USER MANUAL **ALUSYS**

Measuring system for heat flux and temperature survey

Warning statements

⚠ Putting a voltage of over 30 VDC to ALUSYS may result in permanent damage to the system.

⚠ ALUSYS has a rechargeable battery in its MCU. This battery needs periodic recharging and must be removed and stored seperately if the equipment is stored for > 60 days.

⚠ ALUSYS has a rechargeable battery in its MCU. When replacing the battery, consult the manual of the internal battery holder and charge controller (model PS150).

⚠ ALUSYS has an internal battery in its electronics (model CR1000) in the MCU that powers the clock and the SRAM when external power is not supplied. This battery needs periodic replacement.

⚠ The high temperature cable of the HF01 heat flux sensor and its armour are electrical conductors. Use the silicone protection sleeve to avoid leakage of current.

Contents

List of symbols

Quantities	Symbol	Unit
Heat flux	Φ	W/m²
Voltage output	U	V
Sensitivity	S	V/(W/m²)
Temperature	T	°C
Resistance	R	Ω

Subscripts

Property of thermopile sensor	sensor
Property of the surrounding environment	environment

Introduction

ALUSYS is a measuring system for trend-monitoring and mobile survey of heat flux and surface temperature in industrial environments. Sensors and electronics have the robustness necessary for this application. Powered from a low-voltage rechargeable battery it is easy and safe to use. In its standard configuration the system consists of an MCU (Measurement Control Unit) in a metal housing and 12 x heat flux and surface temperature sensors of model HF01. Measured data are stored for later analysis.

Figure 0.1 *the ALUSYS measuring system, for trend -monitoring and comparative surveys of heat flux and surface temperature in industrial environments. Connected to the MCU: one HF01 sensor, as well as the Keyboard Display.*

ALUSYS measures heat fluxes and surface temperatures in demanding environments. It is designed for industrial surveys, for example surveys of aluminium smelters / furnaces.

The ALUSYS system employs dedicated sensors and electronics. Their high accuracy and sensitivity ensure that ALUSYS will still measure under circumstances where competing systems no longer perform reliable measurements; i.e. down to very low heat fluxes.

The measurement and control unit, MCU, has a robust aluminium housing and accepts 12 (order code ALUSYS12) or optionally 3 sensors (order code ALUSYS03).

The system generates a measurement file, including a time-stamp, heat flux and temperature for all sensors. The measurement is stored in the MCU and later downloaded to a PC. The user is responsible for data analysis.

A PC or the Keyboard Display may be used for real time measurement review and control of data stoarage and starting and stopping the measurement.

Powered and charged using a low voltage, ALUSYS is safe to use. The system can operate for a limited time on MCU's internal recharable battery.

For all information on the HF01 heat flux and surface temperature sensors, see the HF01 manual. Optionally other sensor models may be used.

The standard system is equipped with one 15 m long extension cable with 2 connectors for every heat flux sensor.

ALUSYS advantages are:

- robust
- high accuracy, also measuring at low heat flux levels
- equipped with its own clock
- safe, low voltage 12 VDC power supply

Advantages of HF01 heat flux and surface temperature sensor relative to competing models are:

- robust, in particular at high temperatures
- fast response time, reduces the time needed for a survey

ALUSYS and the sensor model HF01 are most suitable for relative measurements, i.e. monitoring of trends relative to a certain reference point in time or comparing heat flux at one location to the heat flux at another location.

Also when performing relative measurements we recommend you to perform an on-site comparison to verify sensor performance. A comparison is made by mounting multiple sensors side by side, and comparing under conditions – temperature, mounting surface and local convection – representative of your test environment. One sensor must serve as a comparison reference. Typically this comparison reference sensor is not used for field measurements but stored in a safe place, so that the same comparison may be repeated at a later moment.

If the user wants to perform accurate absolute measurements, as opposed to relative measurements, we recommend that you calibrate sensors under "simulated service conditions". This is done by creating an environment that closely resembles the measurement conditions while generating a known heat flux; the calibration source might even be the object under test itself. Calibrations are typically traceable to electrical power (voltage and current) and length (surface area of the calibration source). We recommend to calibrate at different temperatures.

Under all conditions the user must make his own uncertainty evaluation and correction for systematic errors.

Options are:

- ALUSYS with 3 heat flux and temperature sensors (ALUSYS03)
- longer length low temperature extension cables with 2 connectors (specify cable length)
- use of other sensor models than HF01
- sensors with extended rated operating temperature range
- MCU with extended rated operating temperature range

Figure 0.2. *HF01 heat flux and surface temperature sensor with frame with magnets*

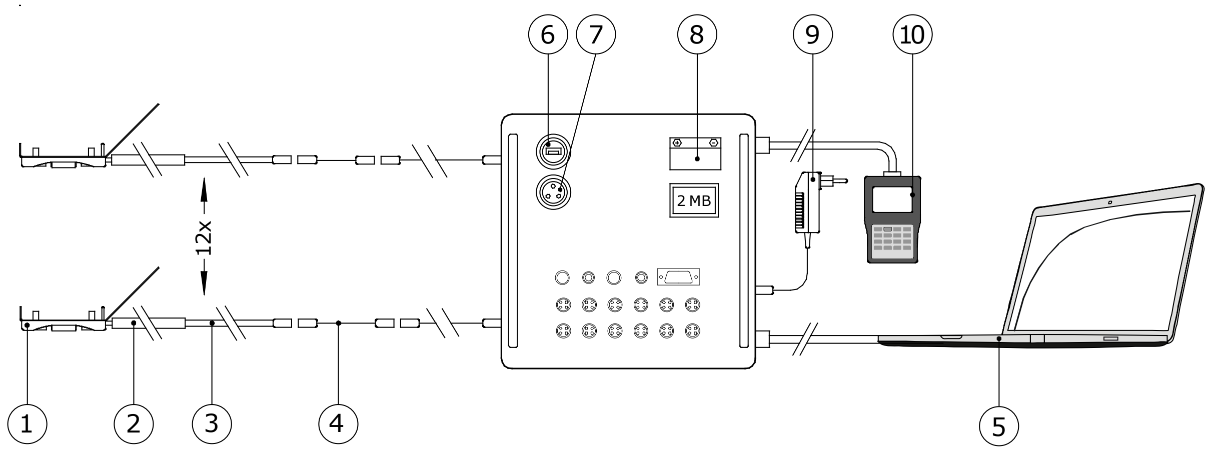


Figure 0.3 *the ALUSYS measuring system;*
(1) HF01 heat flux sensor (with magnet frame), (2) HF01 high temperature cable with silicone sleeve, (3) HF01 low temperature extension cable with connector at the cable end, (4) low temperature extension cables with 2 connectors, (5) PC or laptop (not part of the system). On or inside the MCU: (6) chassis connector for PC connection via USB, (7) chassis connector for power supply to internal battery charge controller, (8) rechargeable battery. Outside the MCU: (9) adapter (100 - 240 VAC), (10) Keyboard (LCD) Display. Items 6 to 9 are part of the MCU.

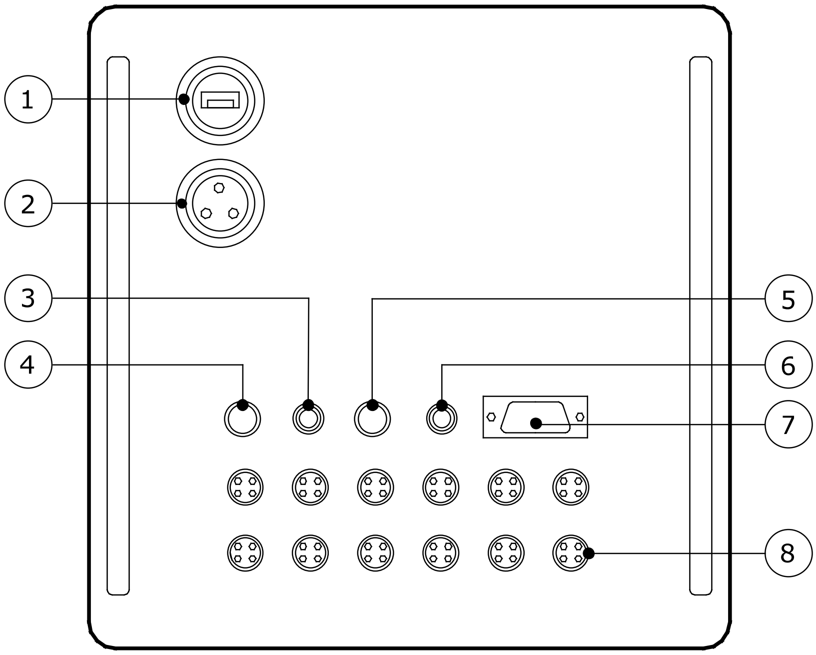


Figure 0.4 *The MCU in detail*
(1) chassis connector for communication with the PC / laptop via USB port
(2) chassis connector for power supply to internal battery holder/ charge controller
(3) red LED [ON] indicating the system receives power
(4) power switch [ON/OFF]
(5) switch for starting recording of measurements [TOGGLE]
(6) green LED [ON] indicating the system is recording measurements. When blinking consult Chapter 9.3
(7) SUB-D connector for the Keyboard Display
(8) chassis connectors for the individual heat flux and temperature sensors

1 Ordering and checking at delivery

1.1 Ordering ALUSYS

The standard configuration of ALUSYS is equipped with 12 x HF01 heat flux and temperature sensor, each with 0.9 m high temperature cable and 3.5 m low temperature extension cable and connector at the cable end. Each heat flux sensor is supplied with 15 m low temperature extension cable with 2 connectors.

Common options are:

- ALUSYS system with 3 x HF01
- low temperature extension cables with 2 connectors (specify cable length)
- other sensor models than HF01
- sensors with extended rated operating temperature range
- MCU with extended temperature range

1.2 Included items

Arriving at the customer, the delivery should include:

- carrying case
- ALUSYS
    - 12 or 3 x HF01 with connector at cable end
    - 1 x MCU01
- adapter 18 VAC
- USB cable
- RS-232 cable (9-pin)
- ALUSYS software (on USB flash drive)
- Loggernet software (on CD-ROM)
- SC USB driver software (on CD-ROM)
- 1 x product certificate ALUSYS
- 12 or 3 x product certificate HF01
- 12 or 3 x HF01 low temperature extension cable with 2 connectors 15 m
- Keyboard Display with cable

2 Instrument principle and theory

2.1 MCU01 Measurement system

MCU01 is a high-accuracy battery-powered measuring system inside a robust housing. It is equipped with a clock and memory. It measures the voltage output of heat flux sensors as well as thermocouples. It has an on-board temperature sensor that acts as a cold junction measurement for the thermocouples. The cold junction temperature can be read from the Ptemp variable (ALUSYS03) or from AM25Ttemp variable (ALUSYS12).

MCU is equipped with on [ON-OFF] button to activate power and a [MEASUREMENT] button to manually start and stop a measurement and data storage of all sensors. MCU communicates with a PC through its Loggernet user interface software. It can also be connected to the Keyboard Display.

The MCU is running the ALUSYS software. The software allows 3 measurements:

- [average] measurement: average heat flux and temperature for a group of 3 sensors. The data are stored for every individual sensor over a single preset time interval. In case you employ 12 sensors there are 4 x groups. This measurement allows you to move around sensors per group on a large installation.
- [all sensors] measurement: average heat flux and temperature for all sensors. Data are stored for all individual sensors at a preset time interval until stopped. This measurement is used for long-term monitoring using all sensors
- [sensor details]: stored on command. To store sensor parameters and internal battery voltages.

MCU's rated temperature range is limited by the formal battery charging and discharging specifications. In practice MCU will continue working at lower temperatures, but at an unspecified battery capacity.

2.2 Electronics in MCU01

The electronics in MCU01 is a model CR1000 measurement and control system.
The USB connection on the MCU connects the CR1000 to a PC. As an alternative the RS232 connector is used to connect the CR1000 to the Keyboard display.

2.3 Rechargable battery and battery charge controller in MCU01

The MCU contains a model PS150 charge controller / battery holder.
The recharable battery is a 7Ah Lead Acid battery as used in small motorcycles. The charge controller accepts 18 to 24 VAC RMS or 16 to 40 VDC, and supplies an unregulated 12 VDC output, which is used to power the MCU electronics.

In case the battery output drops below 10 VDC, MCU's green LED will slowly blink [ON-OFF-ON-OFF] as a warning (see chapter 9.3).

This battery needs periodic recharging. We recommend recharging the battery every month. It must be removed and stored seperately if the equipment is stored for > 60 days. Consult the battery manufacturer for statements on battery lifetime.

MCU's rated temperature range is limited by the formal battery charging and discharging specifications. In practice MCU will continue working at lower temperatures, but at an unspecified battery capacity.

2.4 The Keyboard Display

The Keyboard Kisplay is a simple user interface with a LED screen and a small number of keys. Using the display you can view realtime data, control the experiment: start and stop measurements and data storage.

The Keyboard Display offers a simple alternative to using a PC as user interface.

Keyboard Display and PC cannot be used simultaneously.

2.5 Heat flux sensor HF01

For the measurement principle and theory of the HF01 heat flux sensor, see the HF01 manual.

Heat flux sensors have individual sensor properties, such as their sensitivity and possibly their temperature dependence. It is important that the MCU has the right sensor information entered into its internal software the for each input channel.

Optionally other sensor models may be supplied instead of HF01.

2.6 Adapter

The adapter supplied with ALUSYS is an 100/240 VAC Desktop AC-DC Adapter 24 VDC @ 1.67 A. The external plug on the MCU is connects the adapter to the internal battery charge controller.

2.7 Optional ALUSYS with 3 x heat flux and temperature sensor

This manual is written for the standard version with 12 x heat flux and temperature sensor.
The optional version with 3 sensors:

- is supplied with 3 x sensor
- is supplied with 3 x chassis connector on the MCU
- does not have an internal multiplexer; cannot accept more channels without significant modification
- uses the [average] measurement per 1 x sensor, and not for a group of 3 x sensor

3 Specifications of ALUSYS

ALUSYS is a system for on-site measurement of heat flux and surface temperature in demanding environments. The system is equipped with MCU high-accuracy electronics in a robust housing, and several (12 x, optionally 3 x) heat flux and temperature sensors of model HF01. Optionally other sensor models may be used. The sensors are mounted on the surface under test. The system includes Loggernet user interface software for use on a PC, an adapter for power supply and a Keyboard Display for realtime readout and control of the measurement in the field. Working on 12 VDC it is safe. The system works independent of mains power on its own battery for > 24 hours. A PC is not included. Data review and analysis is the responsibility of the user.

Table 3.1 *Specifications of ALUSYS (continued on next page)*

ALUSYS SPECIFICATIONS	
Description	Measuring system for heat flux and temperature survey
Number of measurement locations	12 (see options)
Measurand	heat flux (12 x)
Measurand in SI units	heat flux density in W/m²
Measurand	surface temperature (12 x)
Measurand in SI units	temperature in °C
Time registration	on board clock, synchronised via user interface on PC
Required data analysis	to be performed by the user
Heat flux sensors (see options)	model HF01 , high temperature heat flux sensor, with frame with magnets, with connector at cable end
Extension cables	for every heat flux sensor: 1 x low temperature extension cables with 2 connectors (length 15 m)
Rated operating temperature ranges	HF01 with high temperature cable: -30 to 550 °C low temperature extension cable: -30 to 240 °C MCU: -15 to +50 °C MCU: non-charging -20 to +50 °C Keyboard Display: -25 to +50 °C
IP protection class	HF01 & high temperature cable: IP68 low temperature extension cable: IP67 MCU and Keyboard Display: IP63 adapter: IP60
Rated operating relative humidity range	0 to 100 % (non-condensing)
Gross weight	approx. 17 kg (no sensors, no extension cables)
Net weight total ALUSYS excluding carrying case	15 kg (no sensors, no extension cables)

Table 3.1 *Specifications of ALUSYS (started on previous page, continued on next page)*

MCU01	
Measurand	analogue voltage and conversion to heat flux using the sensitivities of the heat flux sensors
Voltage measurement accuracy	0.5×10^{-6} V
Measurand	analogue voltage and conversion to temperature using the panel temperature and general thermocouple type K characteristics
Measurand	panel temperature to serve as a cold junction reference temperature for the thermocouple measurements
Measurand	date and time, rechargable battery voltage, internal system battery voltage
Data display	on Keyboard Display
Sample rate	1 1/s
Stored measurement definition	[average] measurement: average heat flux and temperature for a group of 3 sensors, stored for every individual sensor over a single preset time interval [all sensor] measurement: average heat flux and temperature for all sensors stored for all individual sensors at a preset time interval until stopped [sensor details]: stored on command
Storage capacity	> 30 days
Rated power supply and charging voltage range	16 to 40 VDC
Connection to PC	via USB
USB cable length	1.9 m
User interface on PC	Loggernet software (supplied on CD-ROM)
Memory capacity	4 MB > day of data
System requirements for use with PC	Windows XP and later, CD-ROM drive, USB port, and USB or RS-232 (COM) port
Program running on MCU	ALUSYS program (supplied on USB flash drive)
Power switch / LED	red LED [ON] when power is supplied to MCU
Measurement switch / LED	TOGGLE, green LED [ON] when measurement active and data is stored
MCU dimensions	(320 x 320 x120) x 10^{-3} m, brackets of 42 x 10^{-3} m
Connection to Keyboard Display	via SUB-D connector
ADAPTER	
Adapter rated power supply	100 - 240 VAC, 50 / 60 Hz
Adapter output	18 VAC @ 1.2 A
BATTERIES	
Rechargable battery	12V 7Ah Sealed Lead Acid Battery, for example EnerSys Genesis NP7-12
Battry low indicator	green LED
Rechargable battery disposal	follow local regulations
Measurement time interval on a fully charged battery	> 24 hr
Required charging time interval	12 hr
Internal system battery	powering the clock and the SRAM when no external power is connected. Type: 3.6 VDC, 1.2 Ahr, 1/2 AA size cell.
HF01 HEAT FLUX SENSOR	
Specifications	see HF01 manual

Table 3.1 *Specifications of ALUSYS (started on previous pages)*

INSTALLATION AND USE	
Performing a representative measurement	see the chapter on recommended practices for use and the sensor manual
Installation	see the chapter on recommended practices for use and the sensor manual
Cable extension	use optional low temperature extension cable with 2 connectors
CALIBRATION AND FUNCTIONAL TEST	
Production report	included
Performance verification	via functional test
Calibration traceability	HF01 and MCU are traceable to SI units
Uncertainty of calibration of heat flux sensors	± 20 % (k = 2, for model HF01)
Recommended recalibration interval	2 yr
On-site performance verification	see the chapter on calibration and checks in the field: for accurate trend monitoring and relative measurements: perform an on-site comparison. if you want to perform accurate absolute measurements, as opposed to relative measurements we recommend that you calibrate sensors under "simulated service conditions".
MEASUREMENT ACCURACY	
Uncertainty of the measurement	statements about the overall measurement uncertainty can only be made on an individual basis. also see the HF01 manual.
VERSIONS / OPTIONS	
Extension cable	low temperature extension cable with 2 connectors (standard length 15 m, specify lentgth in m)
Other sensors	other sensor models than HF01
Less sensors	ALUSYS with 3 x heat flux and temperature sensor
Higher temperature range sensors	sensors with extended rated operating temperature range
Higher temperature range MCU	MCU with extended rated operating temperature range

4 General directions for performing a heat flux and temperature measurement

There are no standard operating practices for using ALUSYS. We recommend reading the manual of the sensors connected to ALUSYS. Typically this is sensor model HF01.

5 Arrival of a new ALUSYS

5.1 Preparation before arrival

As a preparation, preferably the operator should read this manual.

Table 5.1.1 *List of items that the operator should have available*

ITEM	REMARKS
PC	running Windows XP or later, with CD-ROM drive and one free USB port
Power	110-240 VAC

5.2 Checking upon arrival

When the instrument arrives, it is recommended to check if the delivery is complete. The list of delivered items can be found in the chapter on Ordering and checking at delivery. For the most common overall system check, see the next chapter.

6 System setup and functionality check

The user should be familiar with the warning statements given on page 2 of this manual.

6.1 Setup and functionality check in summary

Table 6.1.1 summarises the setup procedure and a quick system test. The remainder of this chapter explains this in detail.

Table 6.1.1 *Summary of procedures for system setup and a quick system test*

	PROCEDURE
1	install the USB driver
2	install the Loggernet user interface software
3	connect the MCU to power using the Adapter
4	connect the MCU to the PC, using the USB cable, switch on the MCU power
5	connect at least 2 sensors: test the response of the sensors by touching them with your hand
6	make contact with the MCU through Loggernet get the heat flux and temperature data on screen
7	verify that the right serial numbers, sensitivities, reference temperatures and temperature coefficents are entered in the ALUSYS program
8	choose which measurement to perform (average, or all-sensors)
9	check the functionality of the Keyboard Display
10	try downloading data to a PC

6.2 Software installation

Table 6.2.1 *Procedures to install software on the PC*

	PROCEDURE
1	make a backup of all received files, store the serial number and user access code of the Loggernet software in a safe place
2	install the USB driver (delivered on CD-ROM)
3	install the LoggerNet software starting the windows explorer and double clicking the application "Autorun". The latest versions of LoggerNet are delivered on CD-ROM. The installation procedure is straighforward. The directory in which the software is installed is usually called LoggerNet.
4	the ALUSYS software is delivered on a USB flash drive. File extensions are: .CR1 & .DLD. upon delivery the ALUSYS software is already installed on the MCU and "running on power-up".

6.3 PC connection and defining the user interface

Table 6.3.1 summarizes the procedure of connecting to the MCU and creating a user interface. Step 3 and 4 are explained in detail in this section.

6.3.1 Loggernet user interface

Figure 6.3.1.1 *The main menu of Loggernet. The MCU can be connected through [Setup]. During normal operation only [Connect] is used*

Table 6.3.1.1 *Guidelines on how to make contact with the MCU through Loggernet*

	PROCEDURE
1	select [SETUP] - [Add]
2	select CR1000, and give it the appropriate name: 'ALUSYS'
3	select [Direct Connect]
4	select what COM port (typically COM port 1) you plugged the cable in. Set delay at 0.
5	set Baud Rate to 115200
6	set Dataloggers' clock if the datalogger time does not match the server time
7	check if ALUSYS v1705.cr1 is running. If the program is not running, browse to where the ALUSYS program is situated (supplied with the system on a USB flash drive) and click [OK]
8	select AllSens in Tables. Make sure option Table Collected during Data Collection is turned [ON]. Data file option should be: Append to File. Output file should be: C:\CampbellSci\LoggerNet\CR1000_AllSens.dat
9	Repeat preceeding operation for tables: AvgSens1 AvgSens2 AvgSens3 AvgSens4 SensDet
10	we recommend to select 'Scheduled Collection Enabled'

6.3.2 Get real time heat flux and temperature data

From the main menu open the [Connect] screen.

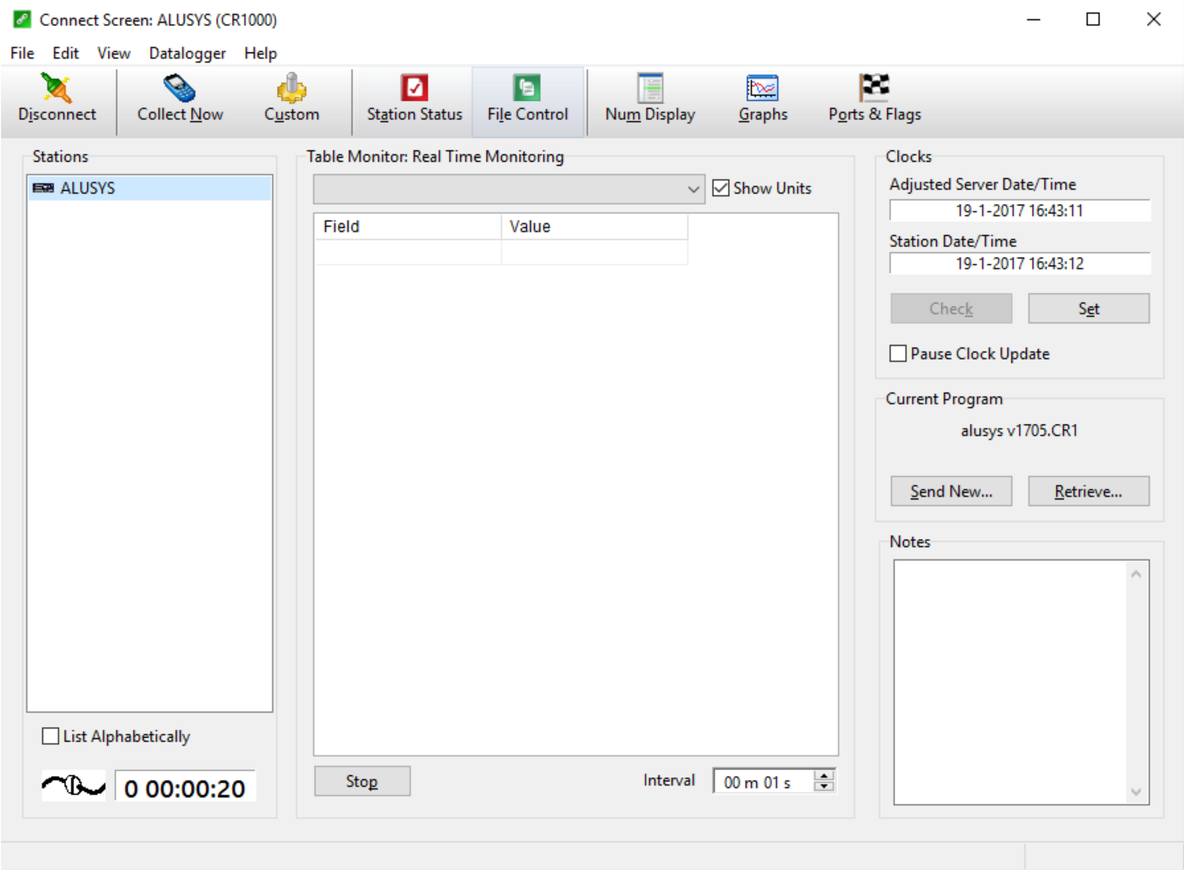


Figure 6.3.2.1 *The screen in Connect. During normal operation the [Numeric] and [Graphs] buttons are used for on-screen data display*

Before starting operation a few elementary steps should be performed:

Table 6.3.2.1 *Verification of contact, synchronising data and time*

1	Press [connect] in the lower left hand corner	The lower left hand corner of the screen shows "connected", and the clock synchronisation of the upper right hand corner shows that the Datalogger time/date is running
2	Press Set Station Clock to set it to the correct date and time	

Check that the correct program is running:

Table 6.3.2.2 *Verification of program*

1	Press [File Control] in the middle of the toolbar on top	The 'File Control' panel should open
2	Check that alusys v1705.CR1 is present on the system	
3	Check that ALUSYSLIBv1701.dld is present on the system	
4	If either of the files are missing, press [send] on the upper left of the tool bar	An upload dialogue box should appear
5	Browse to where the Alusys program is situated and upload both files, regardless of them being present already. Do not choose any run options when uploading the files!	The program will alert when uploading has finished
6	After uploading both files, select the alusys v1705.CR1 and press [Run Options] in the middle of the toolbar on top	The run dialogue box should appear
7	Select run now and run on power-up options. Clearing previous data is optional. Press Ok	The alusys v1705.CR1 program should start recompiling and will alert when it starts running

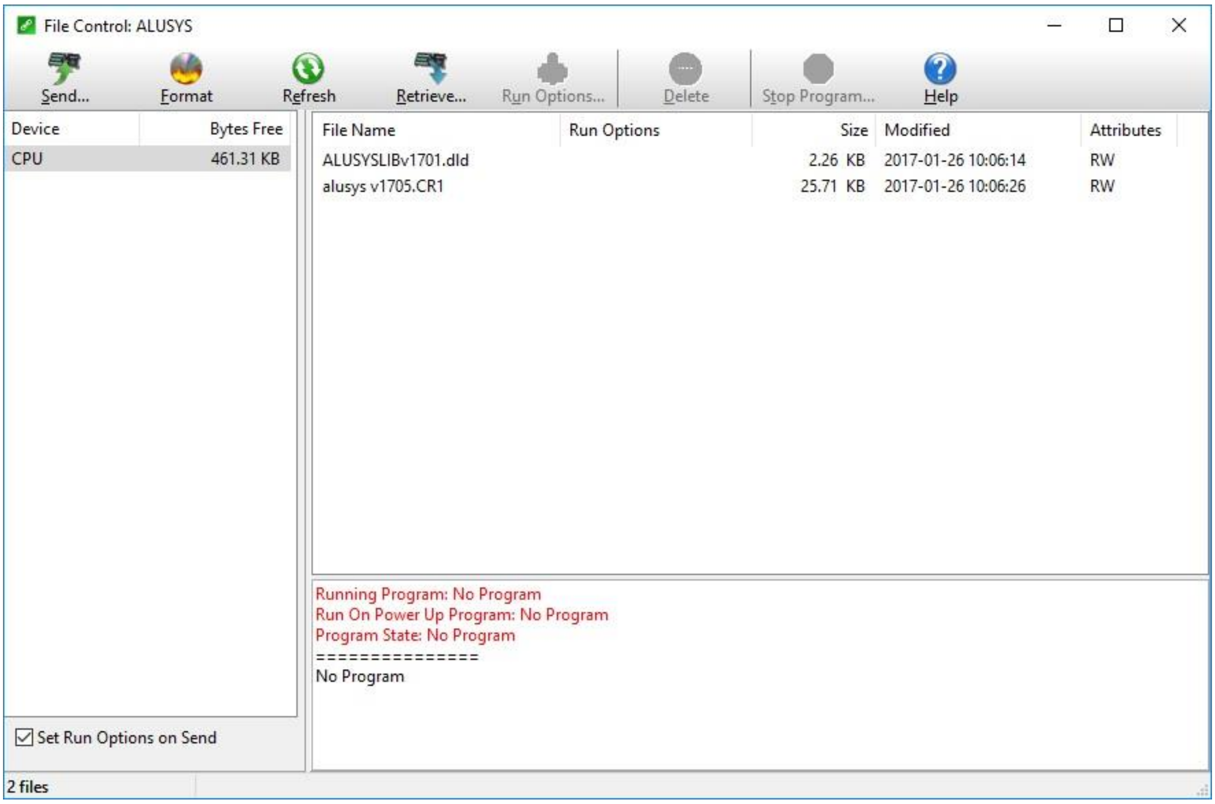


Figure 6.3.2.2 *The 'File control' panel*

On the [Connect] screen, the [numeric display] can be used to view various parameters numerically. Parameters can be added through the [Add] menu.

Definitions of the parameters used in the program are given in Appendix 10.1.

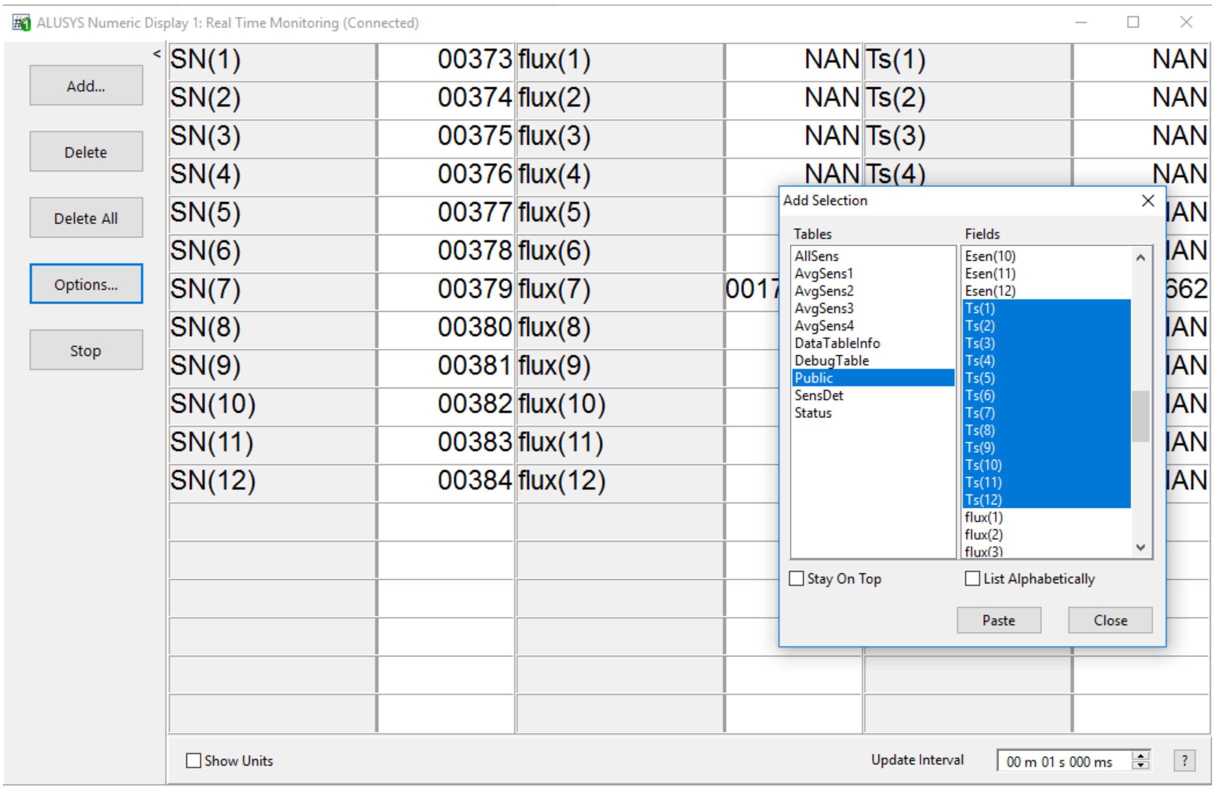


Figure 6.3.2.3 *A [Numeric Display] is used to view the value of parameters numerically. Parameters can be added by pressing [Add], selecting [Public] and dragging the parameters to be viewed to the table. We recommend to display sensor serial number, heat flux and temperature for each sensor*

The [graph display] can be used to view various parameters graphically. Parameters can be added through the [add] menu.

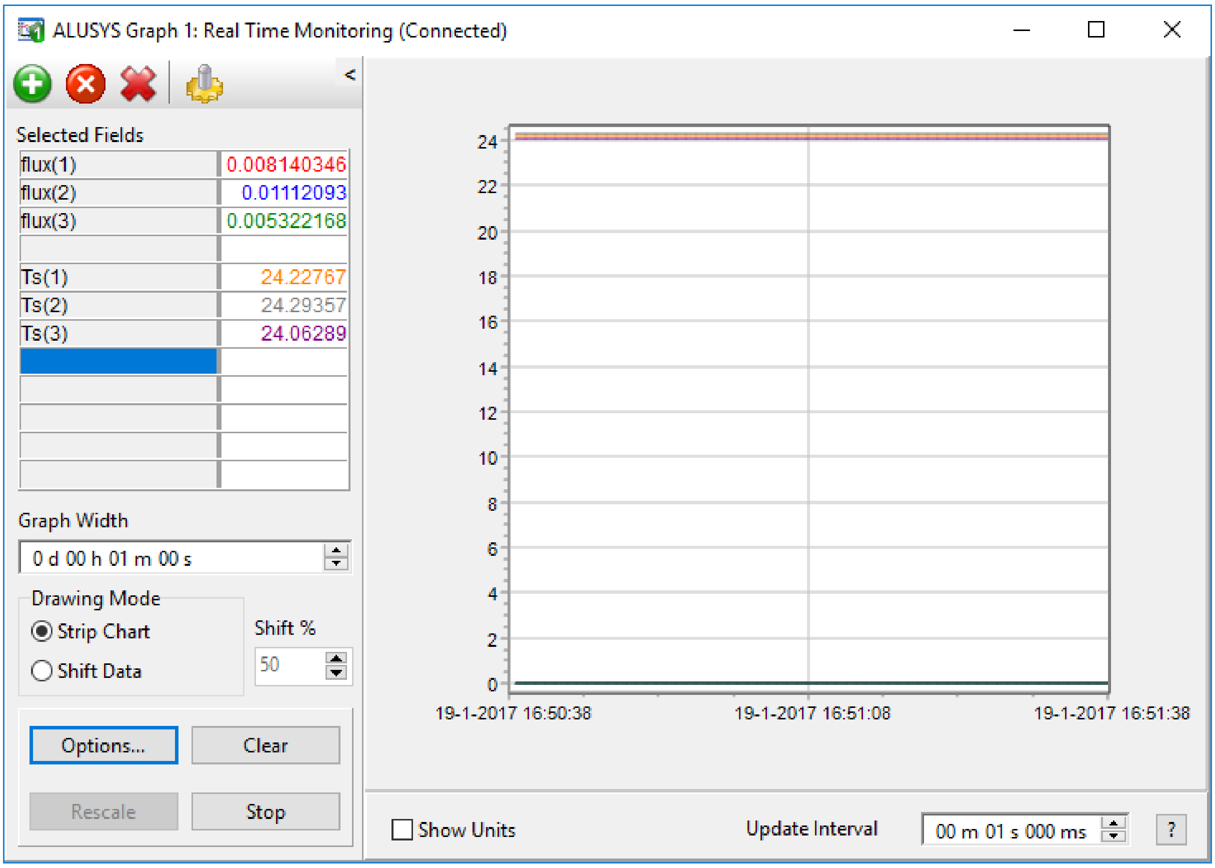


Figure 6.3.2.4 *The Graph Display can be used to view the value of parameters graphically. Parameters can be added by pressing [+], selecting [Public] and dragging the parameters to be viewed to the table. By right clicking on the parameter, color and axis can be changed*

6.4 Creating control buttons

Activating a flag triggers pre-programmed functions for the MCU. Ports are indicators for the status of a control port. We use ports and flags as buttons to control the measurement.

Create the following screen in the [CONNECT] screen choosing [PORTS AND FLAGS] and [ADD], pasting from [PUBLIC]

Pressing the green button left of the name of the flag, activates this flag.

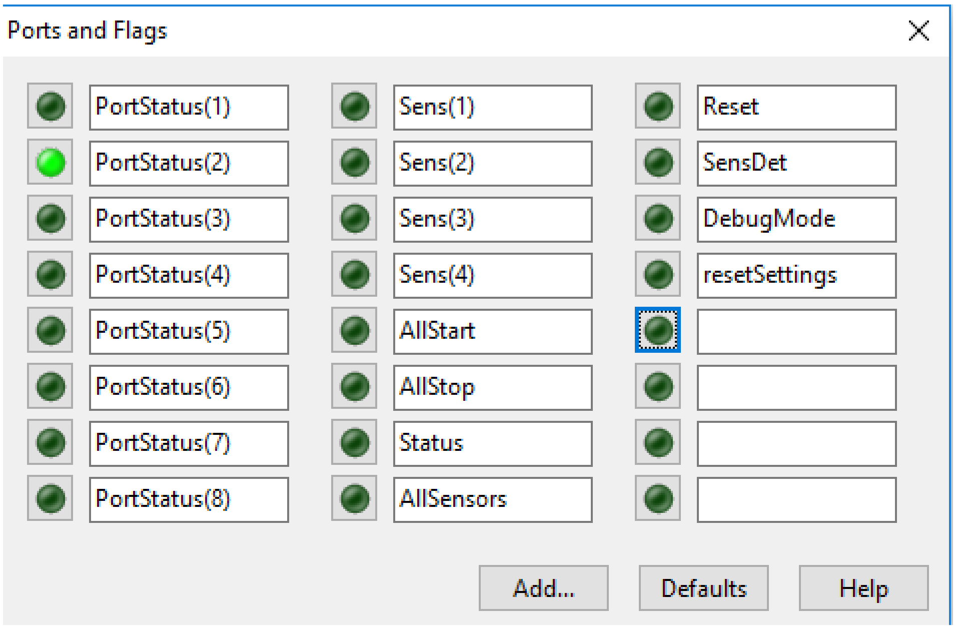


Figure 6.4.1 *The [Ports and Flags] display*

6.5 Functionality check

Table 6.5.1 *Testing the functionality of the system*

PROCEDURE	
Connect sensors	
Collect calibration certificates	Heat flux sensors are individually calibrated and have individual properties. Sensor parameters can be found on their calibration certificates.
Check whether the correct serial numbers, sensitivities, reference temperatures and temperature dependencies are entered in the ALUSYS program running on the MCU	Use the [NUMERIC] screen and check the values of [Esen], [Tref], [TD], and [SN] for each sensor. The values can be changed by double clicking on it and entering the new/correct value.
Push the flag [ALLSTART] to start measuring and storing data.	Verify that the green LED is [ON]
Test the heat flux and temperature response of individual sensors	Touch sensor with your hand or expose to a stronger heat source.

7 Installation of sensors

7.1 Site selection and installation

Table 7.1.1 *Recommendations for installation of heat flux sensors and temperature sensors*

General	Consult the HF01 manual Take into account local safety regulations
Sensor mounting	Avoid any air gaps between sensors and wall. Brush off any corrosion with a steel brush

8 Making measurements

Having prepared the system according to the directions given in chapter 6 & 7, the system is now ready for measuring. See the next paragraph for explanation of the experiment control.

A typical measurement sequence is as follows:

Table 8.1 *Typical measurement sequence*

1	switch the system [ON],	red LED [ON]
2	connect PC or Keyboard Display	
3	connect sensors to the system	
4	push flag [Sensdet]	stores sensor data
5	install sensors on measurement location	
6	choose between the [average] measurement, per group of 3 sensors, or the [all sensor] measurement if needed change [interval] via the numeric screen (typing the value and confirming with [ENTER], or via the Keyboard Display)	
7	for the [average] measurement press flags [sens 1] to [sens 4] for the [all sensor] measurement press flag [allstart]	green LED [ON]
8	measure	
9	the [average] measurement will stop measuring automatically at [interval] setting the [all sensor] measurement can be stopped by pressing flag [allstop]	green LED [OFF]
10	regularly check the measurements by verification of data files and by viewing actual data in the graphs / on the keyboard display	

8.1 Controlling the measurement

Pressing the green button left of the name of the flag, activates this particular flag.

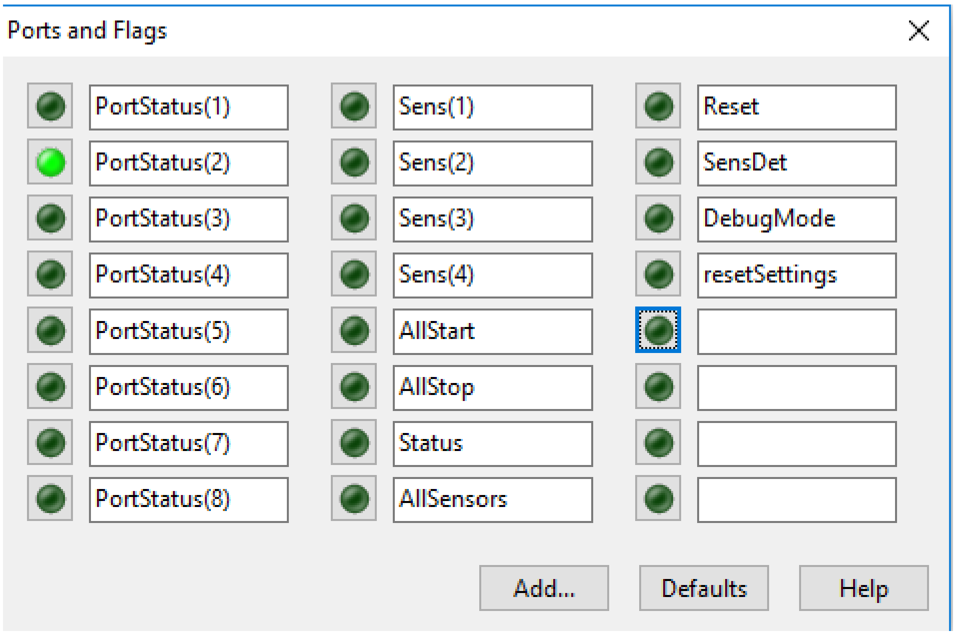


Figure 8.1.1 *The [Ports and Flags] display in the [numeric] screen*

Table 8.1.1 *Explanation of the different flags and ports*

Port Status 1	multiplexer activity
Port Status 2	multiplexer activity
Port Status 3	measurement active
Port Status 4	-
Port Status 5	-
Port Status 6	-
Port Status 7	-
Port Status 8	-
Sens 1	measure sensor group 1 (optionally measure sensor 1)
Sens 2	measure sensor group 2 (optionally measure sensor 2)
Sens 3	measure sensor group 3 (optionally measure sensor 3)
Sens 4	measure sensor group 4 (Note: this flag is not used in ALUSYS03 with only 3 sensors)
Allstart	all sensors [ON]: continuous measurement
Allstop	all sensors [OFF]: stop continuous measurement
Status	[ON] if any measurement is running
Reset	interrupt all ongoing measurements
Sensdet	write sensor details to memory
DebugMode	sets the MCU in debug mode; every 30s the system will log debug data
ResetSettings	resets the system back to factory default settings and resets all active measurements

8.2 Measurement per sensor group - average

With the average instruction the user measures heat flux and temperature of a group of 3 sensors during a set time interval, and store the average. The [interval] default value is 30 s. The output is an average of measured data over that interval. After the interval, the measurement stops automatically.

8.2.1 Control via PC

Table 8.2.1.1 *Setting the [interval] value, via USB to PC*

open the [connect] screen	
select [Interval] from the [public] table	default is 30 s
change the value and press [ENTER]	

To start the averaging measurement:

Table 8.2.1.2 *Performing a measurement of a group of sensors for a short time interval, via USB to the user interface on PC*

open the [connect] screen	
select [ports and flags]	default is 30 s
press [sens 1] to activate sensors 1, 2 and 3 press [sens 2] to activate sensors 4, 5 and 6 press [sens 3] to activate sensors 7, 8 and 9 press [sens 4] to activate sensors 10, 11 and 12	

8.2.2 Control via Keyboard display

The user may also use the keyboard display to control the measurement:

Table 8.2.2.1 *Performing a measurement of a group of sensors for a short time interval, via the Keyboard Display*

after startup, press any key on the Keyboard Display	[Heat Flux Meas] will appear on screen
select [measurement par] with the cursor confirm with [ENTER]	[Measurement par] will appear on screen
the parameters can be changed	[ENTER] and use numeric keys
[Esc] to go back to the [Start] screen	
[Start] Screen, press [Measurement Ctrls]	[Measurement ctrls] appears on screen
select the required [Avg group], [ENTER]	changes to [TRUE]. Measurement [ON], green LED [ON]
[Dev status] will change to [TRUE]	
measurement stops automatically	green LED [OFF]

Figure 8.2.2.1 *activating the measurement via the Keyboard Display*

8.3 Measurement for all sensors - allsens

With the 'allsens' instruction you measure heat flux and temperature of all connected sensors until manually stopped. The data is stored at a time interval [scanrate].

8.3.1 Control via PC

Table 8.3.1.1 *Setting the [scanrate] value, via USB to PC*

open the [connect] screen	
select [scanrate] from the [public] table	default is 1 min
change the value and press [ENTER]	

For the actual measurement:

Table 8.3.1.2 *Performing an all sensor measurement, via USB to PC*

open the [connect] screen	
select [ports and flags]	default is 1 min
press [allstart] to activate all sensors	green LED [ON]
press [allstop] to stop all sensors	green LED [OFF]

8.3.2 Control via Keyboard Display

You may also use the Keyboard Display to control the measurement:

Table 8.3.2.1 *Performing an all sensor measurement, activated by the Keyboard Display*

after startup, press any key on the Keyboard Display	[Heat Flux Meas] will appear on screen
select [measurement par] with the cursor confirm with [ENTER]	[Measurement par] will appear on screen
the parameters can be changed	[ENTER] and use numeric keys
[Esc] to go back to the [Start] screen	
[Start] Screen, press [Measurement Ctrls]	[Measurement ctrls] appears on screen
select [start measure], [ENTER]	changes to [TRUE]. Measurement [ON], green LED [ON]
[Dev status] will change to [TRUE]	
[STOP MEASURE], [ENTER] Measurement stops	green LED [OFF]

8.4 Realtime display of measurements

Display of realtime data is possible via PC or Keyboard Display:

Table 8.4.1 *Viewing realtime measurements on the PC*

open the [connect] screen	
select [graph] or [numeric display]	
Select [public]	select required fields
press [allstop] to stop all sensors	green LED [OFF]

Table 8.4.2 *Viewing the realtime measurements on the Keyboard Display*

after startup, press any key on the Keyboard Display	[Heat Flux Meas] will appear on screen
Select [current sens val] with the cursor confirm with [ENTER]	measurement values will appear on screen

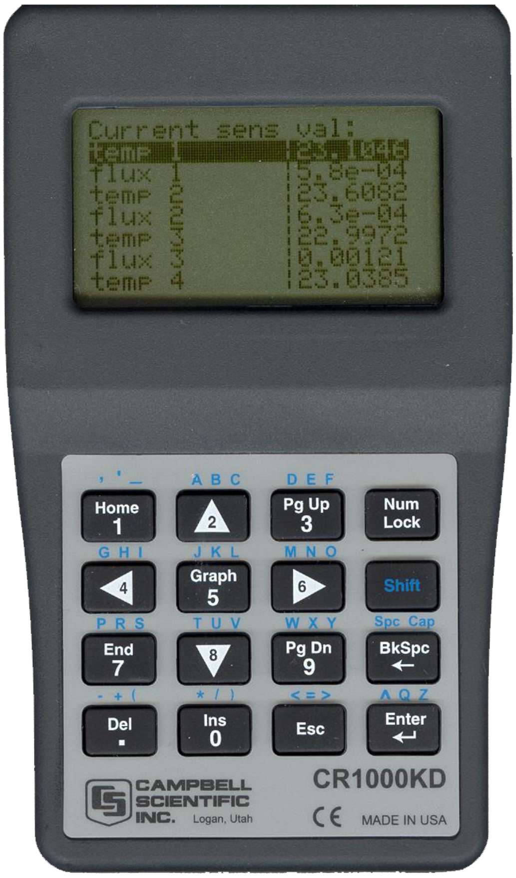


Figure 8.4.1 *Screenshot of the Keyboard Display, showing values of heat flux and temperature for sensors 1 to 4*

8.5 Downloading data to the PC

The measurement data are stored in the CR1000 electronics of the MCU. These data can be retrieved for further analysis.

Table 8.5.1 *Retrieval of measurement data from the MCU to the PC*

	PROCEDURE
1	detailed measurement data can be retrieved using [Collect Now] in the [Connect] screen
2	when retrieving data, immediately make a backup. For example by saving the data on memory card or hard disk
3	details regarding data analysis can be found in the manual of the sensors
4	default directory: C:\CampbellSci\LoggerNet\

Table 8.5.2 *Data are stored in 3 separate files*

	INFORMATION	FILENAMES	STORED DATA PER SENSOR
1	Sensor and battery	CR1000_SensDet.dat	SN Esen TD Tref minimum voltage rechargeable battery minimum voltage lithium battery
2	Interval data per sensor group	CR1000_AvgSens1.dat CR1000_AvgSens2.dat CR1000_AvgSens3.dat CR1000_AvgSens4.dat	Avgflux AvgTs E (effective sensitivity at that temperature) Interval
3	All sensor data	CR1000_AllSens.dat	E Flux Ts Scanrate

The files are comma separated ASCII. They can easily be imported in Excel if the user uses the following procedure:

Table 8.5.3 *Procedure for getting the ASCII-data in an Excel file*

	PROCEDURE
1	open Excel
2	choose [Open file] and select the desired data file
3	choose [Separated] in Step 1 and select Next
4	select [Comma] at [Separation Signs] and uncheck [Tabs] then select [Next]
5	if you have the [comma] assigned as the [decimal separator], select [Advanced]
6	if you have the [comma] assigned as the [decimal separator], choose [.] (dot) as [decimal] and [,] (comma) as [thousands] separator. Select [OK]
7	select [Finish]

9 Maintenance and trouble shooting

9.1 Employing new sensors / resetting sensor parameters

Heat flux sensors are individually calibrated and have individual sensitivities. A certain sensor model also has a calibration reference temperature and temperature dependence. The serial number of the sensor can typically be found between the metal cable and PTFE cable. Its sensitivity, reference temperature and temperature dependence can be found on its calibration certificate.

Table 9.1.1 *Display and change sensor properties*

use the [Numeric Display] from the [Connect] screen	
sensitivity = Esen temperature dependence = TD calibration reference temperature = Tref	
double-click the numeric value of Esen for Sensor 1 and change it to the value on its certificate	this sensitivity is stored in the file CR1000_USB_SensDet.dat
note that the sensitivity values should be entered in x 10^{-9} V/(W/m^2)	for sensor model HF01, enter only the first three digits from the calibration certificate, usually a number around 600
the calibration reference temperature Tref	for model HF01 this is 90 °C
the temperature dependence TD	for model HF01 this is 0.0015 / K
repeat this operation for the value of Esen, Tref and TD of all other sensors	press [Sensdet]: all the values of sensitivity are stored in the file CR1000_USB_SensDet.dat
open [ports and flags] press [Sensdet]: all the values of sensitivity are stored in the file CR1000_USB_SensDet.dat	

9.2 Recommended maintenance and quality assurance

ALUSYS measures reliably at a low level of maintenance. Unreliable measurement results are detected by scientific judgement, for example by looking for unreasonably large or small measured values. The preferred way to obtain a reliable measurement is a regular critical review of the measured data, preferably checking against other measurements, or by comparing results of the two heat flux sensors and two thermocouples when mounted side by side.

Table 9.2.1 *Recommended maintenance of ALUSYS. If possible the data analysis is done on a daily basis*

MINIMUM RECOMMENDED ALUSYS SENSOR MAINTENANCE			
	INTERVAL	SUBJECT	ACTION
1	every measurement campaign	review sensor parameters	verify that the sensor serial numbers and parameters are correctly set.
2	every measurement campaign	on-site comparison	perform an on-site comparison of sensors, see appendix on on-site testing
3	every measurement campaign	storage	if the MCU is stored for more than 60 days you must remove the rechargeable battery. Store in a cool environment.
4	every measurement	data analysis	compare measured data between the measurement locations. Look for any patterns and events that deviate from what is normal or expected. Compare to acceptance intervals. Plot heat flux and temperature data against the other measurements if available. Inspect cable quality, inspect mounting
5	every month	recharging	the battery needs periodic recharging. We recommend recharging the battery every month.
6	12 months	inspection	side by side comparison of two heat flux sensors and their respective thermocouples when mounted side by side.
7	2 years	recalibration	recalibration of heat flux sensor and MCU by the sensor manufacturer
8		lifetime assessment	judge if the instrument will be reliable for another 2 years, or if it should be replaced
9	4 years		replace the battery of the CR1000, encased in the MCU
10	4 years		replace the rechargeable battery

9.3 Trouble shooting

Table 9.3.1 *Trouble shooting for ALUSYS*

General	Inspect the sensors and MCU for any damage. Inspect the quality of mounting. Check the condition of the cables. Check the datalogger program in particular if the correct sensor properties have been entered. Check the voltages of the rechargeable battery and of the internal system battery on the numeric screen. If problems persist, activate debugMode in the ports & flags panel. Check the debug table below. DebugMode logs the debugTable, which can be submitted to the manufacturer for troubleshooting
The HF01 sensor does not give any signal	Use the HF01 manual trouble shooting guide. Check the data acquisition by replacing the sensor with a spare unit.
There are doubts about the MCU measurement	Compare measurement results to those with a calibrated multimeter. Short-circuit the input using a 10 Ω resistor. The heat flux signal should be 0 W/m^2, the temperature signal should reach the panel temperature. A voltage source may be built from a 1.2 VDC battery, and a 1:1000 voltage divider, creating a 1 x 10^{-3} V source. Calculate the expected heat flux and temperature.
The sensor signals are unrealistically high or low	Check the cable condition looking for cable breaks. Check the data acquisition by applying a 1 x 10^{-6} VDC source to it in the 1 x 10^{-6} V range. Look at the measurement result. Check if it is as expected. Check the data acquisition by short circuiting the data acquisition input with a 10 Ω resistor. Look at the output.
The sensor signals show unexpected variations	Check the presence of strong sources of electromagnetic radiation (radar, radio). Check the condition and connection of the shield. Check the condition of the sensor cable. Check if the cable is not moving during the measurement.
The green measurement LED is blinking slowely (every 3s)	The voltage supplied by the internal battery has dropped below 10 V
The green measurement LED is blinking is rapidly	The library file is missing or has been corrupted. Consult chapter 6.3.2. DebugList(1) or DebugList(2) will probably be set to “True”

If any of the following values are set to “True”, the information on the right is applicable:

Table 9.3.2 *DebugTable for ALUSYS*

DebugList(1)	NumberOfSensors was set to > 3 while AM25T is set to not connected. Upload the original files as stated in chapter 6.3.2
DebugList(2)	NumberOfSensors was set to < 1 or > MaxSensors(12). Upload the original files as stated in Chapter 6.3.2
DebugList(3)	Scanrate has been set < 0. The software corrected this to 1 (scanrate = 1 min)
DebugList(4)	Battery voltage below 10 Volts
DebugList(5)	Interval has been set < 4. This is too low for the system (scanrate is 3s). The software corrected this to 30 (interval = 30 sec)
DebugList(6)	Unused
DebugList(7)	Unused
DebugList(8)	Unused
DebugList(9)	Unused
DebugList(10)	Unused

Table 9.3.3 *Trouble shooting for Keyboard display*

General	Check the Keyboard Display (CR1000KD) manual (CR1000 manual) for trouble shooting
The screen seems to be off	Check that the Keyboard Display is properly connected to the MCU Press and hold the 6 key to increase the contrast
The screen displays a black rectangle	Press and hold the 4 key to decrease the contrast
The contrast is off	Press and hold the 4 key to decrease the contrast or the 6 key to increase the contrast

9.4 Calibration and checks in the field

We recommend to re-calibrate the MCU and HF01 every 2 years at the manufacturer.

At Hukseflux HF01 sensors are calibrated under the following calibration reference conditions: heat flux of the order of 1500 W/m^2 , low convection, on a surface with zero in-plane conduction, at 90 °C.

These condictions may not be representative of the your actual measurement condition.

ALUSYS and the sensor model HF01 are most suitable for relative measurements, i.e. monitoring of trends relative to a certain reference point in time or comparing heat flux at one location to the heat flux at another location. Also when performing relative measurements, we recommend you to perform an on-site comparison to verify sensor performance. A comparison is made by mounting multiple sensors side by side, and comparing under conditions – temperature, mounting surface and local convection – representative of your test environment. One sensor must serve as a comparison reference.

Typically this comparison reference sensor is not used for field measurements but stored in a safe place, so that the same comparison may be repeated at a later moment.

If you want to perform accurate absolute measurements, as opposed to relative measurements we recommend that you calibrate sensors under "simulated service conditions". This is done by creating an environment which closely resembles the measurement conditions; the calibration source might even be the object under test itself. Calibrations are typically traceable to electrical power (voltage and resistance) and length (surface area of the calibration source). We recommend to calibrate at different temperatures.

Under all conditions you must make your own uncertainty evaluation and correction for systematic errors.

9.5 Storage of ALUSYS

MCU01 and sensors should be stored in a dry and cool place.

In case the system is stored for a longer time than 60 days, we recommend the rechargeable battery is separately stored or disposed. Consult the battery manufacturer for statements on battery lifetime.

10 Appendices

10.1 Variable names and description

Table 10.1.1 *Explanation of variables and parameters used in the ALUSYS program*

PARAMETERS USED IN ALUSYS PROGRAM		
PARAMETER	**DESCRIPTION**	**UNITS**
PTemp	Panel temperature	°C
Timestamp	Date and time	YYYY-MM-DD HH:MM:SS
Record	Number of the record	-
Flux (#)	Heat flux of sensor #	x 10^3 W/m²
Ts (#)	Temperature of sensor #	°C
E (#)	Sensitivity of sensor # (default 600)	x 10^{-9} V/(W/m²)
TD (#)	Temperature dependence of sensor # (default 0.000015)	1/K
Tref (#)	Calibration reference temperature of sensor # (default 90)	°C
SN	Sensor serial number	######
Interval	time interval for averaging measurements (default 30)	s
scanrate	Data storage time interval for all sensor measurements (default 1)	min
Batt volt	Voltage of the rechargeable battery	V
Ptemp	Internal MCU temperature	°C

10.2 Battery removal

The ALUSYS contains two batteries. A rechargeable battery to power the system and an internal system battery to power the system clock and SRAM. The minimum voltages of both batteries are stored in the datafiles, and can be viewed in the numeric display.

The rechargeable battery needs periodic recharging. We recommend recharging the battery every month. It must be removed and stored seperately if the equipment is stored for > 60 days. The removal of the rechargeable battery is self explanatory; open the, MCU disconnect the battery clamps and open the battery container.

For removal of the internal system battery: consult the manufacturer.

10.3 EU declaration of conformity

We,	Hukseflux Thermal Sensors B.V. Delftechpark 31 2628 XJ Delft The Netherlands

in accordance with the requirements of the following directive:

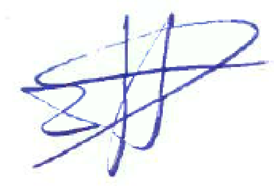
2014/30/EU	The Electromagnetic Compatibility Directive

hereby declare under our sole responsibility that:

Product model:	ALUSYS
Product type:	Measuring system for heat flux and temperature survey

has been designed to comply and is in conformity with the relevant sections and applicable requirements of the following standards:

Emission:	EN 61326-1 (2006)
Immunity:	EN 61326-1 (2006)
Emission:	EN 61000-3-2 (2006)
Emission:	EN 61000-3-3 (1995) + A1 (2001) + A2 (2005)
Report:	08C01340RPT01, 06 January 2009



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Director
Delft
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