

Hanging Pendulum Equipment User Manual



Man 074	3.0.2	04/08/2014	P Day	Rob King-Mason	Chris Rasmussen
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Section 1 : Foreword

It is essential that the equipment covered by this manual is installed and operated by competent and suitably qualified personnel. They must read AND UNDERSTAND the procedures outlined in this manual before attempting installation or operation of the equipment on site.

Early consideration must be given to the space made available to 'house' the equipment inside of the dam (or other structure) in order to avoid installation difficulties and rectification measures at the time of installation.

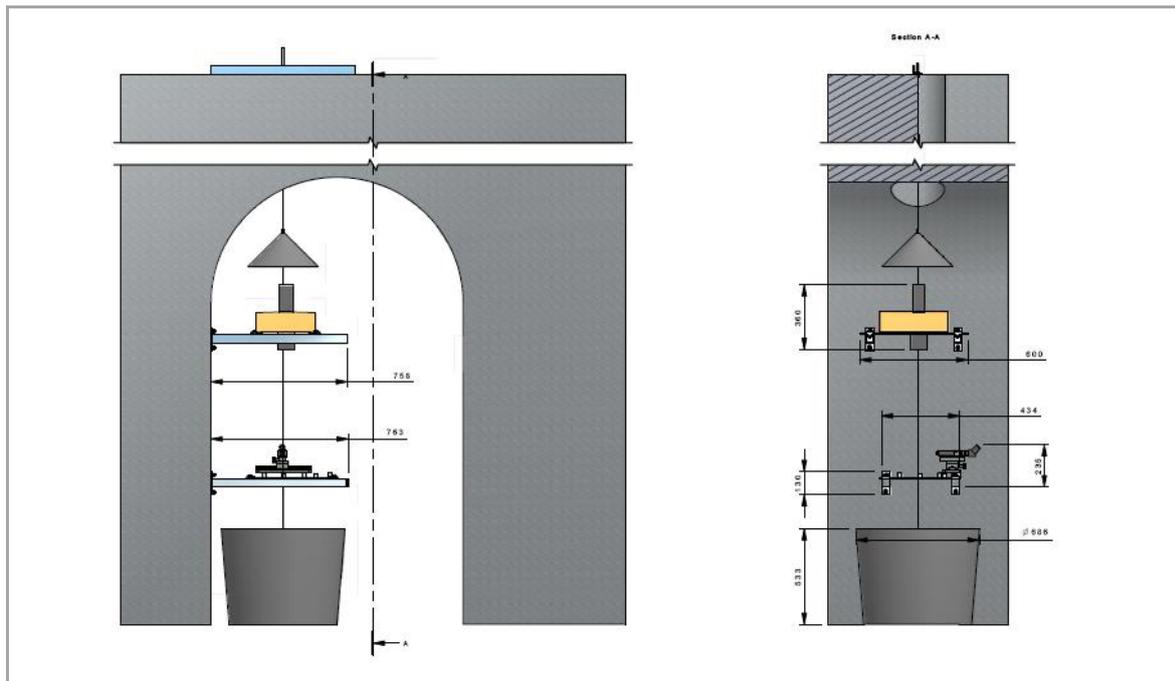
All the equipment is designed to operate consistently under normal site conditions but although all of the components are robust they will not survive mishandling or neglect. Components must be treated with respect and handle with CARE.

This manual can only serve as a general guide and the techniques mentioned will require modification to suit particular circumstances.

Section 2 : Introduction

The hanging pendulum is installed to provide measurements of the rotation or tilting of tall structures such as dams or towers (other uses are possible). A pendulum wire is attached near the top of the structure using a support beam and reference frames are installed at lower levels within the structure so that any such movements are observed as relative displacements between the reference frames and the pendulum wire.

The hanging pendulum system comprises a cylindrical steel weight suspended on the stainless steel wire anchored to the structure. The weight, fitted with damping fins to increase lateral damping, is suspended within a large oil filled cylindrical tank. Measurements can be made at one or several points along the wire (according to the number of access galleries provided) by taking readings of the two perpendicular components of movement using the reference frames equipped with either a vernier microscope or an automated co-ordinator.



Section 3 : General Information

Full utilisation of the hanging pendulum equipment requires that its installation is considered at the design stage of the project.

Anticipated maximum deviation of the structure determines the shaft diameter required to accommodate the resulting movement of the pendulum wire - as the top of the structure moves further than the bottom, which may even be effectively unmoved if it is the axis of rotation. Allowance must be made for the probability that the shafts will be constructed deviating from the vertical and that the shafts joining intermediate level galleries may not be exactly coincident so whenever practical a shaft diameter of 550-650mm is appropriate.

Reading tables may be installed at any elevation along the pendulum wire if a gallery can be practically constructed there. It is usual to install one frame at the bottom of the wire just above the oil bath and to locate intermediate frames in areas where distortion of the structure itself is to be monitored. When the galleries are constructed it is essential to ensure that the walls do not encroach on the shaft aperture too closely to allow room to install the frame in a position not coincident with the shaft centreline and subsequent repositioning of the frame if deviation is excessive.

Because the wire remains vertical while the anchor moves with the structure, readings of movement relative to the wire must be corrected for movements of the anchor and for this reason inverted and hanging pendulums are often used in the same structure so that all movements can be related to the inverted pendulum anchored at depth in stable ground. If this is intended the reference frame for the inverted pendulum is typically placed in the same gallery as the bottom frame for the hanging pendulum. Care must be taken to ensure adequate shaft and borehole separation to allow this.

Section 4 : Installation Technique

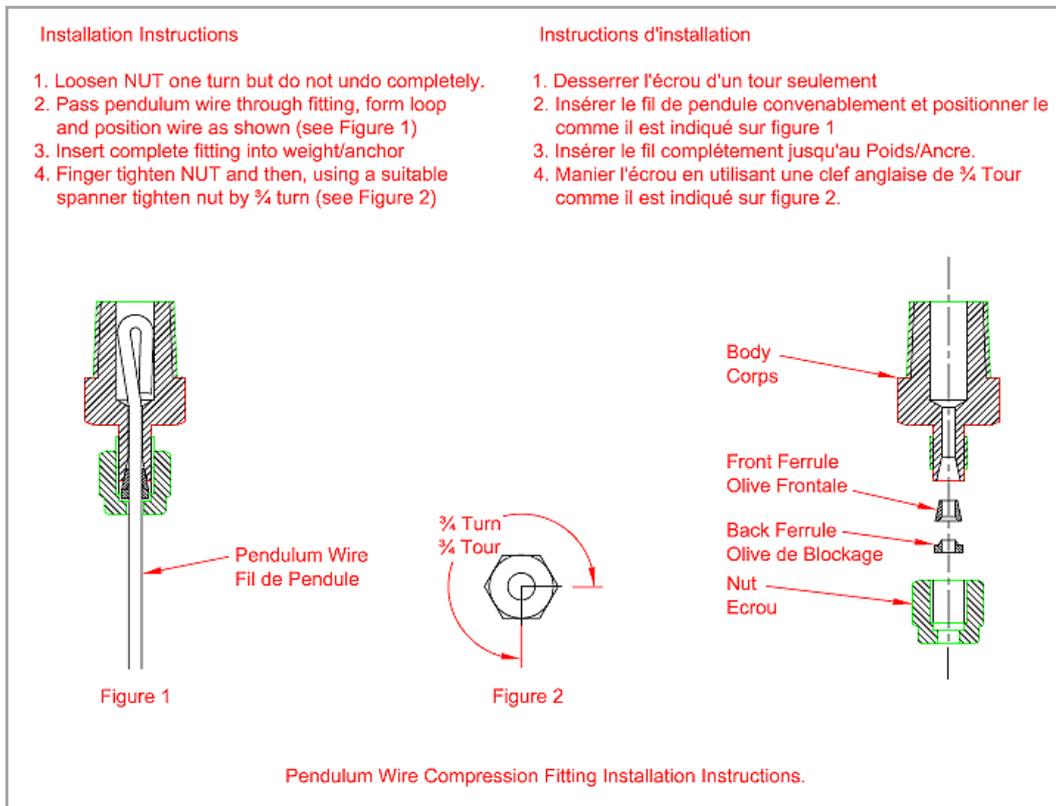
The installation procedures outlined in this manual are intended as a general guide and flexibility in their interpretation is required to suit particular local site conditions.

1. Obtain or improvise a plumbline and from the top of the shaft carefully lower down, ensuring that it passes through the shaft aperture. When the line has entered the (bottom) reading chamber improvise a temporary support (such as a wooden crosspiece) and suspend the plumb line weight about 0.5m above the floor.
2. From the top of the shaft view down the plumbline. If necessary, adjust the lateral position of the temporary support to provide maximum clearance between the line and the shaft walls over the entire length.
3. Allow time for the plumbline to stabilise and then visit the intermediate reading chambers to check that plumbline is in the optimum position(s), with respect to the expected reading table location. If they cannot be satisfactorily positioned then move the plumbline away from the shaft centre in the appropriate direction and repeat the exercise until a satisfactory compromise is obtained. Remember to allow enough wire movement to measure anticipated deviation. Check with the supervisory engineer.
4. Having obtained the optimum position with the plumbline it is now necessary to fix the support beam to the bulkhead above, in the corresponding position. It is probable that the gallery is not completely square so the best method of doing this is to construct another short plumbline and extend the line up to the bulkhead, taking care that the two plumblines are correctly aligned. Mark the position and then secure the suspension beam with the expanding bolts making sure an adequate hole is drilled for the central adjusting threaded rod. Alternatively the suspension beam is located above the bulkhead with an access shaft through to the gallery.
5. Temporarily fix a small weight to the end of the pendulum wire and from the top of the shaft carefully lower down taking care to avoid any kinking. When the wire has entered the bottom gallery continue for a further 2m to provide sufficient spare for installation adjustments.
6. At the top of the shaft cut the wire to provide approximately 1m spare for installation adjustments. Remove the complete wire connector fitting from the suspension beam adjustment rod and remove the nut and the two parts of the compression olive from the connector taking care not to drop or lose the olive parts and noting their correct order of fitment within the connector body.

Pass the nut and olive parts over the pendulum wire ensuring the correct orientation of the parts.

Form the wire into a loop as shown below using pliers, check the wire for cracks after bending. If cracked cut off and form again, when successful pull back into the fitting.

Tighten the nut as per the instructions shown below.



Refit the connector to the adjustment rod and position the bottom lock nut at mid-span on the adjustment rod, pass the rod through the clearance hole in the suspension beam and fit and tighten the 2nd lock nut.

- In the bottom gallery position the damping tank centrally directly under the wire. Following removal of the small weight cut back the wire sufficiently to allow the pendulum weight to be suspended inside the tank with a minimum of 100mm clearance to the base of the tank. Connect the wire to the weight using the aforementioned procedure. Use the lock nut arrangement on the suspension beam assembly at the top of the shaft; make final adjustments to the vertical position of the weight.
- Fill the oil tank to a depth sufficient to completely submerge the pendulum weight. Use a light mineral oil.
- The optical support frame and reading table are supplied in kit-form for assembly on site.

The reading table frame should be positioned inside the pendulum gallery, on a suitable concrete wall with a height to provide convenient viewing position when looking through the microscope. The wall brackets should be mounted 400mm 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



Place the reading table onto the brackets position the table into its approximate position.

Move the reading table to obtain your desired wire starting positions and rotate to align the measuring axes with the required axes of the structure.

When aligned position the four sets of clamps over the clamping bars and tighten to secure the reading table to the wall brackets.

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



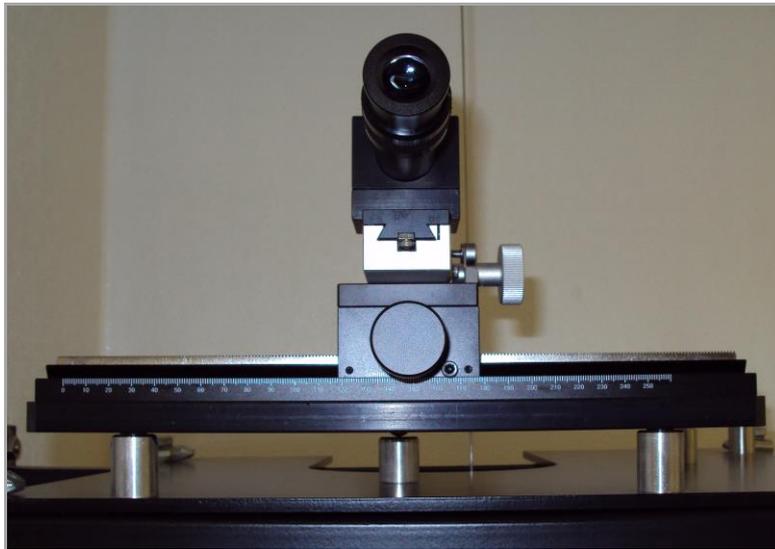
Section 5 : Taking Readings

5.01 Operating the portable measurement microscope.

The Portable Measurement Microscope comprises a telescope with fine "graticules" for viewing the pendulum wire, mounted on a vernier scaled slide with adjustments for focus and measurement.

When not in use the Microscope must be kept in the carrying case provided for protection.

The reference frame has two fixed mountings which allow accurate location of the portable measurement microscope. These mountings are fixed at 90° to each other to enable co-ordinate readings of the pendulum wire position to be taken when the microscope is fitted at each location.



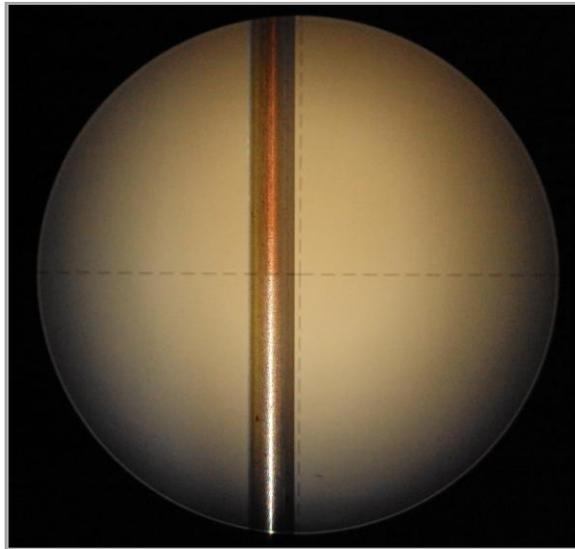
The co-ordinate position of the pendulum wire relative to the fixed reference frame is determined by adjusting the position of the microscope to view the edge of the wire against a graticule on the telescope lens.

The control knob on the front of the microscope is used for traversing the microscope along the track.

The control knob on the right hand side is used to focus the microscope on the wire by moving the microscope lens toward or away from the wire

It is important to read the same edge of the wire each time a measurement is taken; this is usually the left hand edge.

Alternatively, each wire edge maybe recorded and the average of the two readings obtained.



With the graticule aligned with the edge of the wire the microscope position is read-off the vernier scale and recorded.

To read the vernier scale take the closest line on the lower scale that is to the left of the zero line on the upper scale, in the example below it is the 168mm line and is called the lower scale reading. Now read the line on the upper scale that best aligns with a line on the lower scale, on the example below it is the 7th line.

Each of the lines in the upper scale equates to 0.1mm so the 7th line is 0.7mm.

Add this to the lower scale reading to obtain the total reading, in the example below this is 168.7mm



This procedure is repeated again at 90° in the other reading location for the second axis.

The two axes readings obtained are noted on a suitable record sheet as required.

It is essential to carefully establish the first set of readings; these represent the "base datum" from which all future movements are referred.

Section 6 : Routine Maintenance and Servicing

The hanging pendulum system is of simple design and consequently requires minimal maintenance. The following maintenance points will ensure trouble free operation:-

1. Prior to taking readings ensure that the weight is hanging freely within the oil tank. If necessary, gently adjust the oil tank position to ensure maximum clearance and allow sufficient time for the weight to cease oscillation before attempting to sight the wire.
2. When not in use, keep the microscope in a safe dry location in the carrying case provided. When cleaning the microscope lens use only camera cleaning tissue to avoid scratching the lens.
3. Periodically or as required, carefully remove any calcium deposits from all permanently installed equipment, paying particular attention to the microscope mountings.



Bell Lane, Uckfield, East Sussex
TN22 1QL United Kingdom

t: +44 (0) 1825 765044
f: +44 (0) 1825 744398

e: info@itmsoil.com
w: www.itmsoil.com

Soil Instruments Ltd. Registered in England. Number: 07960087. Registered Office: 5th Floor, 24 Old Bond Street, London, W1S 4AW