



INSTRUCTION MANUAL

DIRECT AND INVERTED PENDULUMS

Model DP & RP

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Tel.: 1.450.465.1113 • 1.877.ROCTEST (Canada, USA) • 33.1.64.06.40.80 (France) • 41.91.610.1800 (Switzerland)

www.roctest.com

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Note: This instruction manual covers general principals as to the installation of pendulums. Different parts and setups may be selected which may differ from those presented herein. Therefore, this instruction manual should be read accordingly.

1 APPLICATIONS

Direct and inverted pendulums are designed to accurately measure the relative internal horizontal displacement of points along a true vertical line. The pendulum is used in the following applications:

- monitoring of movements within dams, dam foundations, nuclear power stations, viaducts and bridge piers
- monitoring of structural and foundation movements in buildings
- reference for surveying monitoring method.

The instrument has especially significant place in the field of dam monitoring to detect sliding or overturning of blocks.

2 PRODUCTS

2.1 GENERAL DESCRIPTIONS

The direct pendulum is comprised of a wire suspended from the upper point and a reading station fixed to the structure at the lower point. The wire is tensioned by a suspended weight submerged in a damper tank.

The fixed end of the inverted pendulum is grouted at the lower point of the system. The wire is tensioned vertically by a float. When anchored in a fixed point in foundation, it measures absolute displacement of points along the wire.

2.2 OPERATION PRINCIPLE

The pendulum wire acts as a plumb wire, showing the local verticality. Movements of the structure between the free wire end and the anchor are detected by measuring the variations of the wire position.

3 INSTALLATION PROCEDURES

The following rules should be kept in mind during a pendulum installation.

1. In general, the maximum length of a pendulum shall not exceed 60 m. If the height of the structure to be monitored is superior to this value, it is advised install several pendulums in series.
2. While defining project, one must take into consideration overall dimension of the pendulum parts.
3. The reading table shall be oriented in such a manner to follow the greatest expected displacement.
4. The verticality of the well or borehole shall be sufficient to permit the free movement of the vertical wire in all directions.
5. The complete installation must be protected from the winds, air currents and water fall which may impair the stability of the vertical wire.

3.1 DIRECT PENDULUM

Use the following procedure to install an inverted pendulum.

1. Install the wire anchoring device.
2. With the use of a plumb-line passing through the V-notch of the wire centering bracket, adjust the centering bracket in such a manner that the wire will pass in the center of the cylindrical hole (well or borehole). If the direction of maximum amplitude is approximately known, the wire can be offset by half an amplitude, in the opposite direction of the expected displacement.
3. Install and adjust brackets in relation to the plumb-line wire.
4. Install and adjust the reading table (please refer to the instruction manual of the latter for installation details).
5. Install the wire and the bottom weight. Take into account that elastic elongation of the wire is approximately 2 mm per meter.
6. Adjust the bottom tank (used to damp oscillation of the wire) in such a way that the bottom weight does not touch the tank walls or bottom. Fill tank with oil after stabilization of the weight position.

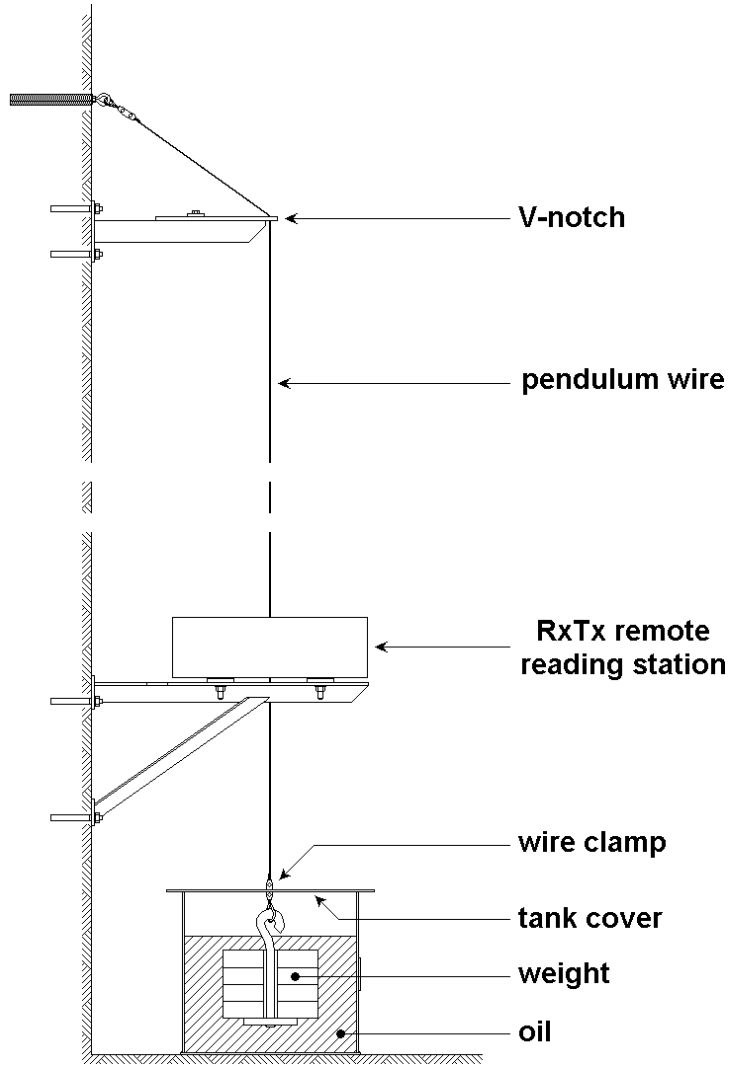


Figure 1: Typical installation of a direct pendulum with a RxTx remote reading station

3.2 INVERTED PENDULUM

Use the following procedure to install an inverted pendulum.

1. Install the brackets of the tank and the readout equipment.
2. Install the tank and the readout equipment over the brackets. Leave some play to be able to adjust them later. Install the float and its tensioning rod.
3. Attach the wire to the weight and lower it into the borehole. Secure the free end of the wire during the operation.
4. Attach the free wire end to the tensioning rod of the tank.
5. Using a pen or a piece of tape, mark a position on the cable to follow its vertical movement during tank filling.
6. Fill the tank with oil until the weight is lifted off the bottom of the borehole. The whole system (float, wire and weight) should be impeded by anything. If necessary, adjust the position of the tank and the readout equipment.
7. Fill the borehole with a cement grout up to the top of the weight.
8. Once the grout is set, adjust definitively the positions of the tank and the readout equipment. If necessary, add some oil into the tank to completely immerse the float without allowing it to enter in contact with walls, bottom or cover.

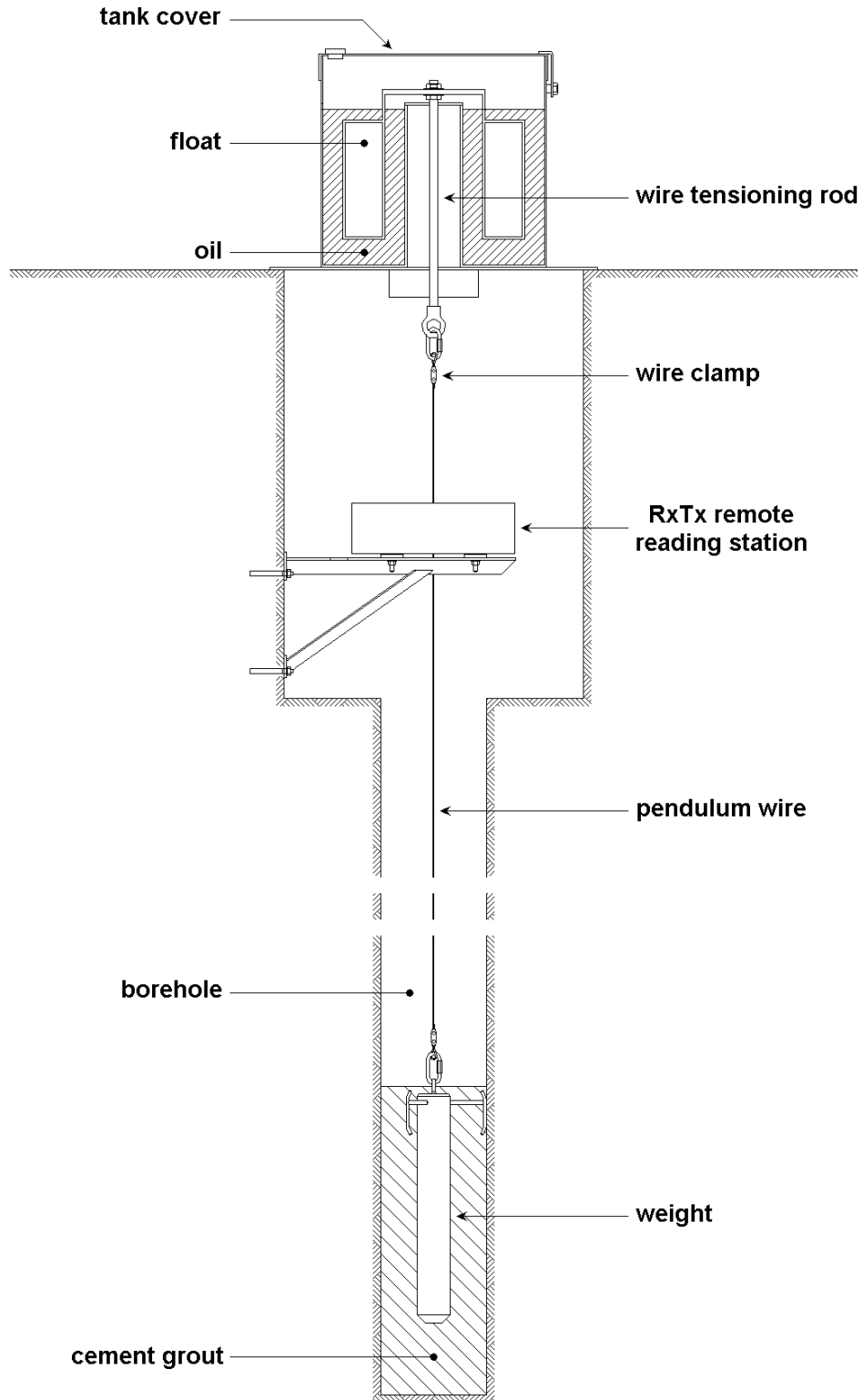


Figure 2: Typical installation of an inverted pendulum with a RxTx remote reading station

4 READING PROCEDURES

The monitoring of the wire position for both direct and indirect pendulums can be done manually and/or electrically with a remote readout unit. The method of reading depends upon the concept of monitoring, the expected values of movements, and the accuracy required.

This instruction manual should be read in conjunction with those related to these reading devices.

4.1 MANUAL READINGS

4.1.1 SIGHTING READING TABLE MODEL 76

To take a reading with a mechanical reading table the operator aligns the cursors on the left and right scales with their respective sights and with the pendulum wire. The positions of the cursors are read directly off the scale and the cursor vernier. The readings are converted to wire displacement values using the charts provided with each reading station.

4.1.2 MECHANICAL READING TABLE MODEL RT-IP50

Readings are taken by means of a digital micrometer. Four reference pins are used to section respectively the depth micrometer in the X and Y axes. Measurements are made by bringing the depth micrometer anvil in contact with the pendulum wire, in reference to the fixed pin.

4.1.3 OPTICAL COORDINOSCOPE MODEL MVR

The setup consists of a reference base permanently installed at the reading point. The coordinoscope is then installed on its reference section respectively at X and Y axes on the base frame. Measurements are taken by focusing or aiming the lens at the pendulum wire and by reading the current lateral displacement on the vernier.

4.2 REMOTE ELECTRICAL READINGS

4.2.1 MODEL RXTX ELECTRICAL REMOTE READING STATION

Please refer to its specific instruction manual.

4.2.2 MODEL PI-30 INDUCTION REMOTE READING STATION

Please refer to specific instruction manual.

5 MAINTENANCE

Pendulums do not require much in term of routine maintenance. The user should always make sure that:

- the wire is always free to move i.e. that it is not stuck by a debris;
- the wire is always protected against wind;
- the liquid level in the tank is appropriate;
- and each part of the whole system remains well anchored to the structure.

6 MISCELLANEOUS

6.1 ENVIRONMENTAL FACTORS

Since the purpose of pendulum installation is to monitor site conditions, factors which may affect these conditions should always be observed and recorded. Seemingly minor effects may have a real influence on the behaviour of the structure being monitored and may give an early indication of potential problems. Some of these factors include, but are not limited to: blasting, rainfall, tidal levels, excavation and fill levels and sequences, traffic, temperature changes, changes in personnel, nearby construction activities, seasonal changes, etc.

6.2 CONVERSION FACTORS

	To Convert From	To	Multiply By
LENGTH	Microns	Inches	3.94E-05
	Millimetres	Inches	0.0394
	Meters	Feet	3.2808
AREA	Square millimetres	Square inches	0.0016
	Square meters	Square feet	10.7643
VOLUME	Cubic centimetres	Cubic inches	0.06101
	Cubic meters	Cubic feet	35.3357
	Litres	U.S. gallon	0.26420
	Litres	Can-Br gallon	0.21997
MASS	Kilograms	Pounds	2.20459
	Kilograms	Short tons	0.00110
	Kilograms	Long tons	0.00098
FORCE	Newtons	Pounds-force	0.22482
	Newtons	Kilograms-force	0.10197
	Newtons	Kips	0.00023
PRESSURE AND STRESS	Kilopascals	Psi	0.14503
	Bars	Psi	14.4928
	Inches head of water*	Psi	0.03606
	Inches head of Hg	Psi	0.49116
	Pascal	Newton / square meter	1
	Kilopascals	Atmospheres	0.00987
	Kilopascals	Bars	0.01
Kilopascals	Meters head of water*	0.10197	
TEMPERATURE	Temp. in °F = (1.8 x Temp. in °C) + 32 Temp. in °C = (Temp. in °F - 32) / 1.8		

* at 4 °C

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Table 1: Conversion factors