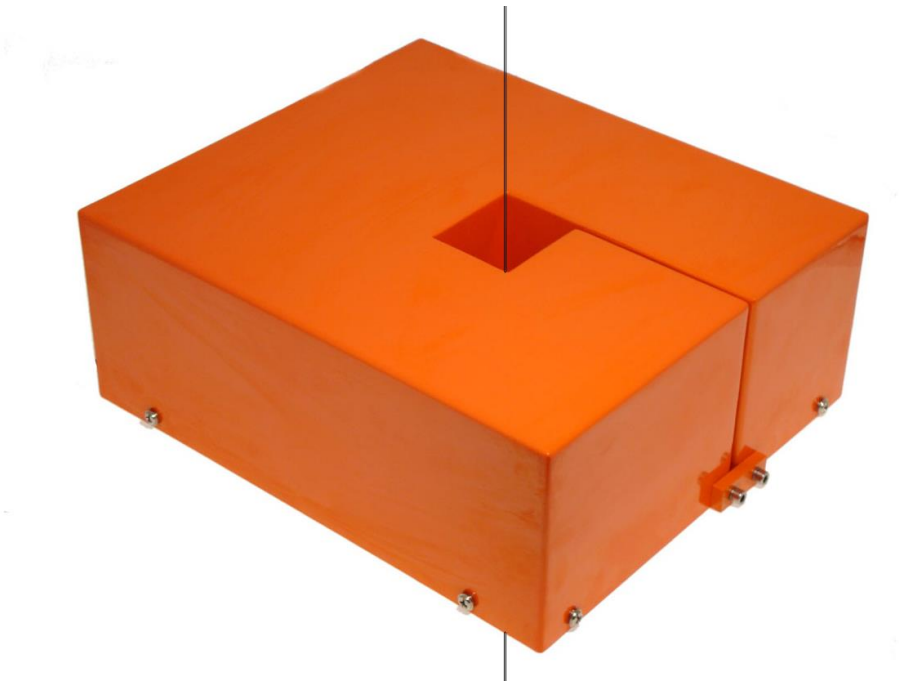
Automatic Pendulum System
User Manual



Man 163	4.0.1	06/08/2014	Philip Day	Chris Rasmussen	Chris Rasmussen
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Contents

Section 1 : Introduction

1.01 Important information

Thank you for choosing the Soil Instruments Automatic Pendulum System. This manual has been written to help you utilise all of the functions of the Automatic Pendulum System. Please read this manual thoroughly before use and keep it handy when using the Automatic Pendulum System.

The following symbols are used throughout the manual:

This Symbol indicates a warning.

Failure to observe the warning may result in injury, product malfunction, unexpected readings or damage to the product that may invalidate its warranty.

This symbol indicates a tip.

Additional information that may be helpful when using or installing the Automatic Pendulum System.

The Automatic Pendulum System is designed to measure Soil Instruments pendulum equipment, we are also confident that it will measure other commercially available pendulum equipment from other manufactures but we will not guarantee its reliable operation with non Soil Instruments products.

Soil Instruments Limited has an ongoing policy of design review and reserves the right to amend the design of the Automatic Pendulum System and this instruction manual without notice.

Please refer to our terms and conditions of sale for warranty information.

Products marked with the [redacted] symbol are subject to the following disposal rules in European countries.

This product is designated for separate collection at an appropriate collection point

Do not dispose of as household waste

For more information, contact Soil Instruments Ltd or the local authorities in charge of waste management

1.02 Taking care of your Automatic Pendulum System

Soil Instruments Automatic Pendulum System has been designed for use in harsh environments however certain precautions should be observed to ensure a long reliable product life.

Do not drop: The Automatic Pendulum System may malfunction if subjected to strong shocks or vibrations.

Do not immerse: The Automatic Pendulum System has been designed to be water resistant but may malfunction if immersed under water.

Keep away from strong magnetic fields: Do not use or store this device in the vicinity of equipment that generates strong electro-magnetic radiation or magnetic fields.

Avoid extremes of temperature: Do not expose to extreme heat or cold temperatures as this may cause damage to the Automatic Pendulum System.

1.03 System components

In addition to this manual you should have:

- Automatic Pendulum System unit
- RS-485 communication lead
- 4-20 mA connection lead
- Software and documentation CD
- Lower light shield (Optional component for strong light conditions)
- Drip deflector/Upper light shield (Optional component for strong light conditions)

Automatic Pendulum System

RS-485 communication

4-20mA connection lead

Z axis datum

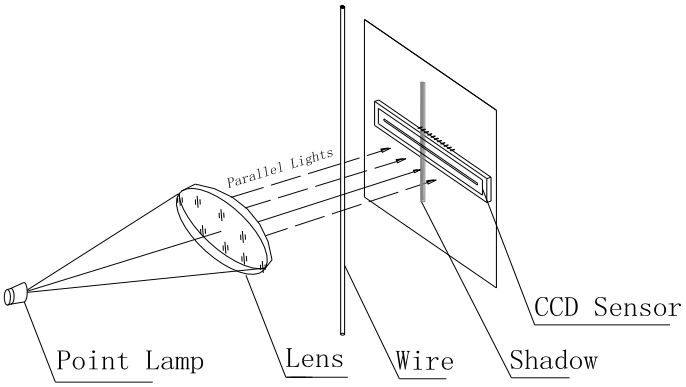
Lower light shield

Drip deflector/upper light shield

1.04 Familiarisation

The Automatic Pendulum System is a precision instrument designed for measuring the displacement of pendulum wire in hanging or inverted pendulum systems. These systems allow the measurement of bidirectional horizontal and vertical (3 axis version) displacements or deflections within large structures, such as dams, high-rise buildings, bridges, etc.

The Automatic Pendulum System uses a high-resolution linear array CCD (*charge-coupled device*) sensor as the measurement system. When the shadow of the pendulum wire generated by parallel light rays projects onto the CCD sensor, CCD gray level scans are generated. The system then identifies the shadow positions of the pendulum wire by analysing those scans. The coordinate positions of the pendulum wire are calculated and output through RS-485 data communications or 4-20mA D/A conversion.

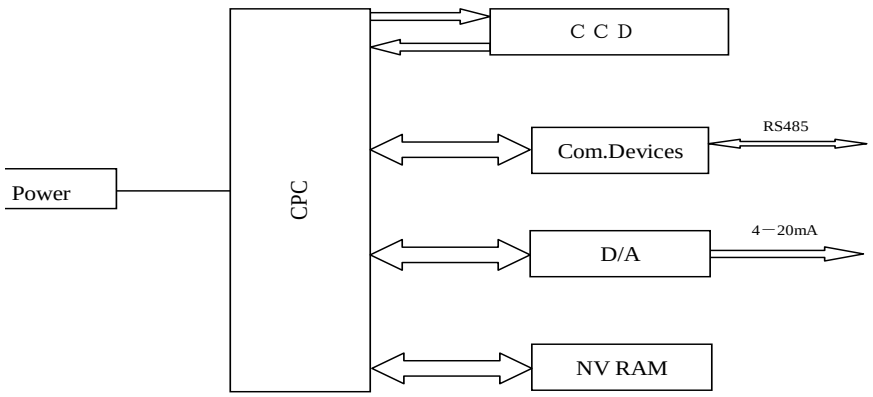


The illustration of the principle of CCD imaging

There are two identical sets of light sources, lens and the CCD sensor within an Automatic Pendulum System in order to measure bidirectional displacements. Those two sets are perpendicular to each other.

A third sensor is fitted to the 3 axis version.

The diagram below shows the working principle of the Automatic Pendulum System.



The illustration of the working principle of the Automatic Pendulum System Features.

Listed below is a short list of the features designed into the Automatic Pendulum System.

- CCD photoelectric imaging providing real non-contact 2D or 3D measurement
- High precision, no electronic drift and good long-term stability
- Advanced intelligent 256 level optical path imaging for greyscale images and strong ambient light-proof abilities
- The optional portable display unit which can display current real time measurements, facilitates installation, debugging and manual measurement tasks
- Automatic measurement using Soil Instruments data logger or connection to a computer via an RS-485 to RS-232 interface
- Networking function using RS-485 connectivity. Every Automatic Pendulum System has a separate network address. You can make an Automatic Pendulum System an independent node in a network through the RS-485 interface using its unique network address.
- The 4-20mA analogue output interface enables the instrument to be compatible with most measuring system with standard signal measurement functions
- Storage of up to 2000 (1200 on 3 axis) sets (times) of measuring data
- Power-Off Protection. Data stored to non-volatile memory
- Fully sealed sensors and electronics to 95% humidity (non-condensing)
- The built-in power supply can be connected to a wide range of voltages (100V-240V AC)

The enclosure of the Automatic Pendulum System is rectangular in shape and has an access slot provided to enable installation onto existing pendulum wires.

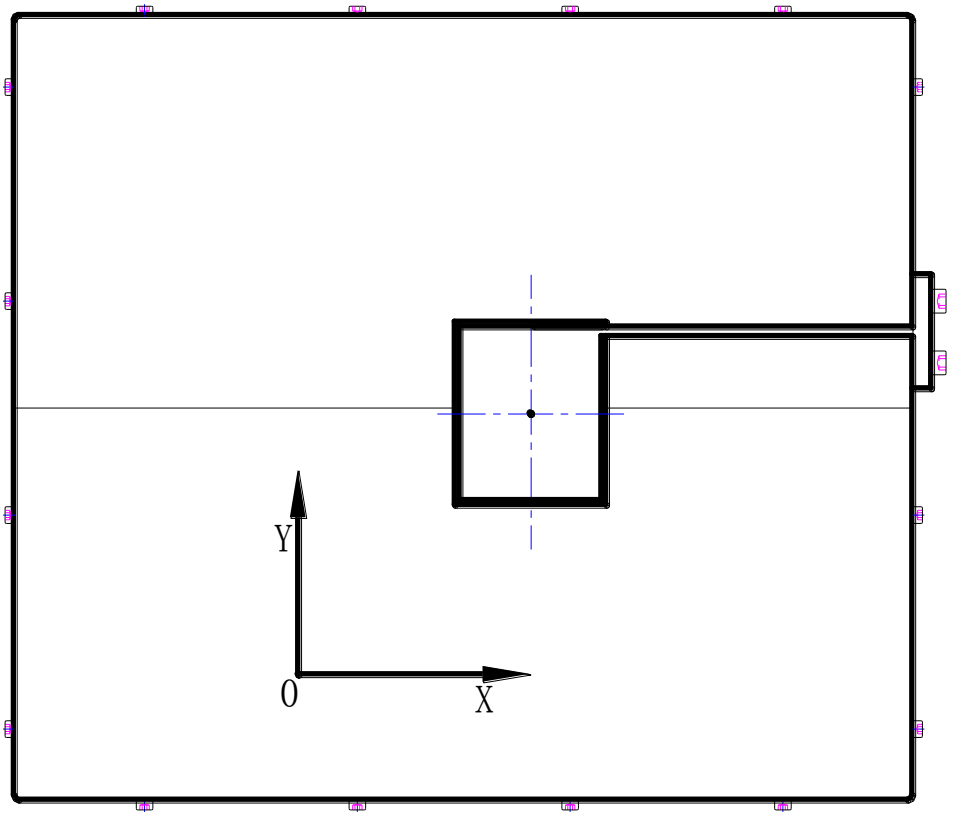
The power cord, RS485 communication/4-20mA analogue output and portable readout connection interfaces are fitted to the base plate of the instrument.

Section 2 : Installation

This section provides details of the standard installation using Soil Instruments mounting bracket set.

2.01 Orientation

Below is the plan view of the Automatic Pendulum System. Axis X and axis Y are reference directions of the instrument. This means the positive directions of those axis reflect the reading changes recorded: when the pendulum wire moves along the positive direction of axis X and Y, the reading on axis X and Y axis will increase.



Reference directions of the Automatic Pendulum System

When installing the Automatic Pendulum Systems, directions for those Automatic Pendulum Systems should be the consistent. For instruments installed on a dam, the positive direction of axis X is always the direction of water flow, the positive direction of axis Y always points to the left bank when looking in the direction of water flow.

The direction of the X and/or Y axis can be reversed within the Automatic Pendulum System by using the communication software via the RS-485 network.

2.02 Mounting onto wall brackets

If you choose to install the Automatic Pendulum System with the Soil Instruments mounting bracket set, you should fix the wall mounting arms to an angle iron frame or a concrete buttress built by the end user onsite.

The wall brackets should be mounted 500mm apart with the pendulum wire positioned at mid distance between them.

Ensure the brackets are mounted in a horizontal position and parallel to each other, a spirit level and shims should be used to achieve this.

The end of the brackets should protrude between 200mm and 400mm beyond the position of the pendulum wire.

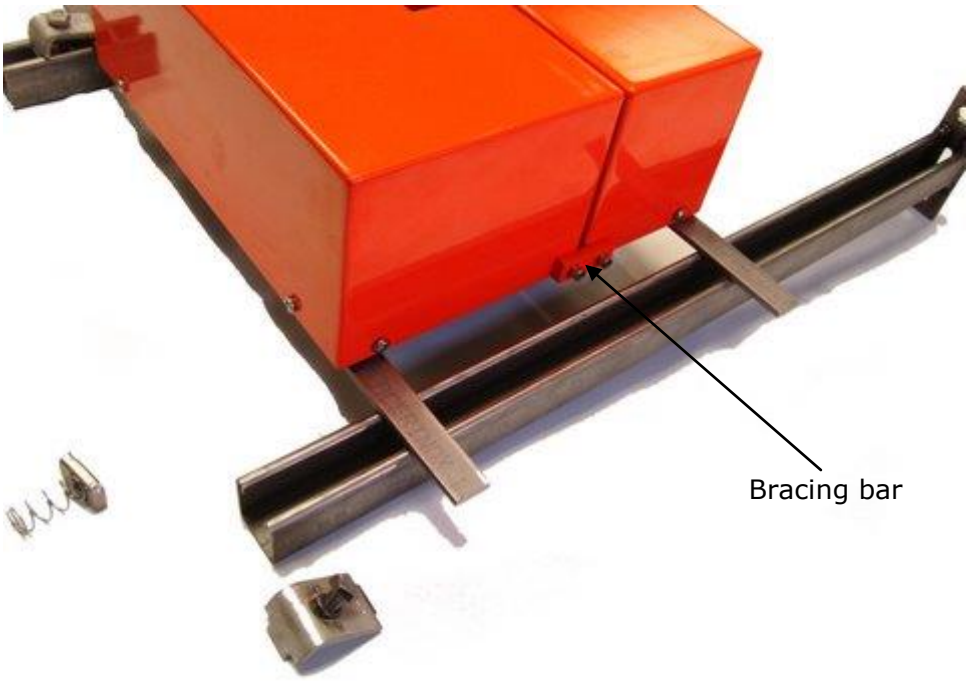
Fit one set of sprung clamp nut, clamp, washer and bolt to each bracket and slide to the rear of the bracket

Affix the clamping bars to the Automatic Pendulum System using the four M10 x 30mm counter sunk screws and spacers.

Ensure the spacers are correctly fitted between the clamping bar and the base plate of the Automatic Pendulum System.

Remove the bracing bar from the wire access slot and place the Automatic Pendulum System on to the mounting arms in the correct orientation taking care to guide the wire down the wire access slot.

Refit the bracing bar across the wire access slot and tighten in position.



Fit the other set of sprung clamp nut, clamp, washer and bolt to each bracket.

If Supplied fit the optional lower light shield using the two M4 x 8mm screws and fit the drip deflector/upper light shield to the wire and position to obtain the minimum required clearance between the lip of the deflector and the Automatic Pendulum System.

2.03 Power connection

The Automatic Pendulum System is available with either an 85-265VAC power connection or an 18-24VDC connection defined at time of ordering the Automatic Pendulum System. The power connection details are identified on the tables below and adjacent to the power cord exit point on the underside of the Automatic Pendulum System.

Definitions on cores of the power cord (A.C. Powered)

Core colour of the 3-core cable	Definition	Description
Brown	L	Live
Blue	N	Neutral
Yellow/Green	GND	Earth Bonding

Definitions on cores of the power cord (D.C. Powered)

Core colour of the 3-core cable	Definition	Description
Brown	DC+	18~24VDC
Blue	DC-(GND)	GND
Yellow/Green	N.C.	Not Connected

Incorrect connection of the power supply or supply voltages may result in damage to the Automatic Pendulum System or risk of electrocution. Connections should only be made by a competent person.

2.04 Alignment

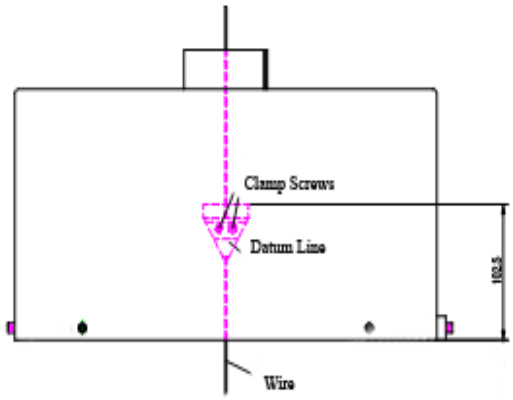
The Automatic Pendulum System can be aligned to the wire manually or by using the optional portable readout unit.

To manually align the Automatic Pendulum System raise the drip deflector/upper light shield and using a ruler measure from the edge of the wire access hole to the wire in both X and Y axis.

Move the Automatic Pendulum System to obtain your desired wire starting positions and ensure the axis are aligned with the axis of the structure being monitored.

For systems fitted with a third axis, attach the Z detection block to the wire and clamp in position 102.5mm from the top of the detection block to the base of the Pendulum System.

Re position the drip deflector/upper light shield allowing for the expected movement in the Z axis.



If using the optional portable readout unit, connect the readout unit to the connector on the underside of the Automatic Pendulum System and switch on the power to the system.

The display unit has a magnetic base so that it can be attached to the Automatic Pendulum System housing.

The portable readout unit will display the position of the pendulum wire for the X, Y and Y axis.

Move the Automatic Pendulum System to obtain your desired wire starting positions and ensure the axis are aligned with the axis of the structure being monitored.

When aligned position the four sets of clamps over the clamping bars and tighten to secure the Automatic Pendulum System to the wall brackets.

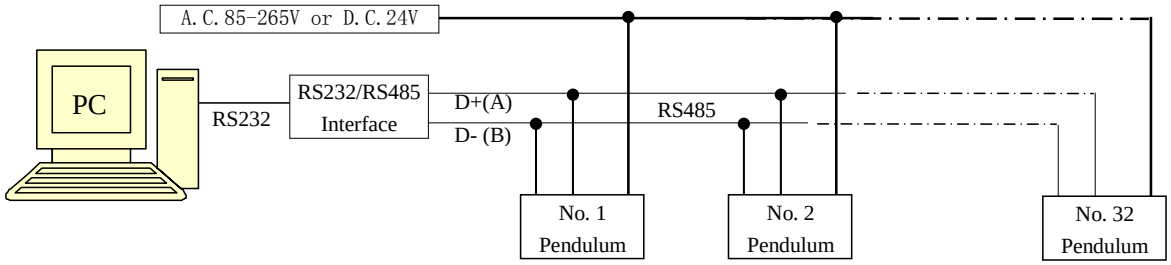
Check using a spirit level that the Automatic Pendulum System is horizontal in both axes.

Cut and fit the plastic cover strips to the exposed sections of the wall brackets and fit the plastic end caps.

Section 3 : Remote operation

3.01 RS-485 connection

Every Automatic Pendulum System has a separate network address. You can connect up to 32 Automatic Pendulum Systems through the RS-485 data interfaces to get a complete measuring network.



RS-485 network formed by the Automatic Pendulum Systems

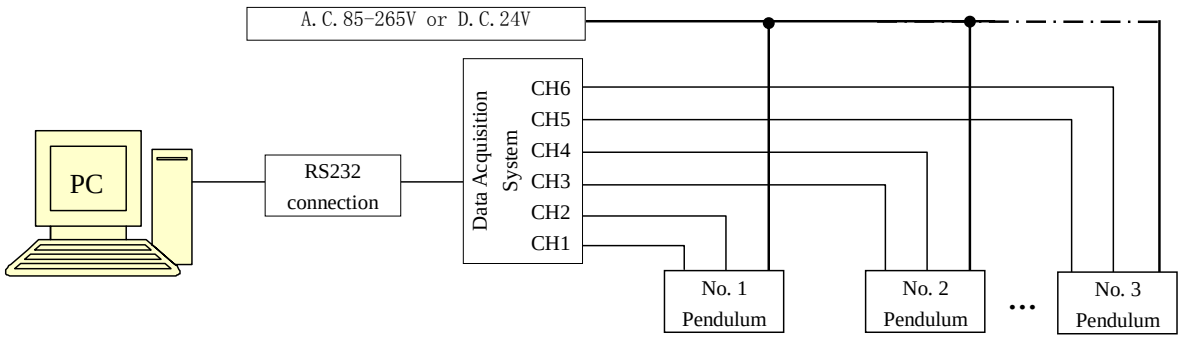
When you are using a RS-485 network, the distance between the farthest Automatic Pendulum System and the computer (PC) should not exceed 1200m. And you should connect a 120-ohm resister through a parallel connection on the RS-485 port of the farthest Automatic Pendulum System to decrease signal reflectance.

When the transmission distance is over the 1200m limit, you can use a fibre optic cable to transmit data. If you are using a fibre optic cable, there will be no limit on your transmission distance, and you can connect up to 99 Automatic Pendulum Systems in the same network.

3.02 Analogue 4-20mA connection

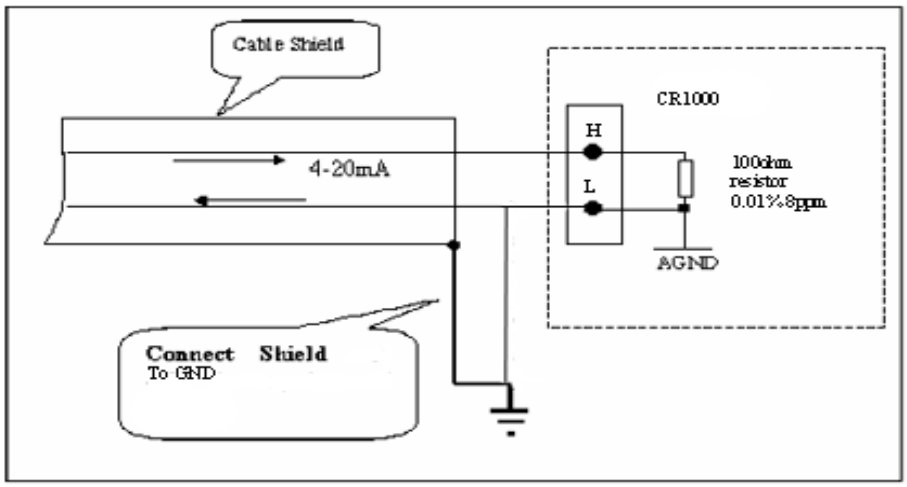
The Automatic Pendulum System provides a 4-20mA analogue output interface which enables you to perform remote measurement by measuring current values.

The 4-20mA remote measurement should be performed using a Soil Instruments Data Acquisition System to collect the analogue data.



Measuring analogue signals using a Data Acquisition System

When you are using a Data Acquisition System to perform remote measurement, you should use one differential channel for each axis of the Automatic Pendulum System.



3.03 Plug connections

The RS-485 and 4-20mA share a 10-pin **Bendix** outlet on the underside of the Automatic Pendulum System. Each system is supplied with a RS-485 communication cable with a 10-pin **Bendix** plug and a 4-20mA cable with a 10-pin **Bendix** plug.

Please follow the labelling on the end of each cable carefully when attaching additional cable.

Use good quality waterproof connectors or a cable splicing kit for connections to the extension/network cable.

For reference purposes the connections are tabulated below.

RS-485 and analogue output outlet connections

10 Pin Bendix (RS485/analogue output)	Definition	Description
A	Ix	Analogue output on axis X
B	GND	Bonding on axis X
C	Iy	Analogue output on axis Y
D	GND	Bonding on axis Y
E	NC	
F	RS485-B	RS485-T/R-
G	RS485-A	RS485-T/R+
H	NC	
J	GND	Bonding on axis Z
K	Iz	Analogue output on axis Z

RS-485 output cable connections

10 Pin Bendix plug	Core colour	Definition	Description
A	Null	NC	
B	Null	NC	
C	Null	NC	
D	Null	NC	
F	BLACK	RS485-B	RS485-T/R-
G	RED	RS485-A	RS485-T/R+
H	Null	NC	

Analogue output cable connections

10 Pin Bendix plug	Core colour	Definition	Description
A	RED	Ix	X-axis 4-20mA output
B	BLACK	GND	X-axis ground
C	GREEN	Iy	Y-axis 4-20mA output
D	WHITE	GND	Y-axis ground
E	SHIELD	GND	Grounding
J	YELLOW	GND	Z-axis ground
K	BLUE	Iz	Z-axis 4-20mA output

Take care that the RS-485 wires are not shorted even when using only the 4-20mA output as this will result in the malfunction of the Automatic Pendulum System.

3.04 Data processing

After the installation and debugging process, the Automatic Pendulum System will display/record the initial values $\mathbf{X_0}$ and $\mathbf{Y_0}$ of the pendulum wire.

When subsequent movement between the position of the pendulum wire and the Automatic Pendulum System occur, the instrument will display/record measured values $\mathbf{X_1}$ and $\mathbf{Y_1}$, the calculated offsets of the pendulum wire are:

$\mathbf{\Delta X = X_1 - X_0}$

$\mathbf{\Delta Y = Y_1 - Y_0}$

$\mathbf{\Delta Z = Z_1 - Z_0}$

Where:

ΔX, ΔY, ΔZ = Displacements on axis X, Y, Z (mm)

$\mathbf{X_0}$, $\mathbf{Y_0}$, $\mathbf{Z_0}$ = Initial readings on axis X, Y, Z

$\mathbf{X_1}$, $\mathbf{Y_1}$, $\mathbf{Z_1}$= Current readings on axis X, Y, Z

If you are using analogue values for measurement and calculation, use the following formulas:

$\mathbf{\Delta X = (I_{X1} - I_{X0}) \times G_{IX}}$

$\mathbf{\Delta Y = (I_{Y1} - I_{Y0}) \times G_{Iy}}$

$\mathbf{\Delta Z = (I_{Z1} - I_{Z0}) \times G_{IZ}}$

Where:

ΔX, ΔY, ΔZ = Displacements on axis X, Y, Z (mm)

$\mathbf{I_{X1}}$, $\mathbf{I_{Y1}}$, $\mathbf{I_{Z1}}$ = Current 4-20mA readings on axis X, Y , Z

$\mathbf{I_{X0}}$, $\mathbf{I_{Y0}}$, $\mathbf{I_{Z0}}$ = Initial 4-20mA readings on axis X, Y , Z

$\mathbf{G_{IX}}$, $\mathbf{G_{Iy}}$, $\mathbf{G_{IZ}}$ = Instrument factors on axis X, Y, Z : $\mathbf{G_{IX}}$, $\mathbf{G_{Iy}}$, $\mathbf{G_{IZ}}$=3.125mm/mA (6.250mm/mA for 100mm range)

For every measuring point, calculated results from the formulas above represent offset of the position of the pendulum wire relative to the Automatic Pendulum System itself, and its direction is related to the installation direction and alignment to the structure.

The Initial values can be set to zero using the communication software via the RS-485 network.

3.05 Communication software

Every Automatic Pendulum System is supplied with a free copy of communication and test software for use when connecting using a RS-485 network.

The following comm. Port settings are required.

Baud Rate 9600
8 Bits
No parity
1 stop Bit

For detailed usage of the software please see the help document within the software.

Section 4 : Maintenance and trouble shooting

4.01 Routine maintenance

The Automatic Pendulum System is a low maintenance device the only regular maintenance required is the cleaning of the optical path. A maintenance schedule should be established dependent on the environment in which the Automatic Pendulum Systems are operating.

For a generally clean environment we recommend monthly cleaning however this can be modified dependant on reliability of the readings and feedback from the maintenance engineers.

To clean the optical paths follow the procedure bellow;

1. Remove the lower light shield.
2. If you see a little dust on the lenses, wipe them using a soft brush dedicated for lens use.
3. If the lenses are very dirty, you can use a piece of lens cleaning paper wetted with water or a slightly wet soft cloth to wipe the surface. Don't use any organic solution to clean the optical path or enclosure.
4. Re-install the lower light shield.

Do not use any solvents or cleaning agents on the lenses.

4.02 Trouble shooting

The Automatic Pendulum System has a Self-diagnosis function. When a fault occurs, the display will show corresponding error code(s) by which you can maintain the Automatic Pendulum System.

Error code or fault symptom	Reason	Solution
Err2	The ambient light is too bright	Enhance light shielding methods or use an additional light shield.
Err3	The light source is too weak	Contact Soil Instruments.
Err4	There's no shadow (no projection), which indicates the pendulum wire has moved out of the measuring range.	Re-adjust the position of the Automatic Pendulum System.
Err5	A fault occurs in the CCD image sensor.	Contact Soil Instruments.
Err6	There are too many shadows, which indicate some dirt exists on the optical path or on the pendulum wire.	Clean up the optical path and the pendulum wire.
Displays are blank.	Power supply failed.	Check to see whether the power supply works properly.
Displays are normal, while communications	Address of the Automatic Pendulum System is not correct.	Reset its address. Check to see whether the

are abnormal.	A fault occurs in the communication line.	communication cable works properly.
No analogue output	A fault occurs in the hardware.	Contact Soil Instruments.

Error codes and troubleshooting information on the Automatic Pendulum System

Section 5 : Help and Support

5.01 FAQ

Which method of connection to the Automatic Pendulum System is the best?

A The RS-485 directly to a computer is the ideal method of communicating and collecting data from the Automatic Pendulum System, it offers the best solution with regard to networking, configuring and data collection.

The analogue 4-20mA output is more appropriate if data logging systems are already being utilised on site and a fixed computer is not available. If Soil Instruments data logging systems are being used then communication via RS-485 is still possible.

The portable readout unit only allows the display of the current reading and is not recommended where regular automatically stored data are required.

Why is orientation and alignment important?

A The alignment and orientation is critical for ensuring that the data generated by the Automatic Pendulum System represents the real movement of the structure.

If the X axis of the Automatic Pendulum System is not orientated accurately with the X axis of the structure then when the structure moves only in the X axis, the Automatic Pendulum System will show less movement in the X axis and some movement in the Y axis

If the Automatic Pendulum System is incorrectly aligned for the anticipated direction and magnitude of movement then the pendulum wire may move beyond the range of the Automatic Pendulum System.

This will result in the Automatic Pendulum System needing to be re-aligned and an offset value applied to subsequent data.

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