_Inst and run.
2. Follow the on-screen instructions.
3. Locate the USB port and connect the device to the computer. The driver for new device will be installed automatically after finishing the software installation. In the case of trouble it is possible to install the driver into the following way:

   Option 1

   - select SensoUSB DriverInstaller icon from SENSOR Electronic folder located in Program Menu Folder or click it on the Desktop Panel (the SensoUSB DriverInstaller.exe file is also in SensoUSB_driver folder on the CD-ROM.
   - locate the USB port and plug in the device (SensoConnectUSB or SensoBeeUSB).
   - Windows automatically identifies the new device and select the appropriate driver.

   Option 2

   - locate the USB port and plug in the device (SensoConnectUSB or SensoBeeUSB).
   - Windows will detect the new device and will initiate the Found New Hardware Wizard prompting you to install the software for the detected USB device.
   - select the "Specify a location" and choose the correct path. Enter E:\SensoUSB_driver\. The "E" is the Disk that Package CD put in. Click "OK" to start the search.
   - once Windows finds the correct driver, click "Next" to install the driver.
4. To verify whether the device is properly installed and to determine the COM port assignment for the device follow the steps:
   - open the "Control Panel", and then double click on the "System" icon.
   - once the System Properties window is displayed select the "Device Manager" button.
   - double-click on Ports (COM &LPT).
   - if the hardware is correctly installed, you should now see the USB device listing and the assigned COM port.
5. If you need to assign the COM port name to another Port Number:
   - double-click on the USB device to view the properties
   - once the properties window opens click on the Port Settings tab and select the advanced button
   - when the Advanced Settings dialog box appears on the screen, click on the COM Port Number drop down the box to check what other port number are available
   - try to reassign COM port to a unused port number
   - click OK when finished.

7. DESCRIPTION OF THE THERMCONDSYS 5500 PROGRAM

Features and Requirements

- The ThermCondSys 5500 program provides:
  - automatic scanning of the configuration of the measuring system
  - calculating thermal comfort parameters
  - on-line viewing and logging all data in a PC computer
  - identification of the low battery level for each module
  - automatic identification of the faulty probe and over range
  - ECO mode that reduces power consumption
- Program requirements:
  - operating system: Microsoft Windows
  - minimal monitor resolution: 1024x760 pixels
  - size of text and other elements in Windows: default 100%

- The program contains the Context Help window which displays a description when the user moves the cursor over the property. The user can enable or disable the Context Help by selecting 'Show Context Help' from the menu item 'Help…' on the menu bar on the front panel.
- Updating the program and downloading the newest version of the instruction are available from the menu bar.
- The program communicates only at the speed 115 200 BPS. It is very important not to start up the program before SensoConnectUSB interface or SensoBeeUSB receiver are connected to the USB port and the power supply is turned on.
- The DataSocket connection automatically convert measurement data into a stream of bytes that is sent across the network to another application.
- The measurement data can be transfer across the network by TCP/IP protocol.

Starting and Configuration

- In the case of select automatic mode the program is scanning all ports of the computer in order to find connected devices. In the manual mode the user have to choose the number of COM port. After establishing contact the program is reading the information of all devices.
- All connected devices are specified on the 'Configuration' window which appears after establishing contact. The user can deactivate (set as OFF) or activate (set as ON) the devices to be used. The program automatically will adjust the device as OFF if the calibration date is expired. However the user can change it and to activate him. If the voltage of power supply is too small or batteries are discharge the indicator of power supply is shining red and the transducer is automatically deactivate.

Front Panel

Running Data

Results are displayed every 2 seconds with the chosen averaging time. Averaging Time determines the time of calculating an average of the measurement results. Averaging is continuous, i.e. the oldest result is being replaced with the youngest result in the cycle of averaging. Averaging Time is independent from Interval Time which is a parameter of logging.

Logged Data

Only logged results are displayed according to logging parameters: Interval Time and Logging Time.

Buttons Selector of Results

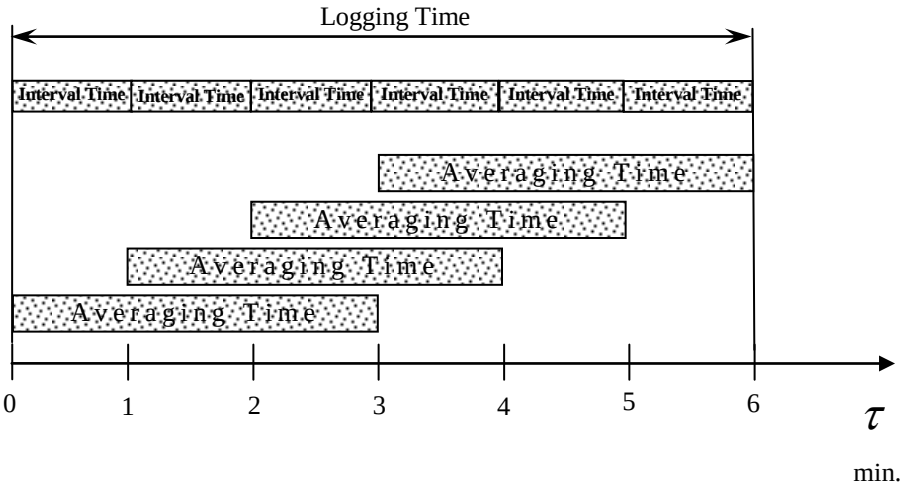
It is possible to select results to displaying and logging by pressing the appropriate buttons above a multicolumn listbox.

Visible results depending on buttons selector

Buttons selector	**Thermal comfort results**	**Input parameters**	**Q-ty**
none	t_a, t_{gc}, v_a, t_r, t_o, PMV, PPD, RH, P_b	W, M, Icl, Ar/Adu	10
Hot Environment	t_{nw}, $WBGT_{in}$, $WBGT_{out}$, E_{req}, E_{max}, SW_{req}, W_{req}		7
Cold Environment	t_{wc}, $IREQ_{min}$, $IREQ_{neut}$, ICL_{min}, ICL_{neut}, DLE_{min}, DLE_{neut}	w, p	7
tadb, teq	t_{adb}, t_{eq}		2
pa, x, ro, Dew, i	p_a, x, ro, Dew, i		5

Logging Procedure

- In order to begin the logging procedure one should press the 'Start' button. A 'Select file for data logging' window appears and the user should choose the name of a file for data logging. Next, there appears a new window 'Comment' in which the user can enter any comment which will be placed at the beginning of a logging file. After pressing "OK" key the logging procedure starts. The start time of the logging and remaining time to the end of logging are shown on appropriate indicators. During the logging procedure the logging indicator is blinking. Some buttons on the front panel are disabled in order not to disturb the logging process. Interrupting the logging in every moment is possible, after pressing the 'Stop' button.
- Interval Time determines an interval between logged data. It can be chosen in the range from 2s to 6h.
- Logging Time determines how long a data will be logged. It can be chosen in the range from 10s to 48h. It is possible to choose unlimited time as well.



- The logged data are stored in the text file. This file can be easily imported to MS Excel. The data logging and statistical analyzing procedure used is made clear in the following figure.

  An example of settings with Interval Time of 1 min, Averaging Time of 3 min and Logging Time of 6 min.

Economy Mode

- If the Economy Mode switch is ON, devices can be switch into the state of asleep when reading results isn't necessary. Asleep is only possible during the logged. Economy Mode reduces the consumption of energy what influences increasing the working time on batteries.
- The Economy Mode switch is active when the Interval Time is bigger than 3 min and the Averaging Time is smaller than the half of the Interval Time.

Automatic End

- When AutoEnd switch is ON, the program automatically will be closed and all devices will be switched into the state of asleep after finishing the logging procedure.

DataSocket Connection

- When you use this protocol, the program communicates with the DataSocket Server. You must provide a named tag for the data, which is appended to the URL. The data connection uses the named tag to address a particular data item on a DataSocket Server. To use this protocol, you must run a DataSocket Server.
- In order to enable or disable the DataSocket connection, select 'DataSocket' from the menu item 'Data Communication…' on the menu bar on front panel.
- You publish (write) data by specifying a URL. You should enter 'localhost' on the publisher computer and IP address of the publisher on the subscriber computer.
- The example of Data Socket Reader is available in the Program Menu Folder (SENSOR Electronic\Examples).

TCP/IP Connection

- The built-in TCP/IP connection enables to communicate between different computers by the networks. TCP/IP routes data from server (ThermCondSys 5500 program) to client.
- The default TCP port number is 5000. In order to change the TCP port number select 'TCP connection' from the menu item 'Data Communication…' on the menu bar on front panel.
- The frequency of data transfer for TCP connection is specified by the Interval Time.
- The data transferred by TCP server are separated by TAB delimiters. The data string can be column headers or the results depending on setting the TCP connection. The part of string with column headers is ended by CR carriage return element. On the end of result string is EOL

  Example data string with results:
  23.1 TAB 23.2 TAB 22.9 EOL

  Example data string with column headers:
  ta[degC] TAB tnw[degC] TAB tg[degC] CR 23.1 TAB 23.2 TAB 22.9 EOL
- The example of TCP Data Client is available in the Program Menu Folder (SENSOR Electronic\Examples).

Physical models and procedure

- **Standard deviation of velocity** [m/s]

$$SD = \sqrt{\overline{v^2} - \left(\overline{v}\right)^2}\ ,\ \text{where}\ \overline{v} = \frac{\sum_{i=1}^{n} \overline{v}_i}{n}\ ,\ \overline{v^2} = \frac{\sum_{i=1}^{n} \overline{v^2}_i}{n}$$

- **Turbulence Intensity** [%]

$$Tu = \frac{SD}{v_a} 100\%$$, where SD – standard deviation

- **Draught Rate** (The percentage of people dissatisfied due to draught) [%]

$$DR = (34 - t_a)(v_a - 0{,}05)^{0{,}62}(37SD + 3.14)$$, for t_a>34 or v_a<0.05 ⇒ DR=0

- **Partial Water Vapour Pressure** in the air [hPa]

$$p_a = 0.061078RH \bullet 10^{\frac{At_a}{B+t_a}}$$

for t_a>0⇒ A=7.5; B=237.3; for $t_a \le 0$⇒ A=9.5; B=265.5

- **Humidity ratio** [g/kg]

$$x = 612.98\frac{p_a}{P_b - p_a}$$

- **Dewpoint Temperature** [^{O}C]

$$Dew = \sqrt[8]{\frac{RH}{100}}\left[112 + 0.9t_a\right] + 0{,}1t_a - 112$$

- **Enthalpy for humid air** [kJ/kg]

$$i = 1.005t_a + x(1.84t_a + 2501)$$

- **Air Density** [kg/m^3]

$$\rho = \frac{(1+x)P_b}{4.62(0.622+x)(t_a+273)}$$

- **Mean Radiant Temperature** [^{O}C]

$$t_r = \left[(t_g + 273)^4 + h_{cg} \frac{(t_g - t_a)}{5.38 \bullet 10^{-8}} \right]^{\frac{1}{4}} - 273 \text{, where}$$

$$h_{cg} = \max\_of \begin{cases} 17.755 v_m^{\,0,6} \\ 2.675 |t_g - t_a|^{0,25} \end{cases}$$

where t_g is globe temperature for globe diameter of 7.5cm

- **WBGT-Index** (Wet-Bulb-Globe Temperature) [^{O}C]

$$WBGT_{in} = 0.7 t_{nw} + 0.3 t_{gc}$$

$$WBGT_{out} = 0.7 t_{nw} + 0.2 t_{gc} + 0.1 t_a$$

where t_{gc} is corrected globe temperature corresponds to globe with a diameter 15 cm

- **Operative Temperature** [^{O}C]

$$t_o = \frac{h_c t_a + h_r t_r}{h_c + h_r} \text{, where}$$

$$h_c = \max\_of \begin{cases} 3.5 + 5.2 v_{ar} \quad for\ v_{ar} < 1\ or\ 8.7 v_{ar}^{\,0.6} \quad for\ v_{ar} \geq 1 \\ 2{,}38 |t_{sk} - t_a|^{0,25} \end{cases}$$

$$h_r = 21.9996 \bullet 10^{-8} AR \left(\frac{t_r + t_{sk}}{2} + 273 \right)^3$$

$$v_{ar} = v_a + \min\_of \begin{cases} 0.0052(58.15M - 58) \\ 0.7 \end{cases}$$

$$t_{sk} = (30 + 0.093 t_a + 0.045 t_r - 0.571 v_a + 0.254 p_a + 0.074432 M - 0.553 I_{cl}$$

where M [Met] – metabolic rate
I_{cl} [Clo] - clothing isolation
AR [-] - body area fraction exposed

- **Required Evaporation Rate** [W/m^2]

$$E_{req} = 58.15(M - W) - C_{res} - E_{res} - CON - R \text{, where}$$

$$C_{res} = 0.08141 M (35 - t_a)$$

$$E_{res} = 1.005995 M (5.619 - p_a)$$

$$CON = h_c F_{cl} (t_{sk} - t_a)$$

$$R = h_r F_{cl} (t_{sk} - t_r)$$

$$F_{cl} = \frac{1}{1 + (h_c + h_r)\left(0.155 I_{cl} - \frac{1 - \frac{1}{1 + 0.30535 I_{cl}}}{h_c + h_r}\right)}$$

- **Maximal Evaporation Rate** [W/m^2]

$E_{\max} = h_e (p_{sk} - p_a)$, where

$h_e = 16.7 h_c F_{pcl}$

$$F_{pcl} = \frac{1}{1 + 2.22 h_c\left(0.155 I_{cl} - \frac{1 - \frac{1}{1 + 0.30535 I_{cl}}}{h_c + h_r}\right)}$$

$$p_{sk} = 0.6105 \exp\left(\frac{17.27 t_{sk}}{t_{sk} + 237.3}\right)$$

- **Required Skin Wettedness** [-],
  Required Sweat Rate [W/m^2]

$$W_{req} = \frac{E_{req}}{E_{\max}}$$

$$SW_{req} = \frac{E_{req}}{1 - 0.5 W_{req}^{\ 2}}$$

if $E_{req} \le 0$ then $W_{req} = 0$, $SW_{req} = 0$

if $E_{\max} \le 0$ then $W_{req} = 2$, $SW_{req} = 2E_{req}$

if $W_{req} > 1$ then $SW_{req} = 2E_{req}$

- **Adjusted Dry-BulbTemperature** [^{O}C]

$t_{adb} = A t_a + (1 - A) t_r$, where A=0.5 for $v_a < 0.2$ m/s

A=0.6 for $0.2 \le v_a \le 0.6$ m/s

A=0.7 for $v_a > 0.6$ m/s

- **Equivalent Temperature** [^{O}C]

$t_{eq}=t_o$ for $v_a<0,1$m/s

$t_{eq} = 0{,}55 t_a + 0{,}45 t_r + \left[\left(0{,}24 - 0{,}75\sqrt{v_a}\right)/(1 + I_{cl})\right](36{,}5 - t_a)$ for $v_a \ge 0{,}1$m/s

- **Wind Chill Temperature** [^{O}C]

$t_{wc} = 13.12 + 0.6215 t_a - 11.37 v_{10}^{\ 0.16} + 0.3965 t_a v_{10}^{\ 0.16}$, gdzie $v_{10}[km/h] = 5.4 v_m[m/s]$

8. GUARANTEE AND REPAIRS

Manufacturer guarantees the correct operation of the devices. The guarantee period is 24 months, beginning from the date of sale. All defects due to faulty material or manufacturing will be repaired. What is under guarantee is repair and replacement of detective parts. Damages of the devices owing to wrong transport or use will not be recovered.