

# THISYS

Apparatus for measurement of thermal conductivity of thin samples



## THISYS MANUAL V1223

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## **Warning:**

THI01 is specified for use up to 120 °C.

THI01 contains heater foils that is mounted across air-filled gaps. Contact with sharp objects, like edges of metal samples, should be avoided.

When working at higher temperatures than 100 °C, contact with water should be avoided. Familiarity with the glycerol safety sheets is assumed.

During transport and storage the slot of THI01 should be closed, using moderate force. For transport in which the horizontality of THI01 cannot be guaranteed, the glycerol in the THI01 should be removed.

In case that a pressure cell is included (optional item), heavy transport and shocks should be avoided. During heavy transport there is an internal transport bolt that should be secured inside the THI01.

Under no condition more than 30 VDC should be put across the THI01 heaters.

Under no condition more than 19 VDC should be put to the MCU input.

Putting a voltage over the Pt100 and thermopile sensors possibly will result in permanent damage.

THI01 as well as MCU are operated from 15 VDC. This DC voltage is delivered by an adapter that is supplied with the instrument. Both instruments are safe to use in a laboratory environment.

When using glycerol, the user is assumed to be familiar with the glycerol safety data. These can be found at the end of this manual.





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## List of symbols

Thermal conductivity	$\lambda$	W/mK
Differential temperature, or temperature rise	$\Delta T$	K
Thermal resistance	R	m <sup>2</sup> K/W
Sample thickness	H	m
Heat flux	$\phi$	W/m <sup>2</sup>

### Subscripts

Property of reference sample	r
Property of unknown sample	m
Property of the heater	heat





## List of system variables

RecNum	= system record number	[-]
Timestamp	= system record timestamp	[-]
PTemp	= mcu01 (cr1000) panel temperature	[°C]
batt_volt	= system dc voltage	[V]
exp_no	= experiment number	[-]
sam_id	= sample identification (string format)	[-]
HS	= sample thickness	[mm]
H_time	= duration of the heating period	[s]
T_step	= temperature step	[°C]
countdown	= measurement countdown	[s]
T	= real time system temperature	[°C]
P_N	= applied pressure on sample stack	[N]
D_T	= differential temperature over the sample	[°C]
Phi_mom	= real time heat flux applied on the sample	[W/m <sup>2</sup> ]
Rm	= measured resistance of the sample	[m <sup>2</sup> K/W]
lambda	= measured thermal conductivity of the sample	[W/mK]
T_measure	= measurement (experiment) temperature	[°C]
warning	= warning code, indicating a possible error	[-]
R_cont	= system contact resistance (used in calculations)	[m <sup>2</sup> K/W]
R_cont_n	= system newly determined contact resistance	[m <sup>2</sup> K/W]
R_serial	= system serial resistance (used in calculations)	[m <sup>2</sup> K/W]
R_serial_n	= system newly determined serial resistance	[m <sup>2</sup> K/W]
Rm_ref	= reference sample resistance	[m <sup>2</sup> K/W]
Rm_ref_n	= newly determined reference sample resistance	[m <sup>2</sup> K/W]
HS_ref	= reference sample thickness	[mm]
lambda_ref	= thermal conductivity of the reference sample	[W/mK]
lambda_ref_n	= newly determined thermal conductivity of the reference sample	[W/mK]
tc_ref	= thermal conductivity temperature dependent coefficient of the reference sample	[W/mK <sup>2</sup> ]
lambda0_ref	= thermal conductivity of the reference sample at 0°C	[W/mK]
C_1	= thermopile parameter	[·10 <sup>-6</sup> V/K <sup>2</sup> ]
C_2	= thermopile parameter	[·10 <sup>-6</sup> V/K]
C_3	= thermopile parameter	[-]

### Additional results table variables:

Phi	= average heat flux applied on the sample	[W/m <sup>2</sup> ]
D_T_20	= final differential temperature over the sample when equilibrium is reached	[°C]

### Additional raw data table variables:

I_heat	= total current through both heaters	[A]
U_heat	= total voltage over both heaters	[V]
U_sen	= thermopile voltage	[mV]





## Introduction

THISYS offers an accurate, fast and uncomplicated measurement of the thermal conductivity of thin samples of high thermal conductivity materials.

The measurement generates an estimate of the thermal conductivity. The data-file of the complete measurement is stored inside the THISYS memory for later analysis.

Typical samples are sheet materials of metals, alloys and high conductivity plastics with various filler materials or fibres. It is a combination of a Thin Sample Instrument (THI01) and a Measurement and Control Unit (MCU). The measurement essentially determines the temperature gradient across the sample when it is heated, in the plane of the sample itself. Employing a specially designed high accuracy thermopile sensor THI01 can handle thin sample materials (less than 0.01 to 6 mm) usually in the thermal conductivity range up to 500 W/mK. Following this method, problems with contact resistance are avoided. The method is a good alternative when procedures according to ASTM D5470 are failing. Using a climate chamber, a large temperature range can be covered, performing measurements at regular intervals. THISYS is fully PC controlled. For use with low thermal conductivity materials a different model, THASYS, is available.

The measurement of thin materials with relatively high thermal conductivity is a classic problem. Commonly used methods like ASTM D 5470 – 01 (Standard Test Method for Thermal Transmission Properties of Thin Thermally Conductive Solid Electrical Insulation Materials) have shown to be highly sensitive to contact resistance, and not applicable with high conductivity materials. THISYS offers a solution to this problem.

THISYS essentially measures the temperature gradient from centre to side across the sample when mounted across a well insulated cavity, and heated with a known uniform flux. By measuring the flux  $\Phi_{\text{heat}}$  (derived from heater power per unit area), the temperature drop across the sample under this stationary heat flux and comparing this with data obtained with a reference sample (with a known thermal conductivity), it is possible to calculate the unknown thermal conductivity using:





$$\lambda = \frac{H_r R_r}{H_m R_m} \lambda_r$$

Where:

$$R = \frac{\Delta T}{\Phi_{heat}}$$

The measurement is performed relative to a known reference material.

The user is supposed to read the manual of the THI01 as well as the THISYS manual.

The user is supposed be familiar with the working principle of THI01 as well as the operation of the main electronics, in the MCU; which are called CR1000.

In the course of time, new versions of the program controlling the THISYS system will be released at Hukseflux. These new versions can be installed by the user.

Support is offered by telephone or e-mail.

In case support is necessary: please e-mail to

[info@hukseflux.com](mailto:info@hukseflux.com) or call Hukseflux at +31.15.214.26.69



# 1 General overview

## 1.1 System description

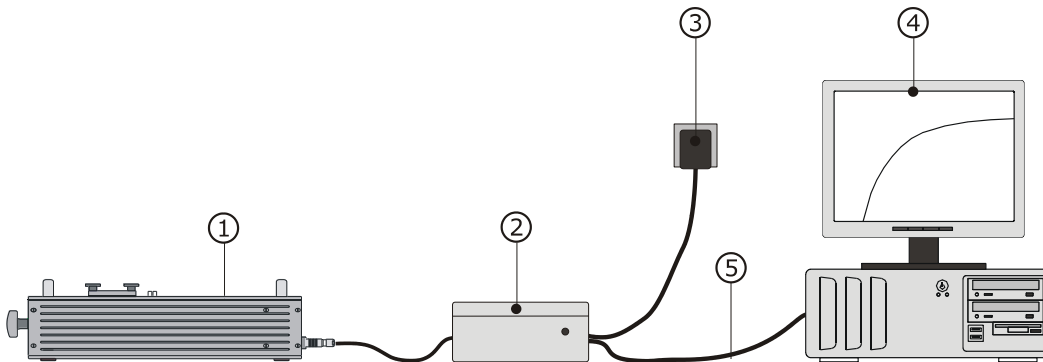


Figure 1.1.1 *THISYS consists of the Thin Sample Instrument (THI01), (1) and a Measurement and Control Unit (MCU), (2). an adapter (3) provides power to MCU as well as THI. It is PC controlled through USB or RS232 (4, 5). The PC is not included with the delivery. The measurement result appears on screen automatically. The THI01 housing contains two heat sinks in a bath of glycerol. It has a slot on top through which the sample is inserted. The sample is heated on two sides. One heater also contains the hot joints of the thermopile sensor. The sample plus heater are then pressed together with the heat sinks using a screw on the side, creating a perfectly symmetrical setup. The glycerol fluid eliminates the problem of contact resistance.*

THISYS consist of THI01 “apparatus for thermal conductivity measurement of thin samples” and a MCU “Measurement and Control Unit”. The MCU is based on a data acquisition system of type CR1000 by Campbell Scientific. The accompanying software is called LoggerNet. Within LoggerNet, a dedicated program is written for THI01 operation. The current version at the time of writing of this document is called thisys v0910.



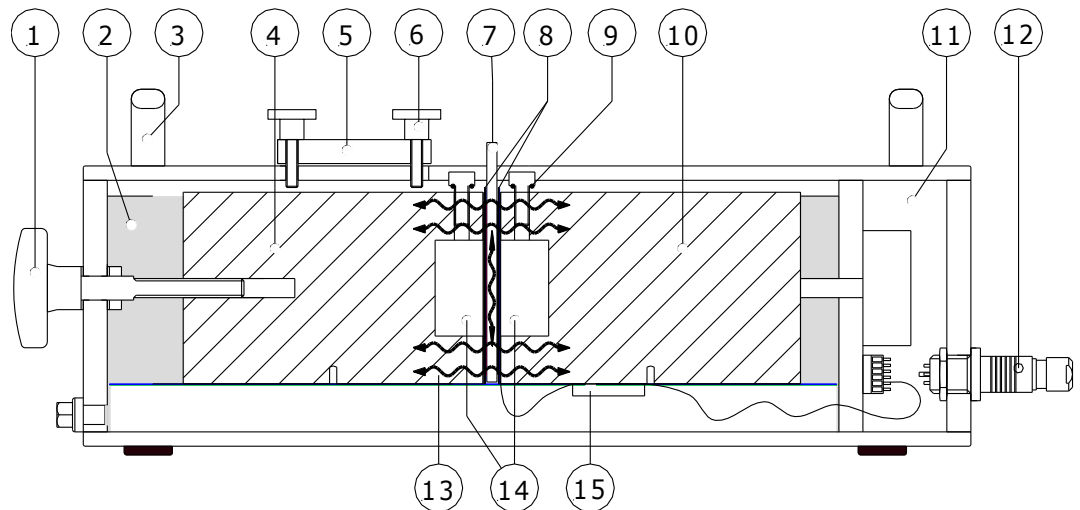


Figure 1.1.2 Cross section of THI01

Explanation of the THI01 parts:

- (1) knob for moving heat sink (4)
- (2) glycerol bath
- (3) handles for lifting the THI01
- (4) heat sink; can be moved with help of knob (1)
- (5) metal cover
- (6) screws tightening metal cover (5)
- (7) sample
- (8) heaters and temperature sensors
- (9) screws for de-pressurization of THI01 for measurements at higher temperatures
- (10) fixed heat sink
- (11) empty compartment
- (12) plug for connection of cables to MCU
- (13) heat flux
- (14) air chambers
- (15) connection for Pt100 and differential temperature sensor

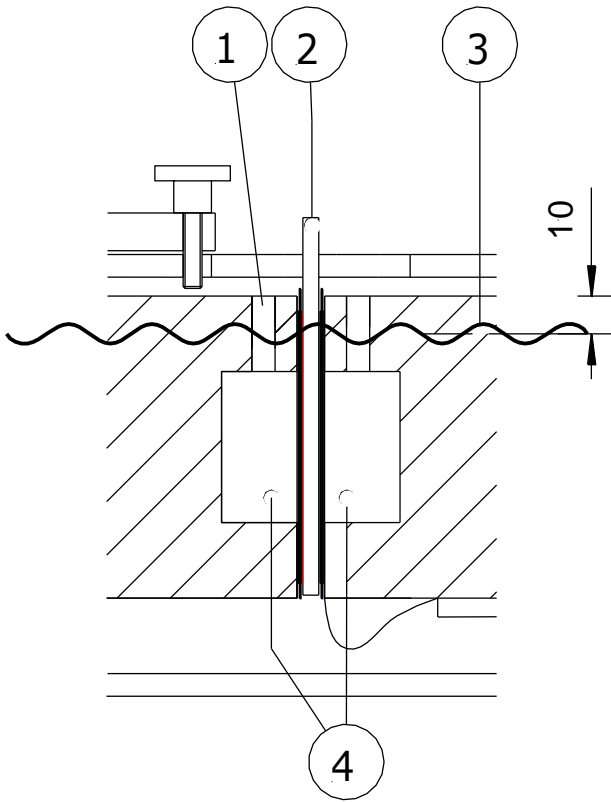


Figure 1.1.3 Cross section of THI01: Showing glycerol level (3) for use at high temperature (above 60 °C). Screws (1) have been removed, to prevent pressure build up in the air chambers (4)

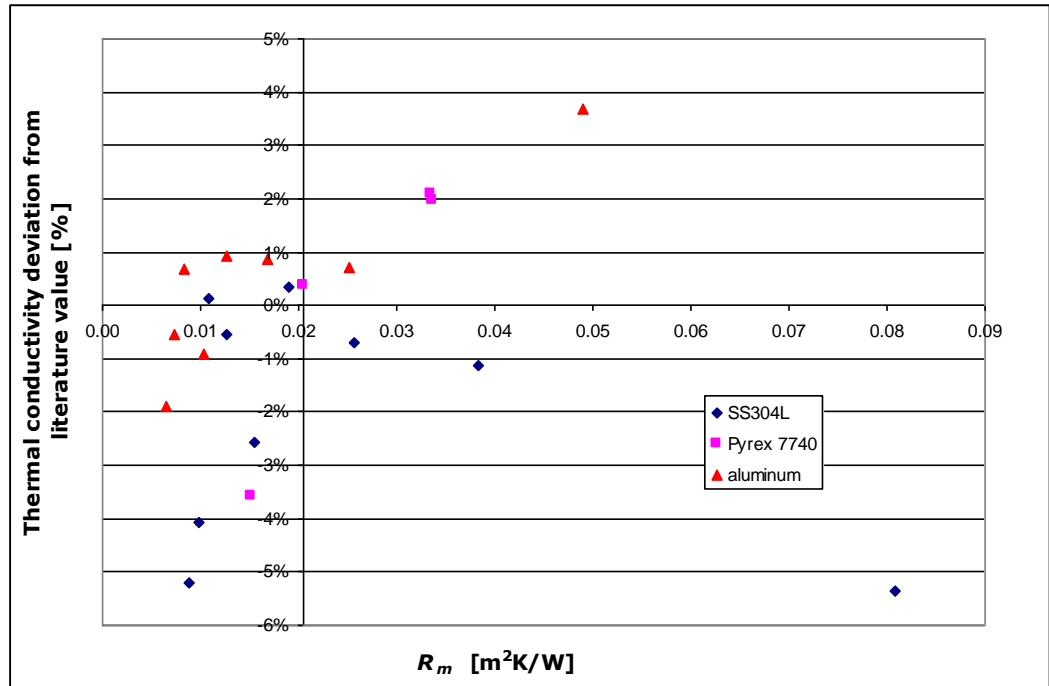


Figure 1.1.4 Test results with THISYS: Measurements were performed with Stainless Steel type 304L (0.1 to 0.7 mm), Pyrex 7740 (2 to 7 mm), aluminium samples (0.06mm). The test shows a remarkable accuracy level of +/- 6% relative to literature values (14.644, 1.087 and 225.940 W/mK respectively).

From above figure, it can be noted that the closer the value of the thermal resistance  $R_m$  of the sample is to that of the reference, the smaller the deviation from literature is. It is therefore recommended to vary the sample thickness in order to have a  $R_m$  as close as possible to  $R_r$ .

The Hukseflux THI01 employs two aluminium "heat sinks". Each of these contains a heater that is mounted over an air-filled, insulating cavity. The sample is installed over the cavities. The resulting temperature gradient (centre-edge) is measured.

Apart from the new design, the technological novelties are:

- a thin thermocouple thermopile (proprietary Hukseflux design) performing an accurate and ultra-sensitive differential  $\Delta T$  measurement
- the fact that the measurement is performed in a bath of glycerol.

The THI01 can handle samples of less than 0.01 to 6 mm thickness. Samples typically are sheet materials with a size of 70 by 100 mm.

The measurement essentially is done at the temperature of the THI01. If necessary, the temperature can be changed by putting

the whole THI01 in a climate chamber, performing measurements while the instrument temperature changes across the required range. In a simplified description, the measurement consists of a heating cycle and a measurement to establish  $\Delta T$ . The THI01 temperature is monitored by a Pt100 temperature sensor to correct for the temperature dependence of the thermopile sensitivity.

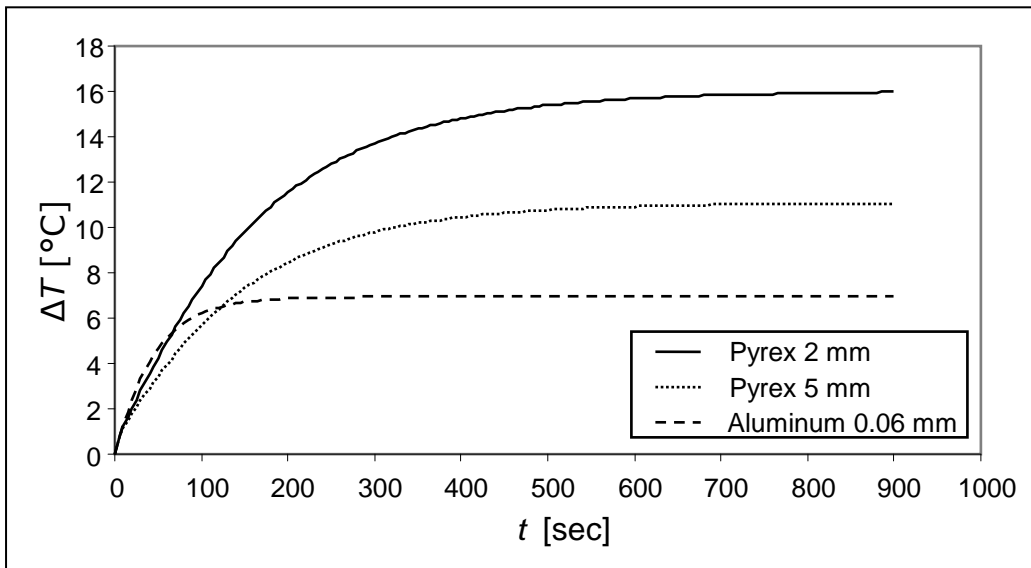


Figure 1.1.5 An example of an analysis of several samples, of different materials and thickness, using the THI01. The graphs represent the signals when putting the heater on. The signal amplitude is inversely proportional to the thermal conductivity  $\lambda$ .

The MCU performs the functions of measurement and control as well as data storage. It is PC operated. Software in a Windows environment is part of the delivery. The parameters cycle time, sample thickness and heater area are entered and the experiment is started from the screen.



## 1.2 Delivery

The following list shows what's included in the delivery:

MCU, THI01, PC cable (USB or RS232)	<p>The MCU, a CR1000 measurement and control module, and a SC32B RS232 interface. Connection can be made either with a 9-pin female connector or a USB cable. The user is supposed to have a free COM port with a 9 pin male connector or a free USB port.</p> <p>The RS232 PC connection should not be confused with the CS I/O connection.</p> <p>Cable length PC to MCU: about 1 meter</p>
Adapter 15 VDC	<p>This adapter can be used with any mains supply from 100 to 240 VAC, 50 or 60 Hz. If possible it is recommended to use this adapter. It can be connected to the MCU directly using the plug that is connected to its cable. Cable length to MCU: about 1 meter. Note: please make sure that the adapter has the right output level.</p>
Pyrex 7740 sample	One reference sample
Cables THI	<p>Two cables, each with different plug. Cable length between THI01 and MCU about 3 meters.</p>
LoggerNet Software	To be installed on the PC for communication with the MCU.
THISYS Software	A program that is specially developed for use with THISYS.

Table 1.2.1 *Delivery: parts and their function.*





### 1.3 General operation

During every measurement, the THISYS program creates the following:

1. A file containing raw data file. This which contains all relevant measurement data as the are collected by the datalogger.
2. A file containing the result of calculations performed by the program, such a thermal conductivity, sample temperature, etc.
3. Messages regarding the dynamics of the measurement, for example thermal stability of the sample and apparatus, and if all signal from the sensors behave as expected.

The THISYS has several modes of operation. A normal measurement at a fixed apparatus temperature is most commonly used. It is also possible to put the THISYS in a climate chamber and vary the temperature of the THISYS as well as the sample up to 120°C while performing the measurements. In addition there is a function that allows the user to check the accuracy of the measurements using a reference sample to assure optimal functioning at all times.

General rules to ensure reliable operation
Check if the software version is the same as described by this manual (chapter 4).
Read the comment in the THISYS vxxxx.CR1 file. This can be done using the dedicated CRBasic compiler of LoggerNet or any text editor that reads the ASCII file format.
Chose a proper measurement time for the sample that will be measured. The measured temperature difference should be constant near the end of the measurement. This may be determined by trial and error (chapter 10.6). By default, this is set to 1200 s.
Always pay attention to warning messages. Try resolve the cause of the message or make sure you know the influence on the final result of the measurement (chapter 8).

Table 1.3.1 *General rules for working with a THISYS.*

Although it is, in principle, possible to run an autonomous measurement with the THISYS once it has been started with a PC, the system will normally always stay connected to a PC trough RS-232 or a USB port. This allows the user to display the measurement data in real time. A typical way of monitoring a measurement is using a 'Graph window' in the LoggerNet





software (figure 1.3.1). It provides an easy way to do a visual quality assurance, see chapter 5.5 for more detailed information.

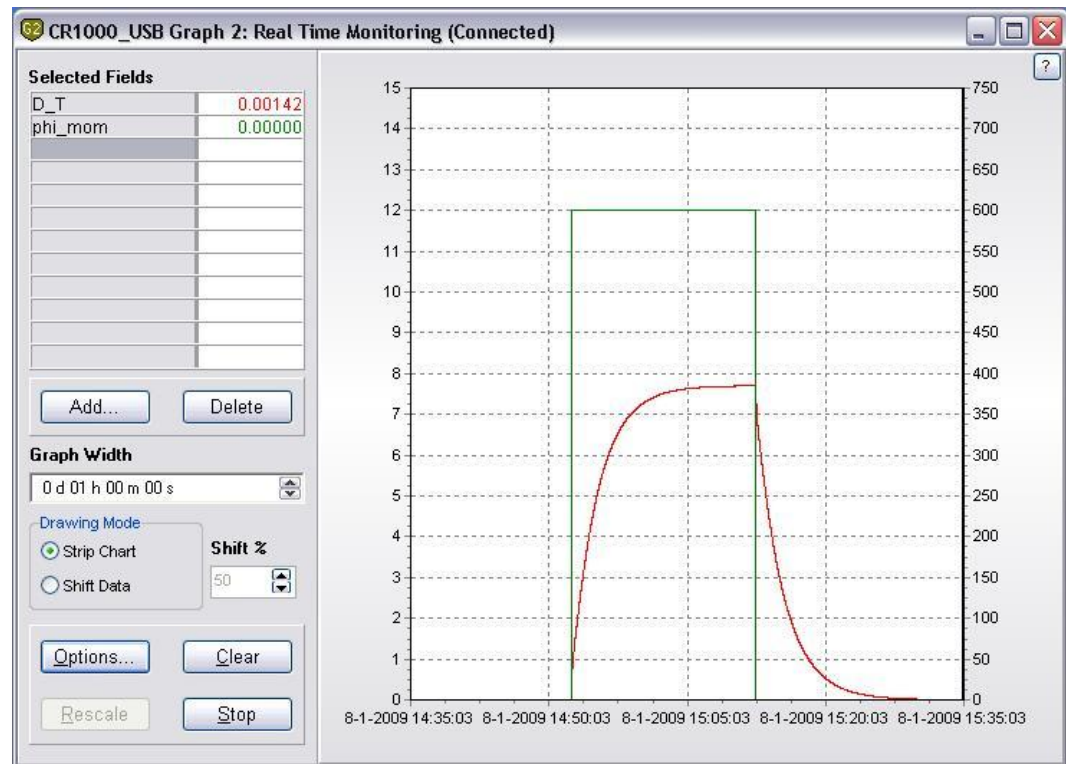


Figure 1.3.1 Signals from the THISYS sensor can be displayed in real time during a measurement to ease quality assurance. The graph shows the response of Pyrex 7740 reference sample with a thickness of 5 mm and a thermal conductivity of 1.09 W/m·K.

The value of the stabilized signal at the end of the response, is determined by the thickness of the samples and the thermal conductivity of the sample. The power supplied through the heater also plays a role, but this will be the same for all measurements.

The figure below shows a typical screen that can be used by the user for numeric in- and output. Variables can be displayed in the screen by clicking add and choose variables from the 'Public' variable list. Variables can be deleted from the screen by selecting the field and pressing delete. Public variables can either be changed by double clicking, entering the value and pressing enter, or using the menu that appears when right-clicking a cell.



CR1000_USB Numeric Display 2: Real Time Monitoring (Connected)					
Add...	RecNum	3,407	R cont	0.028787	
Delete	TimeStamp	09 04:22:55	R cont n	0.028787	
Delete All	PTemp	23.41	R serial	0.002682	
Options...	batt volt	12.31	R serial n	0.002682	
Stop	exp no	1.00	Rm ref	0.020572	
Help	sam id	R cont	Rm ref n	0.020572	
	HS	5.00	HS ref	5.004000	
	H time	1,200.00	lambda ref	1.088600	
	T step	10.00	lambda ref n	0.000000	
	Countdown	0.00	tc ref	0.001440	
	T	21.60	lambda0 ref	1.058000	
	P N	191.18	C 1	0.998000	
	D T	-0.01	C 2	463.000000	
	phi mom	0.00	C 3	0.962000	
	Rm	0.00			
	lambda	0.00			
	T measure	0.00			
	Warning	0.00			

Figure 1.3.2 A typical 'Numeric Display' that can be used for user in- and output.





## 2 Preparation before use

In addition to the delivered parts, it is recommended to have the following items available:

Mains power or low voltage DC power source	Preferably mains power for the Adapter. This can be 100-240 VAC, 50/60 Hz. If this is not available, a power source of 15 VDC at 5 Watts is sufficient. The absolute value of the power supply is not important as long as it is constant within 1% during 5 minutes. A normal battery will be able to meet this specification. The power supply must be available within 1 meter from the point of measurement.
PC	PC, running Windows XP or higher, with CD drive and with one free 9 pin RS 232 port (male connector on the PC) or a USB port.
Glycerol	As the transport of fluids is not allowed by most carriers without special permission, the user must purchase glycerol locally. Glycerol or glycol can be purchased at most pharmacies. Glycerol Fluid, consumer quality of at least 96% purity, 1 litre. The glycerol is used to fill the measurement cavity of the THI01 to reduce contact resistances between the sample and the heat sinks.

Table 2.1 *Items that need to be available.*



### **3 Step 1: Receiving the equipment**

When the system arrives, it is recommended to check if all is there. For a general check: see table 1.2.1. It is possible that additional items were ordered (extension cables, reference samples, etc.). It is recommended to compare to the original order.

- After rough (air)transport with pressure cell (optional), open the THI01 and release the transport nut.
- Purchase 1 litre of glycerol (also called glycerine or glycol). This fluid is available in any pharmacy. It is safe for hands, eyes etc. Fill the THI01 with glycerol. Open the slot. Put in the Pyrex 7740 reference samples. Close the slot using corded knob at the side (part 1 in figure 1.1.2).



## 4 Step 2: Software

The latest version of the software is always shipped with the system, but it is also possible to receive it by email. Always make a backup of all received files before using them.

First, install the Campbell Scientific LoggerNet software; this is straightforward. If help is needed the information on the LoggerNet CD is sufficient in most situations.

A separate disk contains a version of the THISYS software. The file, thisys v0906.CR1 contains a description of the program and a wiring diagram. Version 0906 is the latest at the time of writing this document . Any text editor or the dedicated CRBasic compiled in the LoggerNet package can be used to view (and edit) the file. It can be loaded into the MCU using the Connection screen of LoggerNet.

When operating with a USB cable, the user also needs to install the USB driver on the PC. This driver will install an extra COM port which can be used by LoggerNet to communicate with the MCU (CR1000). During the installation the installer will ask you to connect the system to a USB-port. Make sure chose the same port as will be used during the measurements, because in some situations connection problems may occur when a different port is used.



## 5 Step 3: Installation and Testing

Before the system is ready to do a first measurement, a few things have to be set up. If the MCU is always used in combination with the same PC this procedure has to be performed only once. Next, a first instructive measurement can be made by performing a calibration procedure using the Pyrex 7740 reference samples.

### 5.1 First power up

Use the power supply delivered with the system and make sure the supply is set to 15 VDC. In case the system is equipped with a battery pack, the charging voltage should typically be between 13.8 and 18 VDC. Please consult the battery manual about this. After plugging in the power supply the red LED on the MCU should light up.

### 5.2 Connecting THI01 to the MCU

The THI01 unit can now be connected to the MCU. Both cables should be plugged in: one side in the MCU, other side in the THI01. Both cables have different plugs, so user should take care to insert each plug into the corresponding socket.

### 5.3 Connecting THISYS to the PC

The THISYS can now be connected to the PC using the LoggerNet software. First make sure the software is installed as described in chapter 4.

- Make sure the system is powered up.
- Connect the MCU to on the PC, either with the USB cable or with the RS232 cable.
- Start the LoggerNet software.

The following screen will appear:



Figure 5.3.1 *The main menu of the LoggerNet software (version number may be different).*

To configure the system for normal use, click on the “Setup” button. A screen similar to the following figure will appear:

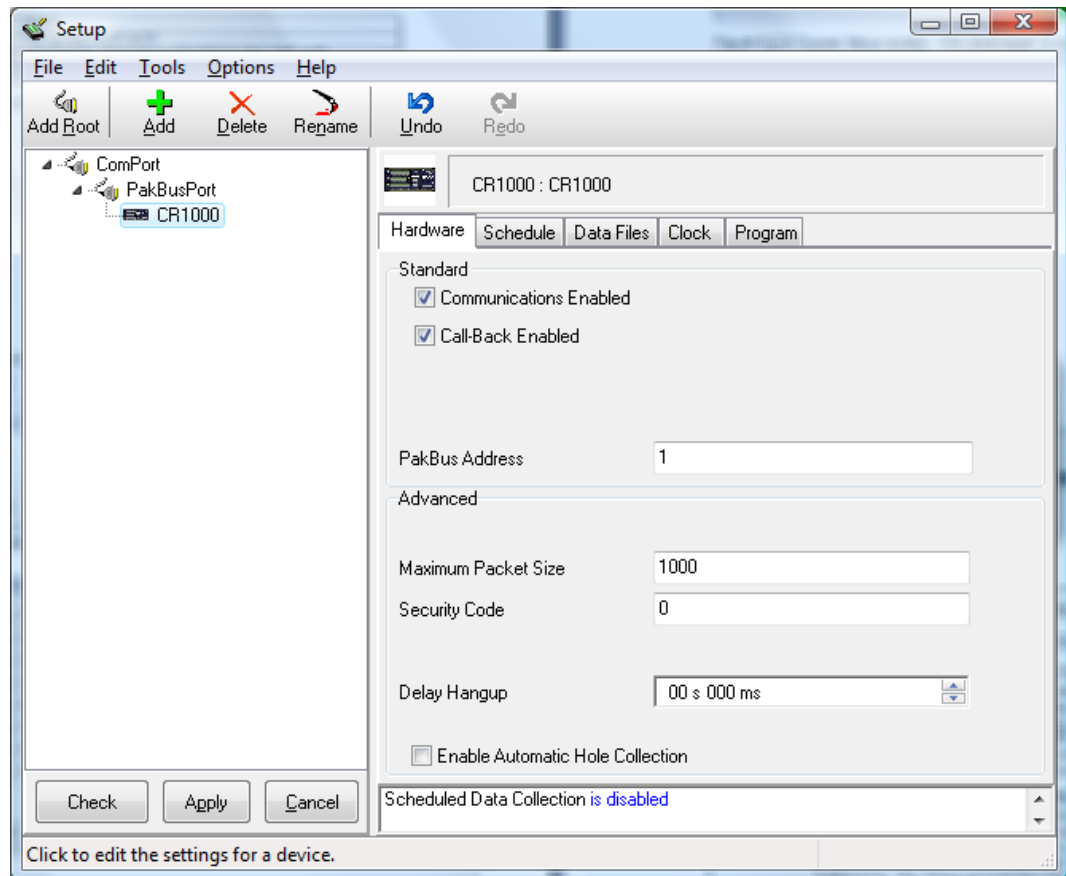


Figure 5.3.2 The setup screen is only used to configure the system when it is used for the first time or case the LoggerNet software is re-installed.

To install the THISYS MCU

- Select the ComPort entry in the left list. Choose “COM4” in the “Com Port Connection” pull down menu. It may be the case that the driver assigned a different com port to the USB connection. A general rule that works in most cases is to chose the highest com port number.
- Click the “Add” button in the top menu. Select “PakBusPort (Other Loggers)”, then select CR1000 and click “Close”.
- Close the Setup screen and answer “Yes” when asked to apply the changes.

### Location of measurement results

The results of a measurement will be written to a data table and stored in the MCU. Even when the power is disconnected the data will be kept. Data is received from the MCU when the steps described in chapter 7 are performed. In the following steps the location of the data files is defined:

- Open the setup screen by clicking on the "Setup" button in the main menu of LoggerNet.
- Select the datalogger the is just installed, CR1000 normally.
- Make sure the logger is connected and powered up and click on the button "Get Table Definitions" in the tab "Data Files".
- Select "RawData" in the list in the centre of the screen to make the setting for the data table "RawData".
- Click on the "..." button next to the field that shows something similar to "c:\Campbellsci\LoggerNet\CR1000\_RawData.dat" and select the directory (folder) to store the data in.
- Repeat the last step for the data table "Results".

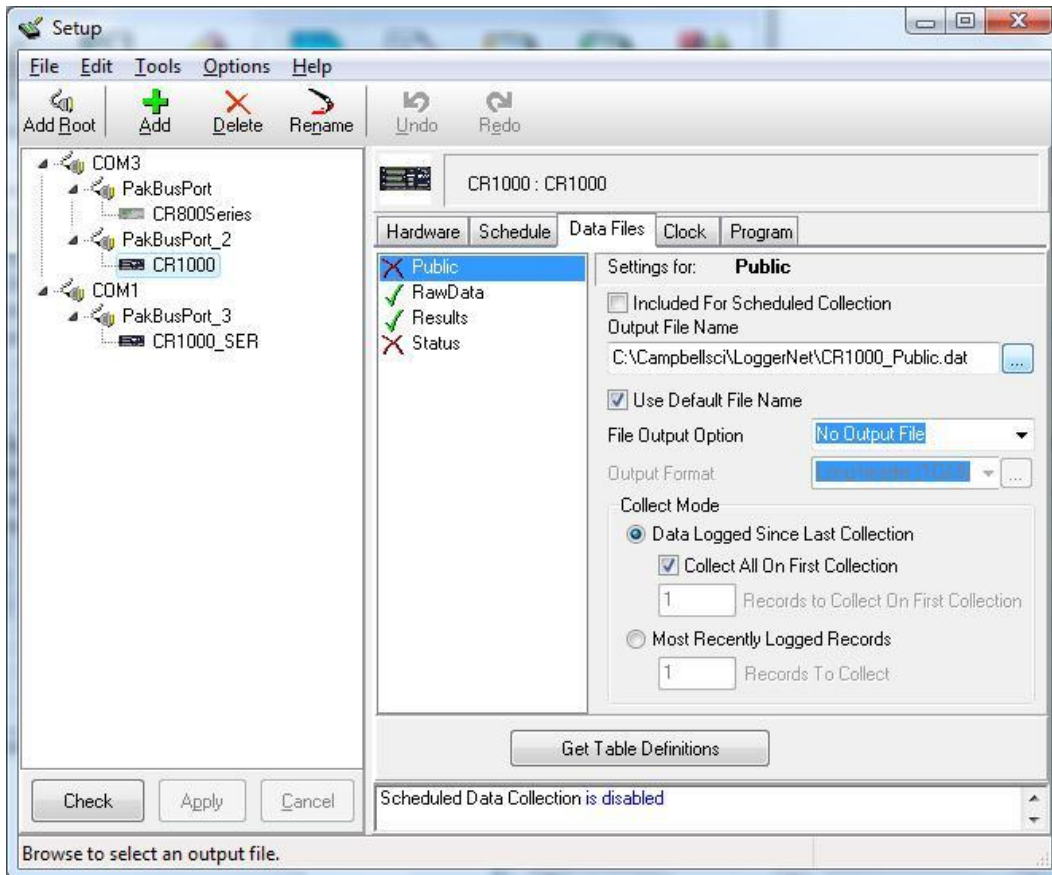


Figure 5.3.3 Changing location of data files

## 5.4 Defining a user interface

After completing all steps above the THISYS is connected to the PC and ready to define a user interface. Loading new software on the MCU, controlling measurements and displaying results is all done in the "Connect Screen". First we ensure that the right software program is loaded in the THISYS MCU, called CR1000 in the setup screen.

- Click "Connect" in the LoggerNet main menu. A screen as in figure 5.5.1 appears.
- Select "CR1000" in the list on the left and click "Connect". The label of the button will change to "Disconnect" when the connection is made.

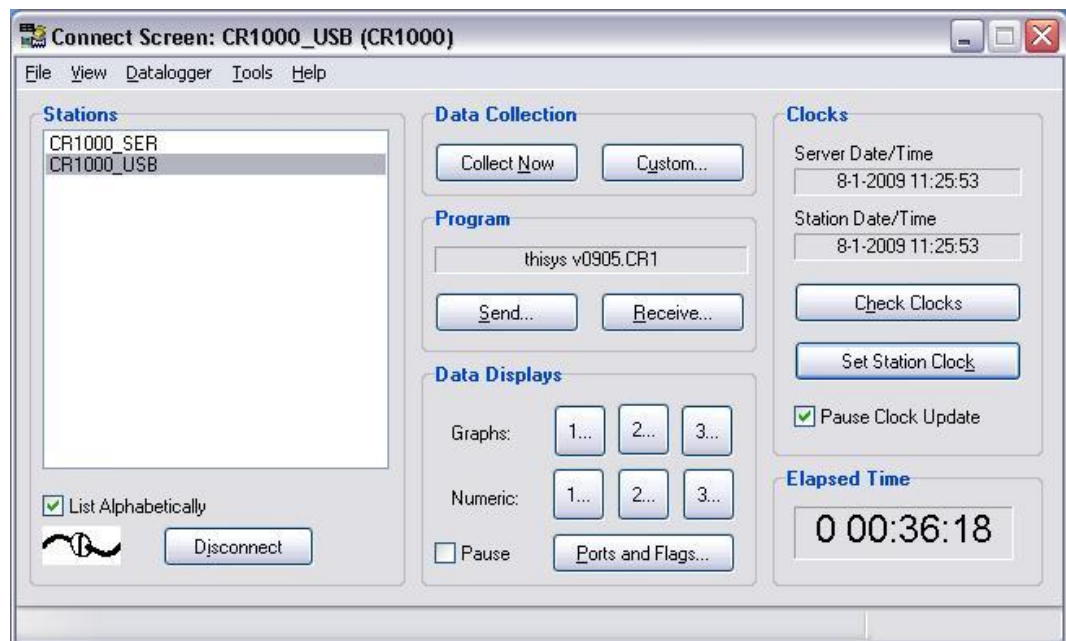


Figure 5.4.1 Connection screen of the LoggerNet software while a system is connected. This screen is used to load a program in the MCU, to receive data and to perform numeric and graphical in- and output communication while a program is running.

The "program" frame should show "thisys vxxxx.CR1" where the x's represent the version number. If this is not the case then click "Send" and select the program delivered with the system. This file should have the extension .CR1.

**WARNING:** when uploading a program to the logger, all data will be erased, as well as the modified values of the variables. Before uploading a new program, user should write down these values and save all measurement data to the PC.

The numbered buttons behind "Numeric:" are used to for numeric in- and output. To define a typical numeric user in- and output screen:

- Click "1..." and a screen similar to figure 5.5.2 will appear. It is possible to define three different numeric screens in total by using "2..." and "3...".
- Click "Add..." and click "Public" in the list on the left to select the public variables of the program in the right list.
- Select the variable "Countdown" go down to the variable "C\_3" and select it while pressing the shift key on the keyboard. Then click "Paste" and close the screen.
- The most commonly used variable are now listed in the numeric screen. They can be rearranged at will by clicking the variable name, drag to the desired cell while holding the mouse button and release the button.
- Pressing "Clear All" will make the screen blank again.
- Adding a one variable or a list of variables in a particular cell can be done by clicking an empty cell and then click "Add" and repeat the procedure as above.

After pressing the 'Start' button, the variables visible in the screen show the current value while the MCU is connected.

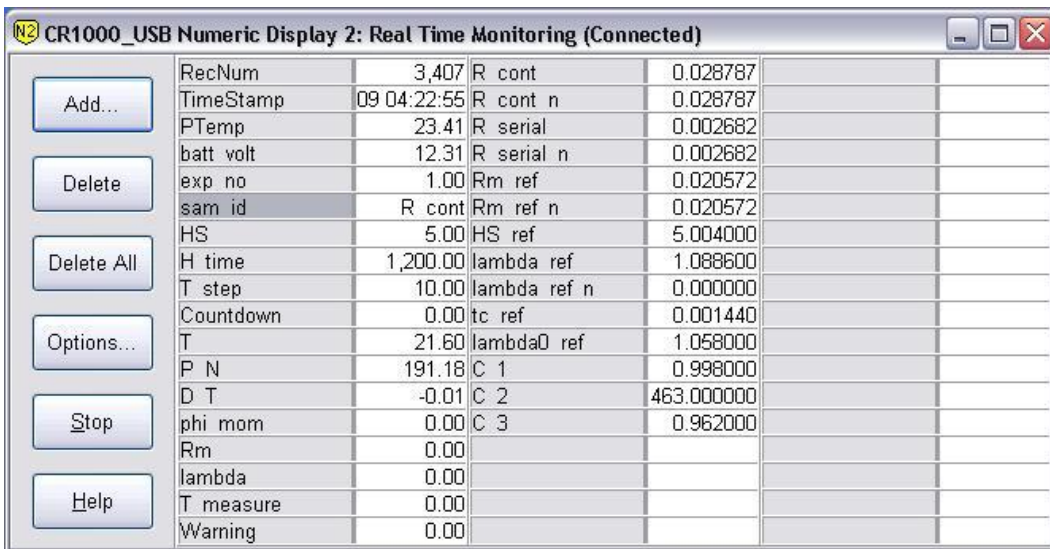


Figure 5.4.2 The Numeric Screen as typically used when viewing the measurement on line.

Chapter 10.1 contains information on relevant variable names and description

The program control is done using flags. A flag is a Boolean operator that can take on a high or low value (on or off respectively). Perform the following steps to setup the "Ports and Flags" screen.



- Open the “Ports and Flags” screen by clicking the button in the “Connect Screen”.
- Click on the top left label and click “Add...”.
- Select public and click “Paste” to add all Boolean variables and close the screen.

Figure 5.5.3 Shows the screen while a measurement is running. A flag can be activated by clicking on the button. Activated flags show up light green.



Figure 5.5.3 The control screen after variables have been added. The buttons can be pressed to activate programmed procedures and to read of the status of the MCU.

## 5.5 Using the interface

The “Numeric Screen” is used for numeric in- and output. Values of variables can be changed as follows:

- Right-click on the field that has to be modified and select “View/Modify Value...” (figure 5.5.1).
- Key in the desired value and click “Apply”.

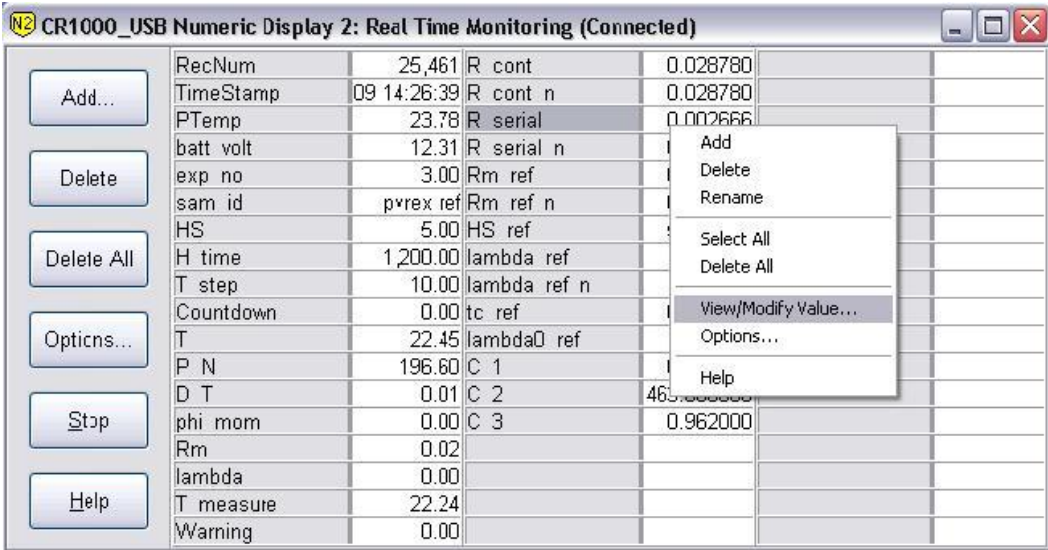


Figure 5.5.1 Changing values of numeric variables in using the right-click menu.

An alternative way is to double-click in the cells, the colour of the cell changes to yellow. Now, key in the desired value and press enter to confirm.

Several variables should be displayed with more than the standard 2 decimals. To change the number of decimals shown for a variable, right click on the cell and choose "Options..." in the pulldown menu. A screen as shown in figure 5.5.2 will appear. R\_cont should be displayed with 5 decimals, C\_1 and C\_3 should be displayed with 3 decimals.

There is also a way to set an alarm for a low or high value as well as some other options that may be convenient to use.

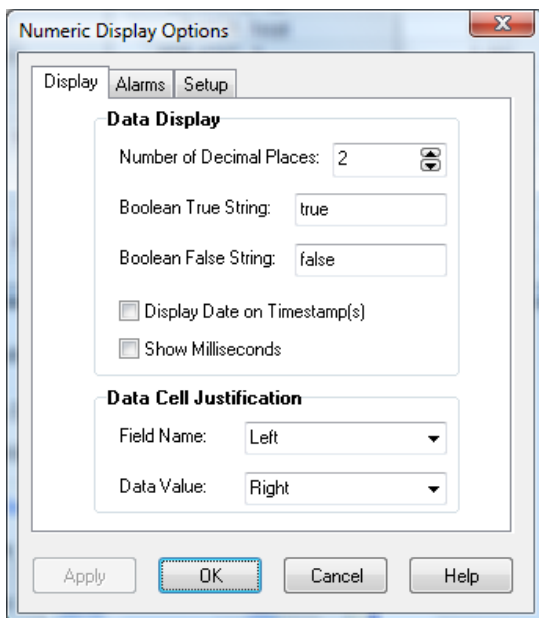


Figure 5.5.2 Options to change the way the variables are displayed.

Next to the numeric screen it is also possible to display a graph of the parameters. This may be useful to check the trend of a parameter. Three different graph screen can be created, just as the numeric screens. A graph screen can be opened by clicking on one of the numbers behind "Graphs:" in the LoggerNet Connect Screen and selecting parameters to be displayed. A screen similar to the following appears.

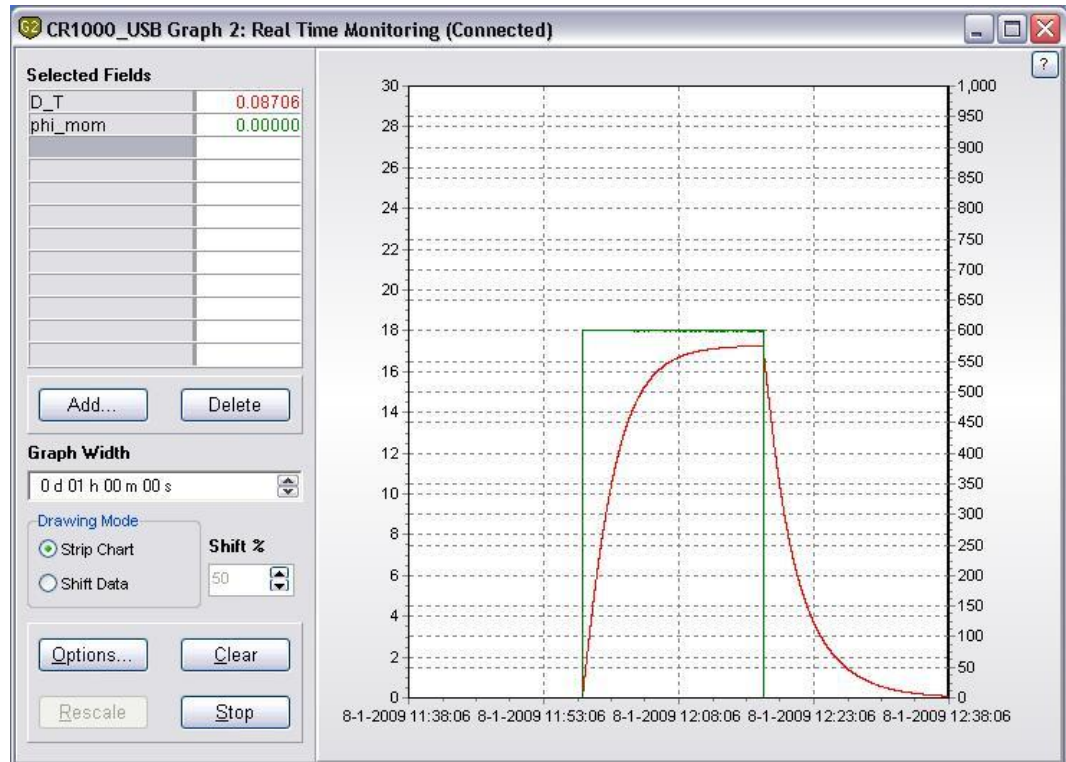


Figure 5.5.3 An example of a graph screen.

In the "Options..." it is possible to set several visualisation options, the vertical scale and the time base.

## 5.6 Preparation of the THISYS

### 5.6.1 Determining system parameters

User should only go through this step for two reasons:

- if a new thissys program has been uploaded to the CR1000. Reason is that typical system parameters are then erased from the MCU
  - if the calibration, as explained in chapter 5.7 is rejected.
- User should not go through this step when first using the system.

Step 1: contact resistance  
 Following steps should be followed:

No sample should be inserted in THISYS	Turn the knob to press the two heat sinks against each other
Make sure the values of C_1, C_2 and C_3 are same as on certificate	If not, modify as explained in chapter 5.5
Value of variable exp_no should be changed	Suggested is '1'
Value of variable sam_id should be changed	Suggested is 'empty'
Press the flag DetermineContRes	
A measurement is started.	
At the end of measurement, a new value is displayed for R_cont_n	This value should be entered in R_cont, as explained in chapter 5.5

Table 5.6.1.1 *Determining contact resistance*



Figure 5.6.1.1 *Ports and flags display when determining R\_cont*

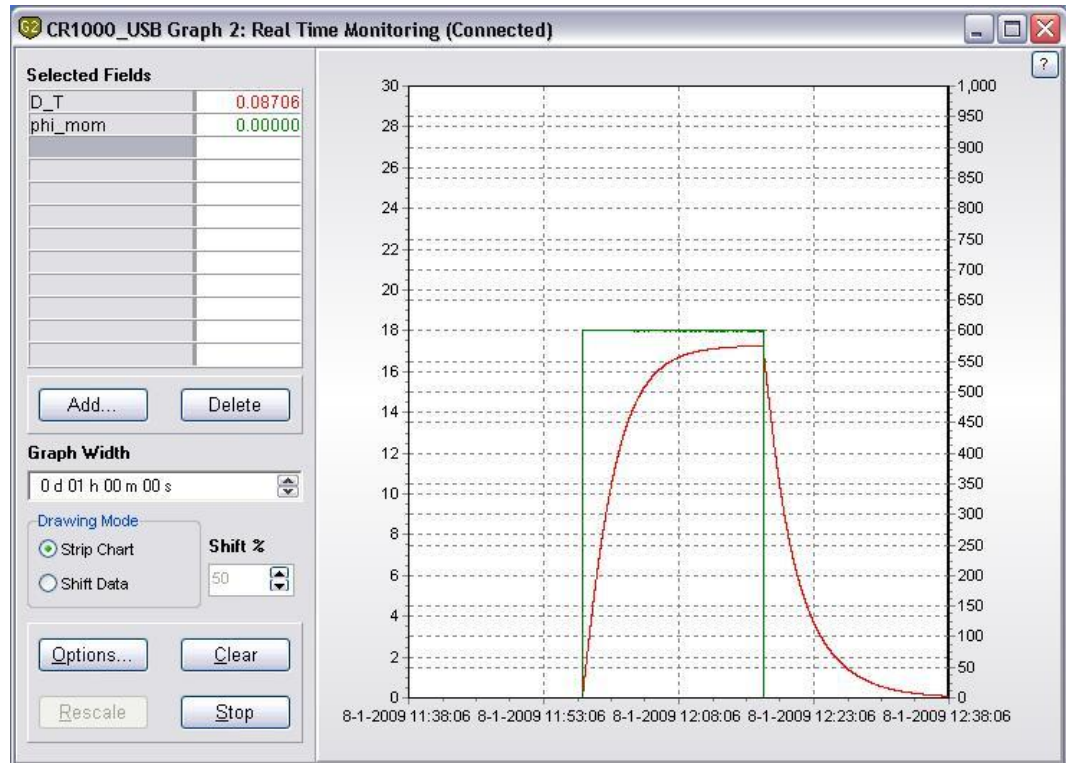


Figure 5.6.1.2 Graph of measurement for determining  $R_{cont}$

Step 2: serial resistance

Following steps should be followed:

A sample of aluminium of 110 x 70 x 10 mm should be inserted in THISSYS	Sample should be minimum 10 mm thick. This sample is not delivered with THISSYS
Turn the knob to press the two heat sinks against each other	
Make sure the values of C_1, C_2 and C_3 are same as on certificate	If not, modify as explained in chapter 5.5
Value of variable exp_no should be changed	Suggested is '2'
Value of variable sam_id should be changed	Suggested is 'alu'
Press the flag DetermineSerialRes	
A measurement is started.	
At the end of measurement, a new value is displayed for R_serial_n	This value should be entered in R_serial, as explained in chapter 5.5

Table 5.6.1.2 Determining serial resistance





Figure 5.6.1.3 Ports and flags display when determining  $R_{serial}$

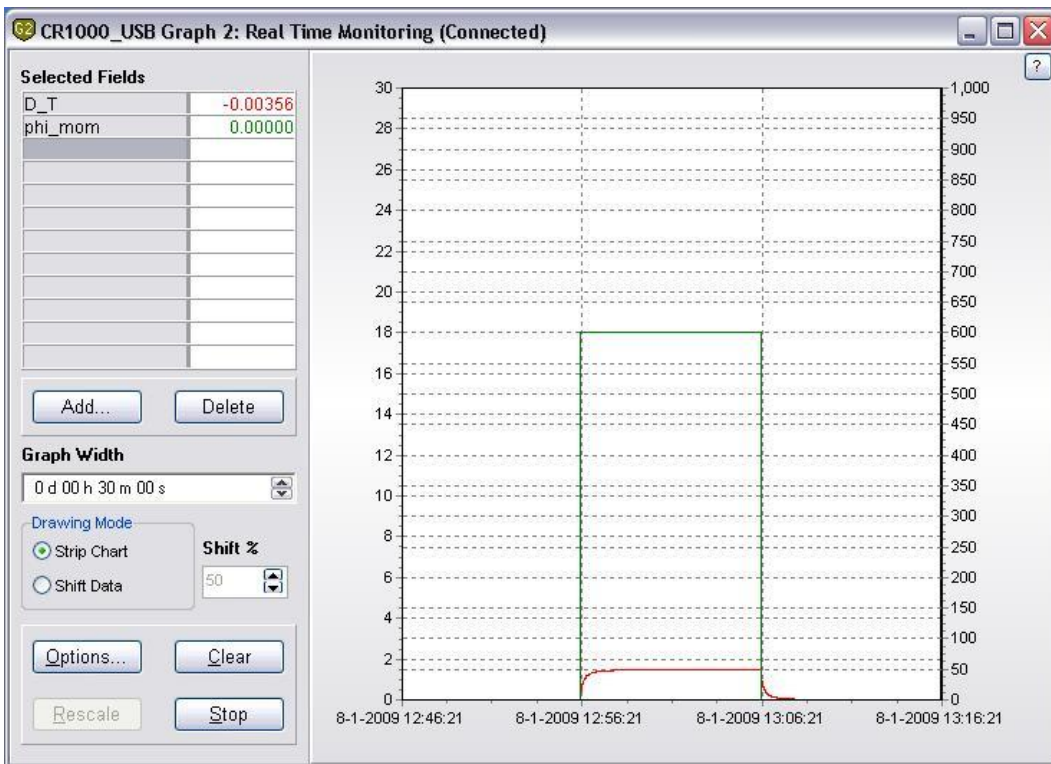


Figure 5.6.1.4 Graph of measurement for determining  $R_{serial}$



### 5.6.2 Determining reference values

User should only go through this step for two reasons:

- if a new thisys program has been uploaded to the CR1000. Reason is that typical system parameters are then erased from the MCU
- if the calibration, as explained in chapter 5.7 is rejected.

User should not go through this step when first using the system.

Following steps should be followed:

A reference sample, as part of the delivery should be inserted in THISYS	Turn the knob to press the two heat sinks against each other
Make sure the values of C_1, C_2 and C_3 are same as on the delivery certificate	If not, modify as explained in chapter 5.5
Make sure Lambda0_ref and tc_ref are set to the correct values for the reference	For Pyrex 7740 Lambda0_ref=1.058 and tc_ref=0.0014
The thickness of the reference sample should be entered in HS_ref	as explained in chapter 5.5
Value of variable exp_no should be changed	Suggested is '3'
Value of variable sam_id should be changed	Suggested is 'reference'
Press the flag DetermineRefRes	
A measurement is started.	
At the end of measurement, a new value is displayed for: <ul style="list-style-type: none"> <li>- lambda_ref_n</li> <li>- Rm_ref_n</li> </ul>	These values must be entered in lambda_ref and Rm_ref respectively.

Table 5.6.2.1 *Determining reference values*

#### **Important!**

In case a different reference sample is used, Lambda0\_ref and tc\_ref should be filled in according to the literature values for the material. Where:

Lambda0_ref	= thermal conductivity at 0 °C	[W/mK]
tc_ref	= temperature depended coefficient	[W/mK <sup>2</sup> ]
HS_ref	= thickness of the reference sample	[mm]





Figure 5.6.2.1 Ports and flags display when determining reference values

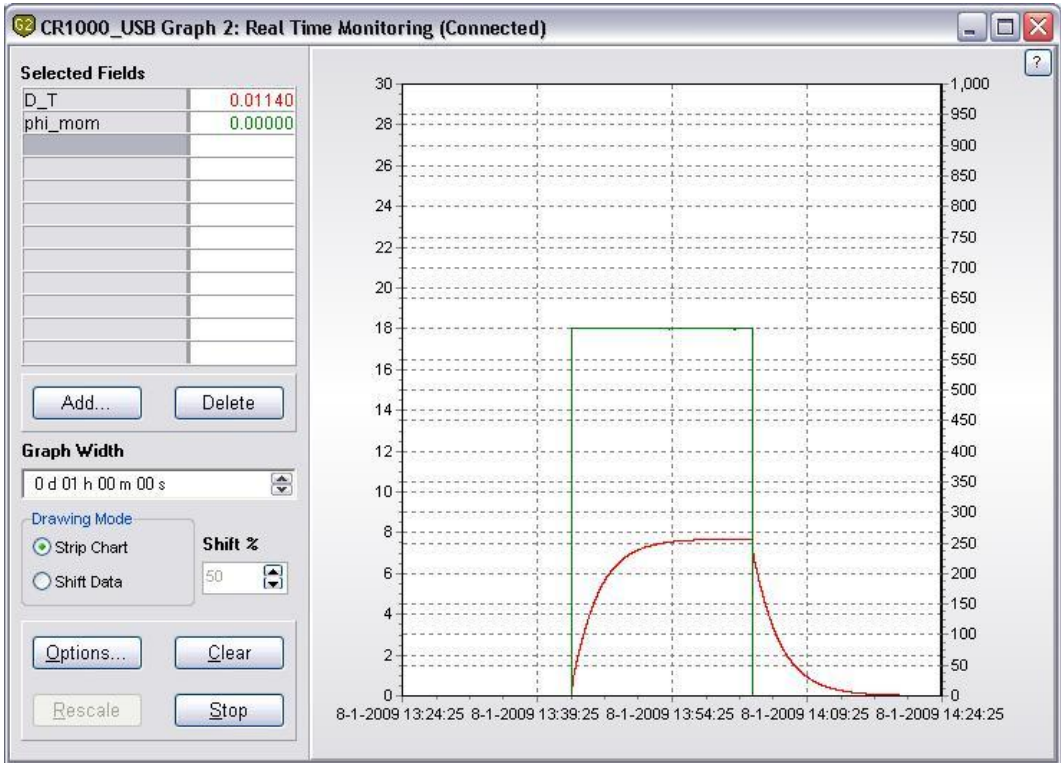


Figure 5.6.2.2 Graph of measurement for determining reference values





## 5.7 Calibration of THISYS

Calibration is performed to determine if the system is working within specifications.

Normally a calibration with the Pyrex 7740 reference sample is necessary. These samples have a very well defined thickness, are stable in almost all environments and have very accurately known thermal properties.

Pyrex 7740 is part of the standard delivery, and can be used with the system preset values.

Make sure that the values of the following parameters are set to the proper value for the Pyrex 7740 reference samples:

<b>variable</b>	<b>value</b>
<i>lambda0_ref</i>	1.058 W/mK
<i>tc_ref</i>	0.00144 W/mK <sup>2</sup>
<i>HS_ref</i>	5.00 mm
<i>lambda_ref</i>	See delivery certificate
<i>Rm_ref</i>	See delivery certificate

Table 5.7.1 Reference sample values

Make sure that the reference values *Rm\_ref* and *lambda\_ref* determined in paragraph 5.6.2 are applicable on Pyrex 7740. The THISYS system is delivered with preset values for Pyrex7740, so in the case of first operation these values should be correct.

### **Important!**

In case a different reference is used the values for the variables in table 5.7.2 should be in accordance with the used reference.

Calibration procedure:

- Put the Pyrex reference sample in the sample space and close the sinks.
- Key in the experiment ID in "*exp\_no*" and a sample ID in "*sam\_id*".
- Wait until the value of the variable "*D\_T*" is smaller than  $\pm 0.01$  indicating thermal stability of the sample and sensor.
- Activate the calibration procedure by clicking the variable "StartCalibration". The system will now automatically perform a test measurement.



- After the procedure is completed, "Countdown" shows 0.00 and the flag "Running" is off, the result is compared with the expected value.
- Check the value of lambda (the thermal conductivity of the sample) this should be around 1.1 at room temperature. When the flag "Cal\_OK" lights up the value of lambda is within 2% of the expected value.
- In case "Cal\_OK" doesn't light up repeat the procedure. In case there is still no successful completion steps in chapter 5.6.1 and 5.6.2 should be followed, in order to determine the contact and serial resistance, as well as the reference sample values.

For reliable results according to the specifications this procedure should be repeated yearly.

At this point, after completing all tests and procedure above, the system is ready for normal use and will give reliable results, when operated in a normal manner.



Figure 5.7.1 Ports and flags during calibration procedure

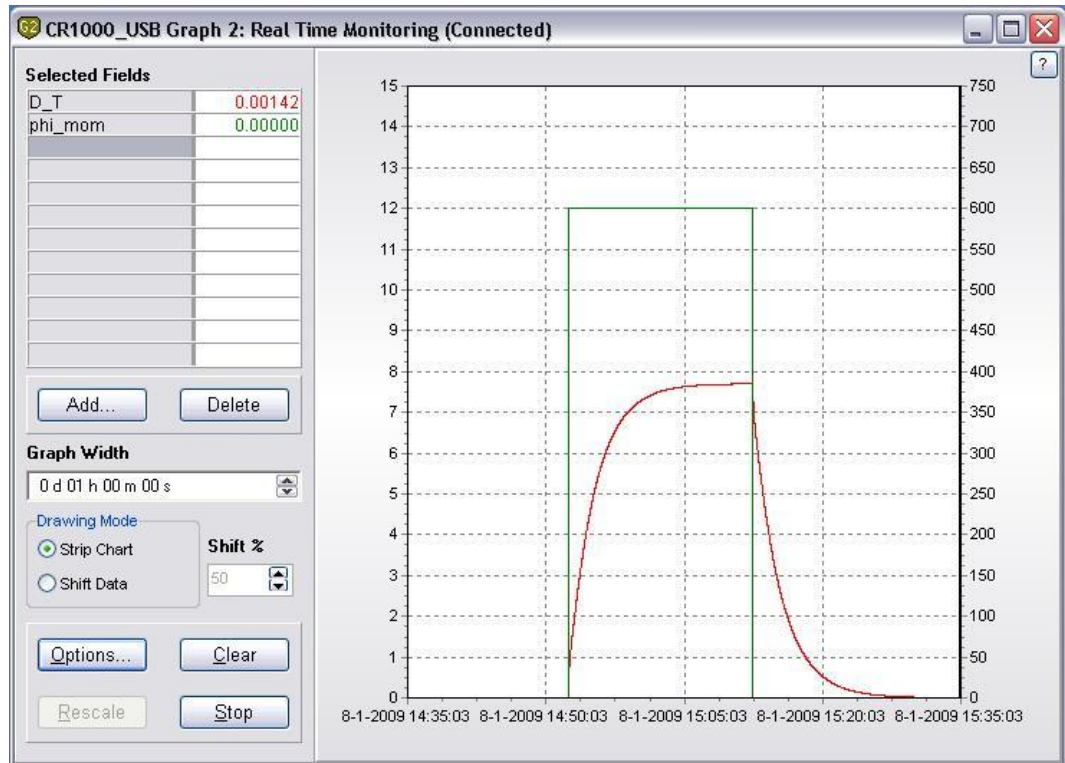


Figure 5.7.2 Typical graph of a calibration procedure





## 6 Performing measurements

This chapter describes how to use the system in standard operation as well as a procedure that can be used for measuring thick samples.

### Standard samples

The procedure to measure standard samples can be used when the measurement is performed at environmental temperature (room temperature) and the thickness and thermal conductivity is within the specifications of the THISYS.

- Measure the sample thickness within 1% accuracy. If stacking samples, the thickness of the stack should be measured
- Write down the sample identification and the thickness, time and date.
- Make sure the sample is clean and dry.
- Open the slot of the THI01.
- Insert a sample between the two heat sinks, increase space between the sinks if need with help of the knob, make sure the samples are located on the central axis of the THI01.
- Close the slot using moderate force or, in case of the optional pressure cell, to the specified pressure has been reached.
- Wait until the  $D_T$  reaches a value between  $\pm 0.01$ .
- Key in the thickness of the sample "HS" and the experiment ID in "exp\_no" and a sample ID in "sam\_id".
- Activate the flag "Start" to start the measurement.





Figure 6.1 After pressing the 'Start' ports, the measurement begins, showing the 'Running' flag

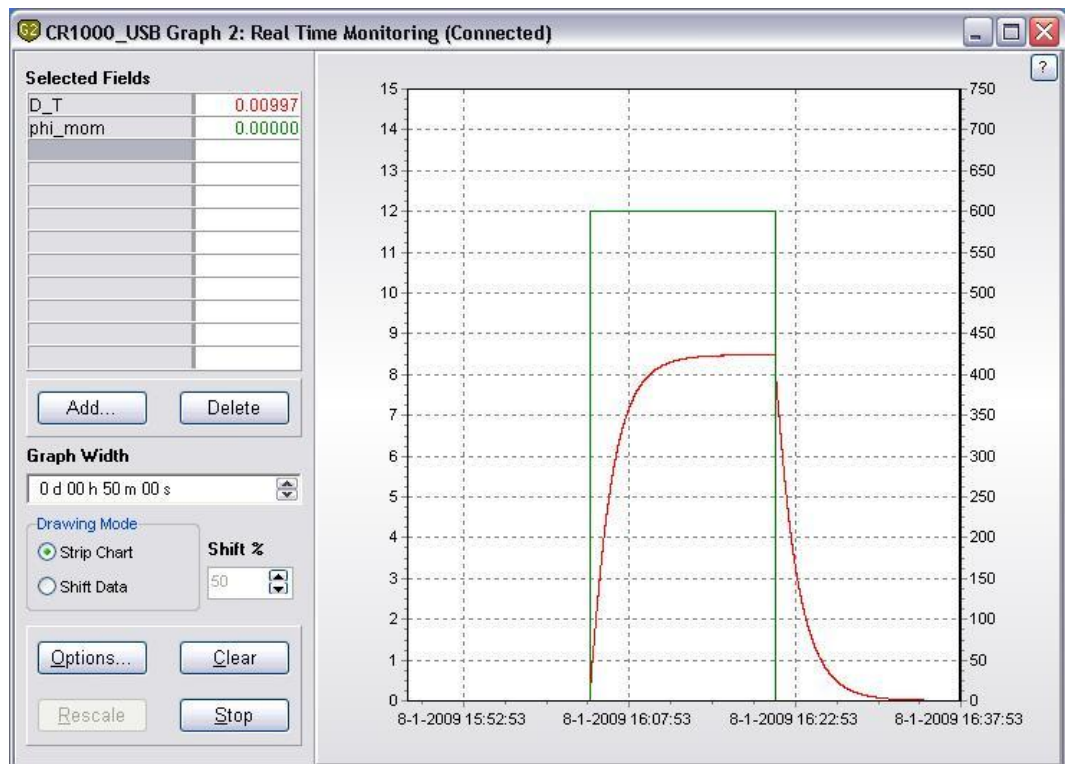


Figure 6.2 Typical graph at the end of a measurement cycle

## 7 Retrieving data

For normal operation the raw data is processed by the MCU and the results are written to a data table. In case extra quality assurance or more advanced data analysis is needed it is possible to write the raw data to a data table. The location of the files is set during the setup procedure (see chapter 5.3).

### 7.1 Downloading data

In normal operation the results of a measurement are stored to the data table CR1000\_Results.dat, when the datalogger name (MCU) is CR1000. When raw data is needed the table CR1000\_Rawdata.dat is filled as well. Normal operation is selected by starting a measurement using the flag "Start" (not the flag "StartCalibration"). The file format is ASCII with comma separated columns. This file format can be imported in virtually any application for data analysis or in Microsoft Word or Microsoft Excel.

Downloading the data from the MCU is done using the button "Collect Now" in the "Connect Screen". All data tables will be copied to the selected directory (chapter 5.3).

Instead of closing the screen that appears by clicking on "Ok", it is also possible to view the collected data by clicking on "View File" (see figure 7.1.1). This screen has, beside viewing of numerical data, the possibility of creating graphs by selecting the data column and then click on the graph icon in the menu bar.

TIMESTAMP	RECORD	batt_volt_Min	exp_no	sam_id	P_N	T_measure	D_T_20	Phi
"2008-11-25 10:43:37"		12.32	"1"	"R_cont"	207.8	22.37	0.178	600.5
"2008-11-26 01:53:25"		12.31	"2"	"pyrex"	208	20.86	1.554	600.8
"2008-11-26 02:37:12"		12.32	"3"	"pyrex"	207.9	21.29	1.554	600.7
"2008-11-26 04:04:53"		12.31	"4"	"PE"	199	21.71	8.56	600.2
"2008-11-26 04:54:59"		12.31	"5"	"R_cont"	202	22.03	0.18	600.6
"2008-11-26 05:08:14"		12.31	"6"	"R_cont"	201.9	22.11	0.18	600.6
"2008-11-26 05:47:39"		12.31	"7"	"PMA"	200.3	22.35	8.54	600
"2008-11-26 06:05:17"		12.31	"8"	"pyrex"	198.7	22.56	1.554	600.1
"2008-11-26 06:23:44"		12.31	"9"	"1_sl2"	199.5	22.74	1.623	600.1
"2008-11-26 06:40:57"		12.31	"10"	"3_sl2"	197.1	22.88	1.618	600.1
"2008-11-26 07:04:45"		12.31	"11"	"12_sl2"	206.6	22.93	2.016	600
"2008-11-26 07:26:44"		12.31	"12"	"11_sl2_sl2"	198.1	22.98	2.178	600
"2008-11-26 07:48:50"		12.31	"13"	"1_sl2_sl2"	202.1	23.09	0.749	600.2
"2008-11-26 08:05:56"		12.31	"14"	"3_sl2_sl2"	206.7	23.09	2.142	599.9
"2008-11-26 08:30:14"		12.31	"15"	"3_sl2_sl2"	201.3	23.2	0.72	600.1
"2008-11-26 09:16:39"		12.3	"16"	"13_sl2_sl2"	206.9	23.09	1.682	600
"2008-11-26 09:43:08"		12.31	"17"	"7_sl2_sl2"	199.8	23.14	1.942	600
"2008-11-26 10:20:03"		12.3	"18"	"4_sl2_sl2"	200.6	23.09	2.654	599.9
"2008-11-26 10:39:30"		12.3	"19"	"2_sl2_sl2"	204.8	23.17	1.289	600.2
"2008-11-27 01:48:53"		12.31	"20"	"2_sl2_sl2"	205.2	21.26	1.266	600.6
"2008-11-27 02:37:50"		12.31	"21"	"2_sl2_sl2"	204.8	21.61	1.688	600.4
"2008-11-27 03:26:15"		12.3	"22"	"2_sl2_sl2"	200.8	21.79	0.6	600.5
"2008-12-12 02:38:00"		12.31	"30"	"R_cont"	200.6	21.9	0.178	600.4
"2008-12-12 03:39:00"		12.31	"31"	"pyrex"	204.4	22.19	1.555	600.6
"2008-12-12 04:57:14"		12.31	"32"	"2067ms"	193.7	22.34	6.334	599.8
"2008-12-12 06:19:07"		12.31	"33"	"2067ms"	199.4	22.56	7.188	599.5
"2008-12-12 07:11:57"		12.31	"34"	"2015s"	202.4	22.98	7.356	599.4

Figure 7.1.1 Viewing a data table using LoggerNet.



Alternatively the data can be imported in for example Microsoft Excel. This can be done by starting Excel, chose File, Open..., chose in "Files of type" the option "All Files". Now, go to the directory where the data file is located, select the file and click Ok. Click on "Next >" in the screen that appears, tick the comma option and click "Finish" to open the file. The Excel sheet that is now created should look similar to figure 7.1.2.

	A	B	C	D	E	F	G	H
1	TOA5	CR1000_USB	CR1000	19247	CR1000.Std.15	CPU:thissys v0905.CR1	12683	Results
2	TIMESTAMP	RECORD	exp_no	sam_id	T_measure	P_N	lambda	HS
3	TS	RN			Deg C	N	W/mK	mm
4			Smp	Smp	Smp	Smp	Smp	Smp
5	14-1-2009 16:11	0	1		22.19	198.3	0.891	5
6	15-1-2009 9:22	1	1		20.8	196.5	0.86	5

*Figure 7.1.2 A typical data file as downloaded from the MCU and opened in Microsoft Excel.*

An detailed explanation of the head can be found in the appendix (chapter 10.1) including all variable names and the units in which they are displayed.

## 7.2 Collecting raw data

When raw measurement data is needed, a measurement should be started using the "StartCalibration" flag instead of the "Start" flag. Raw measurement data, such as the sensor signal and system temperature, will be stored in real time to the data table "Rawdata". All other options can be set in the normal way. If the thermal conductivity matches the set reference sample values (chapter 5.6), the "Cal\_Ok" flag which will light up after completion of the measurement. This can be ignored without any complications.

Viewing the file is done in exactly the same way as described in the foregoing chapter 7.1.



## 8 Warning messages

Warnings are not necessarily errors, but are indicating that the user should pay attention to this aspect of the measurement.

When "Warning" equals for example 221:  
This can be decomposed in:

$$\text{Warning} = 200 + 20 + 1$$

The messages can now we looked up in table 8.1, as below.

Warning	Significance	Numerical addition to " Warning"
War_lambda	The thermal conductivity is out of range	1
War_H_t	The heating time is out of range	2
War_P_sta	The power is possibly unstable	10
War_grad	The temperature gradient before the measurement is possibly too large	20
War_grad_A	The signal amplitude is possibly not sufficiently stable	200

Table 8.1 *Warnings are given as a summation of separate messages.*





## 9 Delivery and spare parts

THISYS delivery includes the following items:

- MCU01
- THI01
- One Pyrex 7740 sample
- Calibration form for Pyrex sample
- Manual THI01
- Calibration form for THI01
- THI01 cable with connectors 1
- THI01 cable with connectors 2

Spare parts are:

- Thermopile plus heater assembly
- THI01 cable with connectors 1
- THI01 cable with connectors 2

The THISYS delivery does NOT include: glycerol contact fluid, the aluminium sample as described in chapter 5.6.1 for measurement of the serial resistance and tools to measure the sample thickness.

Options are:

- Pressure sensor
- Power supply for thin sample analysis

Services:

- Recalibration of the Pyrex 7740 sample
- Analysis of samples



# 10 Appendices

## 10.1 Relevant variable names and description

variable	description	Units
<b>General system variables</b>		
PTemp	Temperature of CR1000 datalogger in MCU	°C
Batt_volt	Current power supply voltage	V
RecNum	Record Number	
TimeStamp	Time	
<b>General measurement variables</b>		
Countdown	Time to go to the end of measurement	s
Exp_no	Experiment number for user reference	-
Sam_id	Sample ID for user reference	-
T_measure	Sample temperature at start of measurement	°C
lambda	Measured thermal conductivity	W/k·m
H_time	Heating time (3x heating time is total measurement time)	s
T	THI01 temperature	°C
Phi_mom	heatflux trough the sample	W/m <sup>2</sup>
D_T	Temperature difference over the sample	
R_cont	Contact resistance	K·m <sup>2</sup> /W
R_cont_n	New determined contact resistance; see chapter 5.6 for explanation	K·m <sup>2</sup> /W
R_serial	Serial resistance	K·m <sup>2</sup> /W
R_serial_n	New determined serial resistance	K·m <sup>2</sup> /W
Rm	Sample thermal resistance	K·m <sup>2</sup> /W
P_N	Force on sample (optional)	N
T_step	Temperatures step used in automated measurements	°C
HS	Thickness of sample	mm
Warning	Warning code (chapter 8)	-
<b>Calibration data regarding the reference sample and the temperature difference sensor</b>		
Lambda0_ref	Thermal conductivity of sample at 0 °C	W/k·m
Tc_ref	Temperature coefficient of reference sample	W/k·m·°C
Lambda_ref	Thermal conductivity of sample at current temperature	W/k·m
Lambda_ref_n	New determined thermal conductivity of reference sample; for measurement of thermal conductivity of reference sample, see chapter XXX	W/k·m
HS_ref	Thickness of reference samples	mm
Rm_ref	Thermal resistance	K·m <sup>2</sup> /W
Rm_ref_n	New determined thermal resistance	K·m <sup>2</sup> /W
<b>Continued on next page</b>		



Continuation form previous page		
C_1	Calibration constant sensor	V/K <sup>2</sup>
C_2	Calibration constant sensor	V/K
C_3	Calibration constant sensor	-

Table 10.1.1 *Numeric program variables and their function. The variables have the same order as in the program and numeric screen*

## 10.2 Data tables

	A	B	C	D	E	F	G	H
1	TOA5	CR1000_USB	CR1000	19247	CR1000.Std.15	CPU:thissys v0905.CR1	12683	Results
2	TIMESTAMP	RECORD	exp_no	sam_id	T_measure	P_N	lambda	HS
3	TS	RN			Deg C	N	W/mK	mm
4			Smp	Smp	Smp	Smp	Smp	Smp
5	14-1-2009 16:11	0	1		22.19	198.3	0.891	5
6	15-1-2009 9:22	1	1		20.8	196.5	0.86	5

Figure 10.2.1 *A screenshot of the 'Results' data table header.*

The cells in the first row contain the following information from left to right:

- File format (always the same), ASCII comma separated.
- Station name, chosen by the user during installation on PC.
- Logger model, always CR1000 data logger.
- Serial number of the built-in CR1000 logger.
- Operating system version on the CR1000.
- Program name.
- Program ID
- Data table name.

The second row contains data label of the corresponding column, the third the units in which the data is displayed. The fourth column gives information on how the data is collected, this information is not relevant in this context.

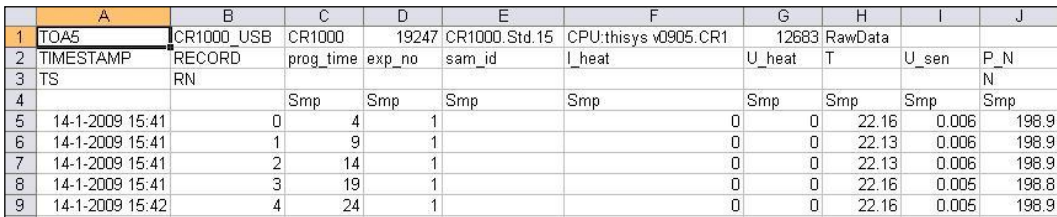


The following variables are written to the results table:

exp_no	Experiment ID
sam_id	Sample ID
T_measure	THA01 temperature of current measurement
P_N	Force on the sample in N (shows 0 when not installed)
lambda	Thermal conductivity
HS	Thickness sample
Phi	Heat flux from heater
Rm	Thermal resistance of the sample
R_cont	Contact resistance
R_serial	Serial resistance
Cal_OK	Calibration value within specifications

Table 10.2.1 *List of variables written to 'Results'*

The raw data table is only recorded when using the flag "StartCalibration" as described in chapter 7.2. The figure below shows the raw data table imported in Microsoft Excel.



	A	B	C	D	E	F	G	H	I	J
1	TOA5	CR1000_USB	CR1000	19247	CR1000.Std.15	CPU:thissys v0905.CR1	12683	RawData		
2	TIMESTAMP	RECORD	prog_time	exp_no	sam_id	I_heat	U_heat	T	U_sen	P_N
3	TS	RN								N
4			Smp	Smp	Smp	Smp	Smp	Smp	Smp	Smp
5	14-1-2009 15:41	0	4	1		0	0	22.16	0.006	198.9
6	14-1-2009 15:41	1	9	1		0	0	22.13	0.006	198.9
7	14-1-2009 15:41	2	14	1		0	0	22.13	0.006	198.9
8	14-1-2009 15:41	3	19	1		0	0	22.16	0.005	198.8
9	14-1-2009 15:42	4	24	1		0	0	22.16	0.005	198.9

Figure 10.2.2 *A screen shot of the 'Rawdata' data table header.*

The following variables are written to the RawData table:

exp_no	Experiment ID
sam_id	Sample ID
I_heat	Current trough the THI01 heater
U_heat	Voltage over the THI01 heater
T	THI01 temperature
U_sen	Sensor signal from the THI01
P_N	Force on the sample (shows 0 when no force is sensor installed)

Table 10.2.2 *List of variable written to 'RawData'*



### 10.3 MCU compatibility with THASYS

The THISYS and THASYS are systems which are very closely related. THISYS is a sensor that is designed to measure the thermal conductivity of thin good sheet material with a high thermal conductivity, such as for example metal foils. The hardware of the MCU of both systems is identical. By changing the software of an MCU delivered with a THISYS it can also be used with a THASYS and vice versa. Please refer to the THASYS manual for general information and to the THA01 manual for the physical working principles of THASYS. These manuals are available at on request a Hukseflux Thermal Sensors.

To switch between THISYS and THASYS programs on the MCU (note that description below works both ways: from thissys to thasys program and from thasys to thissys program), following steps should be taken:

First, user should make sure all data is saved to the computer, by using the 'Collect Now' button.

Additionally, the variables of the system should be saved. This is done by selecting 'Custom' under Data Collection on the Connect Screen. The screen as depicted below then appears. 'Public' should be selected, then 'Start Collection'. Data can be found under the path described in picture below:



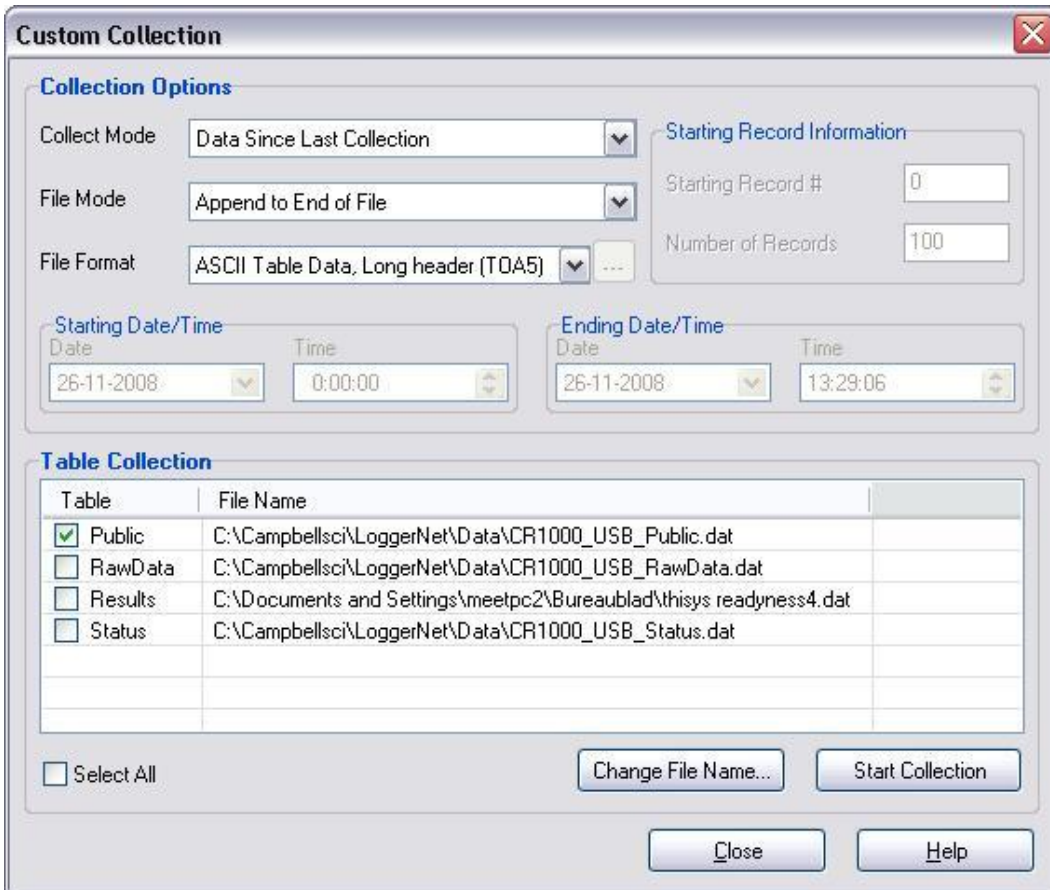


Figure 10.3.1 Saving Public Data

Secondly, the correct program should be chosen:  
On the connect Screen, select Datalogger, then File Control, as pictured below:

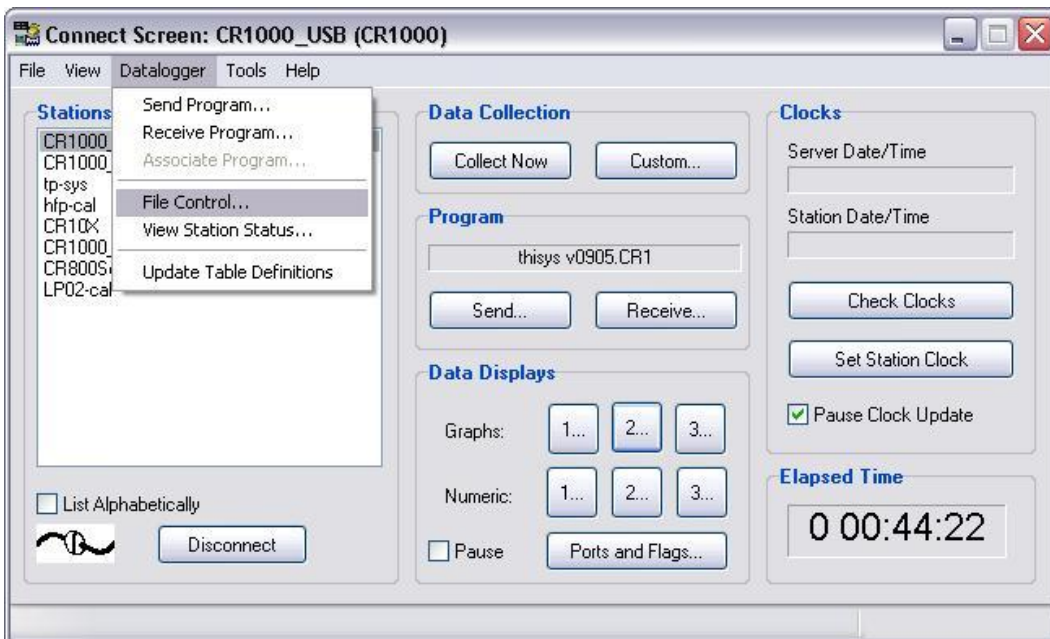


Figure 10.3.2 Selecting 'File Control' within the Connect Screen



Following screen then appears, user should then select either thisys or thasys program for running on the MCU. This can be done by clicking once on the program name, then selecting 'Run Options'

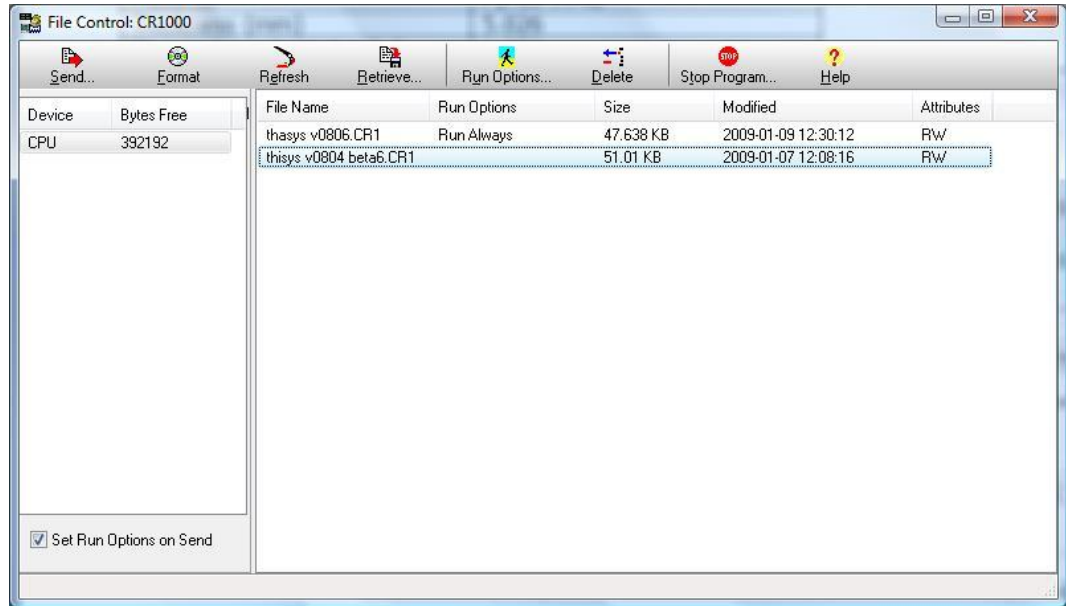


Figure 10.3.3 Selecting the correct program to use in MCU

The 'Select Run Options' screen appears, where both boxes, 'Run Now' and 'Run On Power-up'

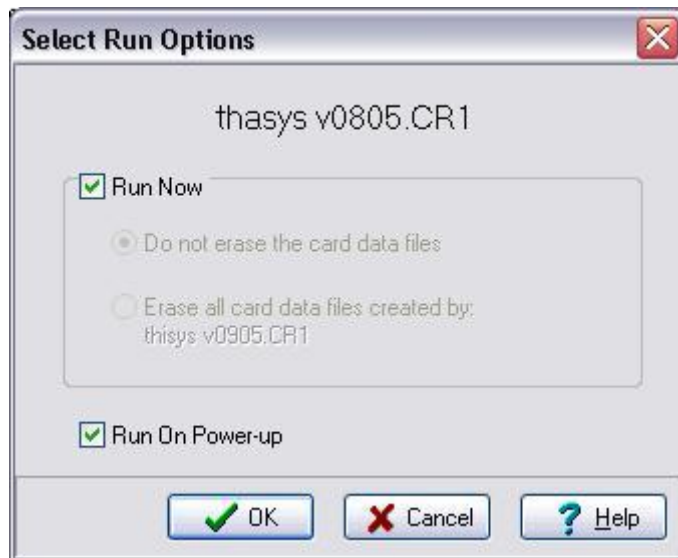


Figure 10.3.4 Select Run Options

User should now have switched successfully between programs on the MCU.





## 10.4 Transport safety optional pressure cell

In case there is an optional pressure cell installed in the THA01, the pressure cell is blocked to prevent damage during transport.

The top cover plate of the THA01 needs to be removed to release the transport safety. This can be done by using a 3 mm Allen key to remove the 8 screws at the top side of the THA01 (see top view figure 1.1.2).

Figure 10.4.1 shows where the pressure cell (5) is situated. The tread end prevents a force to be applied to the pressure cell during transport.

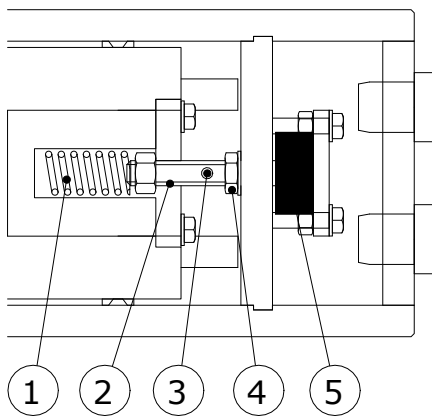


Figure 10.4.1 *Detailed view of the pressure sensor and the transport safety nut (4). The spring is not visible in reality.*

Releasing the safety nut:

- Put a rod of 3 mm in diameter in the hole (3) to block the thread end.
- Release the safety nut (4) by at least two full turns.

After following the steps 1, 2 and 3 of this manual the system is ready to use.

## 10.5 Appendix on typical thermal properties

A table describing the typical values for the thermal properties of some materials is given below. Note that the list is only indicative, it has no value as a literature source. For good literature values, use for example the "Handbook of Chemistry and Physics", or HBCP as it is often called, by CRC press.







Material	Material	Specific Heat	Thermal	Thermal
	Density	Capacity	Conductivity	Effusivity
	kg/m <sup>3</sup>	J/kg·K	W/m·K	JW/m <sup>2</sup> K
air	1.29	1004	0.025	6
aluminum	2698	921	225.940	23688
bronze, commercial	8800	377	188.280	24979
copper	8940	385	397.480	36983
fused silica glass	2200	745	1.381	1504
gold	19300	128	317.980	28027
lead	11350	130	34.309	7107
nickel	8900	444	87.864	18623
plate glass	2500	753	1.213	1511
silicon	2330	703	125.520	14338
silver	10500	236	426.770	32520
soil, clay (wet)	1500	2929	1.506	2572
soil, sandy dry	1650	795	0.264	588
PTFE	2170	1004	0.251	740
thulium	9300	160	8.368	3526
tin	7310	226	61.086	10044
tungsten	19300	134	196.650	22543
water (h <sub>2</sub> o) (liquid)	1000	4184	0.603	1588
water (h <sub>2</sub> o) (solid)	917	4217	2.092	2844
zinc	7140	389	111.710	17617

Table 10.5.1 *A list of typical values of thermal properties of various materials. This list is only indicative.*





## 10.6 Glycerol Material Safety Data Sheet (93 / 112 EC)

This safety sheet is a copy of the Material Safety Data Sheet Version according to 93/112 EC of 10-08-2000 of the company Ephuysen Chemie. The THA01 user is responsible for obtaining the latest Version of this sheet from the manufacturer when purchasing glycerol for use with THA01.

<p><b>1 identification of the substance / preparation and of the company/ undertaking</b></p> <ul style="list-style-type: none"><li>• Production details -</li><li>• Trade Name: Glycerine</li><li>• Article Number: 013311</li><li>• Manufacturer / Supplier: Ephuysen Chemie N. V. Noordeweg 3 3336 LH Zwijndrecht The Netherlands Tel: 00-31-78-612702 Fax: 00-78-6121129 e-mail <a href="mailto:ppelt@ephuysen.com">ppelt@ephuysen.com</a></li><li>• Further information available from: environmentally Department</li><li>• Information in case of emergency: see above</li></ul>
<p><b>2 Composition / information on the ingredients</b></p> <ul style="list-style-type: none"><li>• Chemical characterisation: Cas No Description: 56-81-5 Glycerol</li><li>• Identification numbers: -</li><li>• EINECS Number: 200-289-5</li></ul>
<p><b>3 Hazards identification</b></p> <ul style="list-style-type: none"><li>• Information concerning to particular hazards to man and environment: Not applicable</li></ul>
<p><b>4 First-aid measures</b></p> <ul style="list-style-type: none"><li>• General information: No special measures required</li><li>• After inhalation: Supply fresh air; consult a doctor inn case of complaints</li><li>• After skin contact: Generally the product does not irritate the skin</li><li>• After eye contact: Rinse opened eye for several minutes under running water</li><li>• After swallowing: If symptoms persist consult a doctor</li></ul>
<p><b>5 Fire fighting measures</b></p> <ul style="list-style-type: none"><li>• Suitable extinguishing agents: Use fire extinguishing methods suitable to surrounding conditions</li><li>• Protective equipment: No special measures required</li></ul>
<p><b>6 Accidental release measures</b></p> <ul style="list-style-type: none"><li>• Person-related safety precautions: Not required</li><li>• Measures for environmental protection: Dilute with plenty of water</li><li>• Measures for cleaning / collecting: Absorb with liquid binding material (sand, diatomite, acid binders, universal binders, sawdust).</li><li>• Additional information: No dangerous substances are released</li></ul>





### **7 Handling and storage**

- Handling :-
- Information for safe handling: No special measures required
- Information about fire - and explosion protection: No special measures required
- Storage:
- Requirements to be met by storerooms and receptacles: No special requirements
- Information about storage in one common storage facility: Not required
- Further information about storage conditions: None
- Storage class: -
- Class according to regulation an flammable liquids: void

### **8 Exposure controls / personal protection**

- Additional information about design of technical facilities: No further data; see item 7
- Ingredients with limit values that require monitoring at the workplace: 56-81-5 glycerol OEL: 10 mg/m<sup>3</sup>
- Additional Occupational Exposure Limit Values for possible hazards during processing: Glycerine is (almost) odourless. The MAC-value can exceed the limit unnoticed.
- Additional information: The lists valid during the making were used as a basis
- Personal protective equipment: -
- General protective and hygienic measures: The usual precautionary measures are to be adhered to when handling chemicals
- Respiratory protection: not required
- Protection of hands: not required
- Eye protection: Goggles recommended during refilling

### **9 Physical and chemical properties**

- Form: viscous
- Colour: Colourless
- Odour: Odourless
- Change in condition: -
- Melting point / Melting range: 18.2 °C
- Boiling point / Boiling range: 290°C
- Flash point: 177 °C
- Ignition temperature: 400 °C
- Danger of explosion: the product does not present an explosion hazard
- Explosion limits:
- Lower: 0.9 Vol %
- Vapour pressure: at 50 °C 0.003 hPa
- Density: at 20 °C 1.26 g/ cm<sup>3</sup>
- Solubility in / Miscibility with water: Fully miscible
- PH value; Not determined
- Viscosity:
- Dynamic: at 20 °C 106.9 mPas





<p><b>10 Stability and reactivity</b></p> <ul style="list-style-type: none"><li>• Thermal decomposition / conditions to be avoided: No decomposition if used according to specifications</li><li>• Dangerous reactions: No dangerous reactions known</li><li>• Dangerous decomposition products: No dangerous decomposition products known</li></ul>
<p><b>11 Toxicological information</b></p> <ul style="list-style-type: none"><li>• Acute toxicity:LD/ Lc50 values relevant for classification: 56-81-5 glycerol Oral LD50: 250 mg/kg(mus)</li><li>• Primary irritant effect:</li><li>• On the skin: It is not irritating</li><li>• On the eye: No irritating effect</li><li>• Sensitisation: No sensitisation effects known.</li><li>• Additional toxicological information: When used and handled according to specifications, the product does not have any harmful effects to our experience and the information provided to us. The substance is not subject to classification according to the latest Version of the EU lists.</li></ul>
<p><b>12 Ecological information</b></p> <ul style="list-style-type: none"><li>• Ecotoxicological effects:</li><li>• Aquatic toxicity: 56-81-5 glycerol LC50/24 h: &gt; 5000 ppm (fish)</li><li>• General notes: generally not hazardous for water</li></ul>
<p><b>13 Disposal considerations</b></p> <ul style="list-style-type: none"><li>• Product</li><li>• Recommendation: Smaller quantities can be disposed with household waste</li><li>• Uncleaned packaging</li><li>• Recommendation: Disposal must be made according to official regulations</li><li>• Recommended cleansing agents: Water, if necessary together with cleansing agents.</li></ul>
<p><b>14 Transport information</b></p> <ul style="list-style-type: none"><li>• Land transport ARD / RID (cross border)</li><li>• UN-Number: -</li><li>• Hazard label: -</li></ul>
<p><b>15 Regulatory information</b></p> <ul style="list-style-type: none"><li>• Labelling according to EU Guidelines: The substance is not subject to classification according to EU lists and other sources of literature known to us. Observe the general safety regulations when handling chemicals, The product is not subject to identification regulations under EU Directives and the Ordinance on Hazardous Materials (German GefStoffV).</li><li>• National regulations</li><li>• Classification according to VbF: Void</li><li>• Technical instructions (air): Class Share in %: NK 100.0</li><li>• Waterhazard class: Generally not hazardous for water.</li></ul>
<p><b>16 Other information</b></p> <p>This information is based on present knowledge. However, this shall not constitute a guarantee for any specific product features and shall not establish a legally valid contractual relationship.</p> <ul style="list-style-type: none"><li>• Department issuing MSDS: Environmentally Department</li><li>• Contact: P. van Pelt</li></ul>





### 10.7 International Chemical Safety Card for Glycerol

The following pages contain information on the International Chemical Safety Card for glycerol. The THA01 user is responsible for obtaining the latest Version of this card from the glycerol manufacturer when purchasing glycerol for use with THA01.

<b>International Chemical Safety Cards</b>			
<b>GLYCEROL</b>			ICSC: 0624
<b>GLYCEROL</b> <b>Glycerin</b> 1,2,3-Propanetriol 1,2,3-Trihydroxypropane $C_3H_8O_3$ / $CH_2OH-CHOH-CH_2OH$ Molecular mass: 92.1 CAS # 56-81-5 RTECS # MA8050000 ICSC # 0624			
<b>TYPES OF HAZARD/ EXPOSURE</b>	<b>ACUTE HAZARDS/ SYMPTOMS</b>	<b>PREVENTION</b>	<b>FIRST AID/ FIRE FIGHTING</b>
<b>FIRE</b>	Combustible. Gives off irritating or toxic fumes (or gases) in a fire.	NO open flames.	Powder, alcohol-resistant foam, water spray, carbon dioxide.
<b>EXPLOSION</b>			In case of fire: keep drums, etc., cool by spraying with water.
<b>EXPOSURE</b>		<b>PREVENT GENERATION OF MISTS!</b>	
<b>INHALATION</b>	Cough.	Ventilation.	Fresh air, rest.
<b>SKIN</b>	Dry skin.	Protective gloves.	Remove contaminated clothes. Rinse skin with plenty of water or shower.
<b>EYES</b>	Redness. Pain.	Safety goggles.	First rinse with plenty of water for several minutes (remove contact lenses if easily possible), then take to a doctor.
<b>INGESTION</b>	Nausea. Vomiting.	Do not eat, drink, or smoke during work.	Rinse mouth. Give plenty of water to drink. Rest. Refer for medical attention.





<b>SPILLAGE DISPOSAL</b>	<b>STORAGE</b>	<b>PACKAGING &amp; LABELLING</b>
Ventilation. Collect leaking liquid in covered containers. Absorb remaining liquid in sand or inert absorbent and remove to safe place.	Separated from strong oxidants. Dry.	
<b>SEE IMPORTANT INFORMATION ON BACK</b>		
<b>ICSC: 0624</b>	Prepared in the context of cooperation between the International Programme on Chemical Safety & the Commission of the European Communities © IPCS CEC 1993	





<b>International Chemical Safety Cards</b>	
<b>GLYCEROL</b>	<b>ICSC: 0624</b>
<b>I M P O R T A N T  D A T A</b>	<p>PHYSICAL STATE; APPEARANCE: HYGROSCOPIC, VISCOUS COLOURLESS LIQUID.</p> <p>PHYSICAL DANGERS:</p> <p>CHEMICAL DANGERS: The substance decomposes on heating producing corrosive fumes of acrolein. Reacts with strong oxidants causing fire and explosion hazard. Reacts violently with acetic anhydrides in the presence of a catalyst.</p> <p>OCCUPATIONAL EXPOSURE LIMITS (OELs): TLV: ppm; 10 mg/m<sup>3</sup> mist (ACGIH 1995-1996).</p>
<b>PHYSICAL PROPERTIES</b>	<p>Decomposes below boiling point at 171°C Melting point: 18.2°C Relative density (water = 1): 1.26 Solubility in water: miscible Vapour pressure, Pa at 20°C: &lt;0.1</p> <p>Routes of exposure: The substance can be absorbed into the body by inhalation of its mist.</p> <p>INHALATION RISK: Evaporation at 20°C is negligible; a nuisance-causing concentration of airborne particles can, however, be reached quickly on spraying.</p> <p>EFFECTS OF SHORT-TERM EXPOSURE: The substance irritates the eyes, the skin and the respiratory tract.</p> <p>EFFECTS OF LONG-TERM OR REPEATED EXPOSURE:</p>
<b>ENVIRONMENTAL DATA</b>	<p>Relative vapour density (air = 1): 3.17 Flash point: 177°C. Auto-ignition temperature: 370°C Explosive limits, vol% in air: 0.9-? Octanol/water partition coefficient as log Pow: -1.76</p>
<b>NOTES</b>	
	Also consult ICSC # 0090, acrolein.
	NFPA Code: H1; F1; R0
<b>ADDITIONAL INFORMATION</b>	
<b>GLYCEROL</b>	
<b>ICSC: 0624</b>	
<b>© IPCS, CEC, 1993</b>	
<b>IMPORTANT LEGAL NOTICE:</b>	Neither the CEC or the IPCS nor any person acting on behalf of the CEC or the IPCS is responsible for the use which might be made of this information. This card contains the collective views of the IPCS Peer Review Committee and may not reflect in all cases all the detailed requirements included in national legislation on the subject. The user should verify compliance of the cards with the relevant legislation in the country of use.



## 10.8 CE declaration of conformity



According to EC guidelines 89/336/EEC, 73/23/EEC and 93/68/EEC

We: Hukseflux Thermal Sensors

Declare that the product: THISYS

Is in conformity with the following standards:

Emissions:

Radiated:	EN 55022: 1987	Class A
Conducted:	EN 55022: 1987	Class B

Immunity:

ESD	IEC 801-2; 1984	8kV air discharge
RF	IEC 808-3; 1984	3 V/m, 27-500 MHz
EFT	IEC 801-4; 1988	1 kV mains, 500V other

Delft  
January 2009