In-Place Inclinometer

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STRUMENTI E MISURE GEOTECNICHE
E STRUTTURALI

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WARNINGS

This instrument must be utilized only for the application it has been designed for, OTR declines all responsability for any improper use.

Do not let the instrument fall into the hole quickly.

Do not put the instrument in flammable liquids or potentially explosive gases.

Do not use the instrument in water where an electric dissipation is in progress.

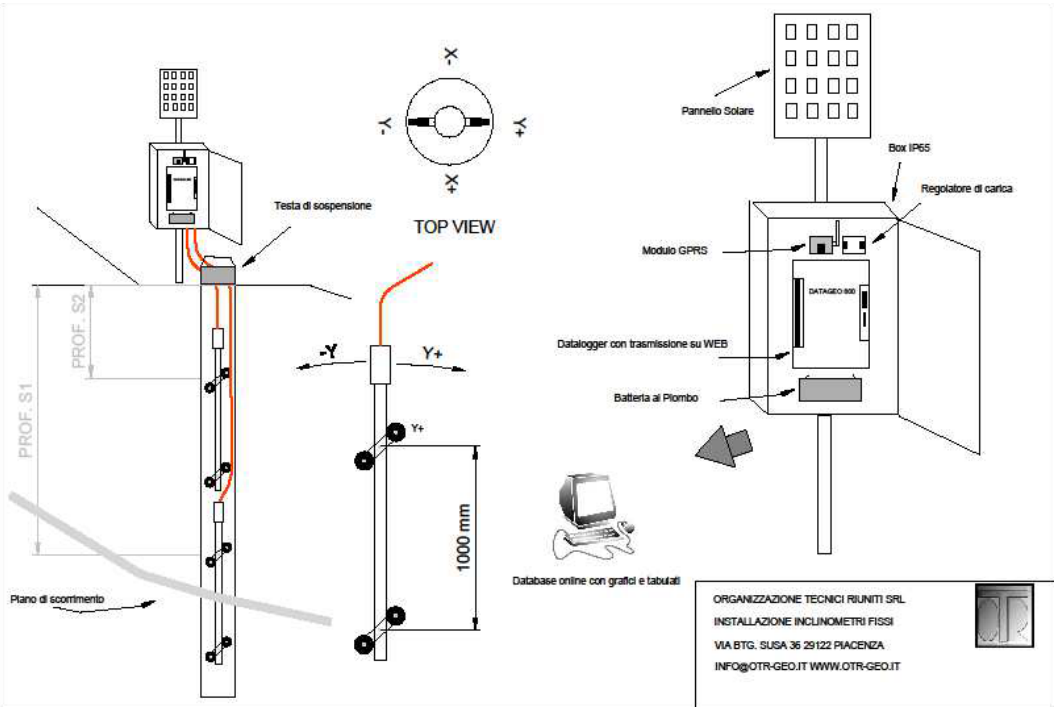
Use protective gloves.

Furthermore

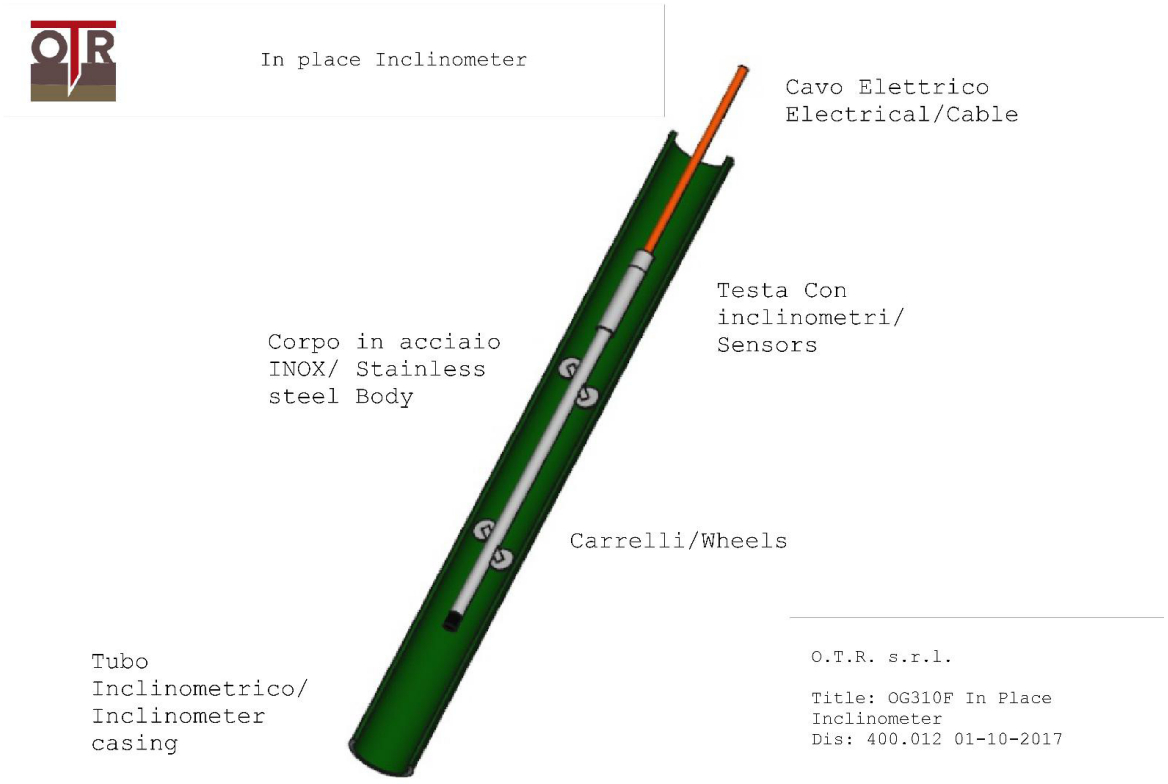
- Do not open the instrument, contact the manufacturer for checks and repairs;
- Keep out of reach of children;
- Do not connect the instrument to the readout unit with wet hands;
- Clean the instrument and its cable with alcohol or water, do not use acetone or aggressive liquids for plastics or labels;
- Use surge arresters for installations with unprotected cables longer than 30 meters.

Application

In-place inclinometers are used to permanently and automatically monitor variations in the inclination of landslides, geologically unstable areas, rock masses and unsteady walls. They can also be used in the field of civil engineering, especially in tunnels and underground structures, slurry walls and retaining walls, earth fill and concrete dams, and foundation piles.
The measuring system consists of series inclinometer probes, which are lowered into a preinstalled vertical tube. The inclinometer is suspended at the proper depth by means of a steel cable connected to a top cap with a fastening device. Vertical in-place inclinometers can be equipped with uniaxial or biaxial MEMS sensors.



Description



In-place inclinometers consist of a cylinder equipped with a sensor and a suspension ring, which is mounted on a stainless steel bogie. The bogie features two pairs of castor wheels which make it possible to make the sensor slide into the tube while maintaining its orientation. The distance between the two sets of wheels (wheelbase) is 1000 mm.
The probe can be equipped with uniaxial or biaxial micro electromechanical MEMS sensors, which ensure great sturdiness. The sensors inside the cylinder are embedded in resin, and can withstand high pressure. The full scales of +/-10° or +/-15° or +/-30° allow measurement resolution and stability which are appropriate to the normal conditions of use.

Identification

Every InPlace Inclinometer is identified:

- Serial number associated to calibration report;
- Model;
- Input/Output;

Technical Specifications

Voltage Supply	12-18 Vdc
Current Consumption	Max 25 mA
Output	±4 Vdc, 280 mV/°
Temp Output	NTC 3 K on demand
Resoluton	0.001°
Thermal drift	±0.002°/K
Wheels step	1000 mm

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Installation

Before installing a vertical in-place inclinometer, it is advised to take some measurements using a removable probe, so as to find the right depth and location at which the inclinometer probes will be positioned.
The 1000 wheelbase makes it easier to position the probe at the established depth. A steel wire connected to the top cap of the probe makes it possible to lower the inclinometer into the borehole and to suspend it at the proper depth.

The inclinometer sensors detect 2 axes. The Y-axis runs along the plane of the castor wheels, and the X-axis runs perpendicularly to the plane of the castor wheels.

For the probe installation, it is advised to acquire the following materials (which can be provided by OTR as accessories): top cap, steel wire (1.5 mm in diameter), and fastening clamps.
In order to install the instrument, proceed as follows:

- Cut a length of steel wire equal to the installation depth (+ 20 cm) of the first in-place probe (the one that is installed deeper down). Tie the cable in a loop around the suspension ring which is welded to the sensor cylinder. Tie the steel wire with a fastening clamp;
- Starting from the instrument, unwind the electrical cable and tape it to the steel wire every 1 to 2 meters;
- Prior to installing the instrument, take a control reading with the readout unit, positioning the instrument at a known angle and checking that the measurement taken by the readout unit is correct;
- Insert the in-place probe in the tube aligning the wheels with the groove, then lower the instrument to the selected depth using the steel wire;
- Route the steel wire at the center of the tube welded on the top cap. Create a loop in the cable, and clamp it with a fastening clamp after the in-place probe has reached the selected depth;
- Route the electrical cable over the top cap for the following wiring;
- Repeat all the steps above for all the in-place probes to be installed in the tube;
- After the installation has been completed, take some control measurements and write down the obtained values.

In case the instruments are removed, either for maintenance or to take measurements with a removable probe, remember taking measurements before and after repositioning the probes, so as to process data correctly.

Readout

Measurements can be taken by a portable, manual readout unit or by a data logger (which is advised for continuous monitoring) and they are expressed in electrical units (mV) or they can directly be converted into angles [°].
The Geotester readout unit can display the value as a tension (mV) and/or as a physical quantity [°].
For indications on how to use a given readout unit, please refer to its instruction manual

Taking Measurements

In order to take measurements, it is necessary to connect the instrument cable to the readout unit, following the instruction manual of the instrument in use:

- Whether the instrument is equipped with a uniaxial or biaxial sensor with output signal in mV, the wiring has to be carried out connecting the cable connectors according to their functions, which are shown below.

Red cable	= + 15 volt
Black cable	= GND
Light blue cable	= Signal Y
Green cable	= Signal X
Shield	= Protective earth to connect to earth of datalogger

Data Processing

- The measurement of the local displacement of the in-place inclinometer is obtained by measuring the tension (mV) with the electrical inclination transducer for the X- and Y-axes, and then processing the data as a variation in the trim of the in-place inclinometer inside the tube where it is installed.

- Depending on the instrument and the reading unit in use, the electrical measurement is expressed in mV to be converted in [°] degrees using the instrument's sensitivity factor shown on the instrument's calibration sheet (supplied by OTR):

Here follows an example of a conversion of electrical data (in mV) with a vertical in-place inclinometer equipped with a MEMS sensor.

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Calculations and Formulas

According to the following definitions and given a generic reading

Yo = Y-axis inclination expressed in mV (reading "Zero" Yo) – along the plane of the castor wheelsi

Xo = X-axis inclination expressed in mV (reading "Zero" Xo) – perpendicular to the plane of the castor wheels

Y' = Inclination on the Y-axis expressed in in mV (reading "Performance" Y')
X' = Inclinazione sull'asse X espressa in mV (Lettura di "Esercizio" X')
1000 = 1000 mm wheelbase of the in-place probe

KY = Y axis sensor sensitivity factor
KX= X axis sensor sensitivity factor

Y axis local displacement:

$$\Delta IY = 1000[\sin(Y'/KY)-\sin(Yo/KY)] \text{ with } KY = mV/°$$

X axis local displacement:

$$\Delta IX = 1000[\sin(X'/KX)-\sin(Xo/KX)] \text{ with } KX = mV/°$$

Result of the local displacement of the in-place inclinometer probe on the Y-X plane, expressed in mm:

$$\Delta I = (\Delta IY^2+ \Delta IX^2)$$

Direction of the local displacement of the in-place inclinometer probe on the Y-X plane, or azimuthal angle:

$$\theta = \text{arctg}(\Delta IY/ \Delta IX)$$