MEMS Inclinometer Systems

Applications

The 6100 MEMS Series Portable Inclinometer Systems are used to determine and measure the lateral movements in and around...

- **Landslides**
- **Unstable Slopes**
- **Dam Embankments**
- **Landfills**
- **Slurry walls**
- **Caissons**
- **Piles**
- **Sheet Piling**
- **Tunnels**

Model 6000-6 Inclinometer Cable Pulley, shown attached to Model 6500 Inclinometer Casing.

Model 6100 MEMS Inclinometer Probe pictured with the GK-603 Inclinometer Readout Box.

Operating Principle

Inclinometer probes are designed for use with standard, grooved inclinometer casing. Spring-loaded wheels on the probe engage the grooves in the casing thus maintaining the probe in a known orientation. Casing is grouted inside near-vertical boreholes (boreholes at other angles can be accommodated with some loss of resolution), cast inside concrete piles or slurry walls, or attached to steel pilings.

In use, the inclinometer probe is connected to a cable and lowered to the bottom of the casing and then raised in increments equal to the wheel spacing. At each increment the probe is read by a readout box connected to the upper end of the cable. The readout gives a measurement of the tilt of the casing to the vertical, at each depth increment. Repeat surveys of the casing reveal changes in these tilts, which can be analyzed to provide plots of lateral deflections of the casing, in orthogonal directions, at every depth increment.

Advantages and Limitations

The connector on the end of the probe is of extra-high quality (hermetically sealed, with gold plated pins) which helps improve signal accuracy. It's design is such that the connector can be easily removed and replaced if it suffers from damage or excessive wear. A protective cap is supplied to cover the cable connector when not in use.

Wheels are self lubricated for longer life. In addition, the wheels are designed to be replaceable with minimal effort and expense, should wear become excessive.

During the running of a deflection survey the readout box has the capability of displaying the check sum on the LCD screen. Also, at the end of a survey, the Model GK-603's internal software can be used to display simple deflection plots on the LCD. Both features provide a useful tool for checking the survey data in the field so that reading errors are minimized.

The overall cost is lower than comparable systems.

Model 6100 MEMS Inclinometer Probe

Model 6100 MEMS Inclinometer Probe.

The Model 6100 MEMS Inclinometer Probe is designed to measure the tilt of vertical inclinometer casing at selected depth increments, consists of a waterproof, stainless steel housing, and contains two MEMS (Micro Electro Mechanical Sensor) transducers, one with its axis in the plane of the spring-loaded wheels; the other at 90°.

At the base of the probe is a rubber cushion designed to reduce shock loading on the accelerometer, should the probe be dropped on to a solid surface. The accelerometers are capable of withstanding a certain amount of rough handling (shocks < 2000 g), but allowing the probe to fall against hard surfaces can permanently damage the accelerometer requiring factory repairs. Therefore, it is very important to handle the probe with care at all times.

The 6100 MEMS Inclinometer Probe has a restricted range of ±15°. This is more than ample for all nominally vertical boreholes. Custom-built 6100 MEMS probes can be made to accommodate special applications, such as casings installed on the sloping face of a dam embankment. Horizontal versions can also be supplied.

Technical Specifications

Standard Range	±15°
Sensors	2 MEMS sensors
Output @ 15°	±4 VDC
Resolution[1]	±0.025 mm/500 mm (±0.0001 ft/2 ft)
Linearity	0.02% F.S.
Repeatability	0.02% F.S.
Total System Accuracy[2]	±6 mm/30 m (±0.25 in/100 ft)
Temperature Range	0°C to +85°C
Temperature Coefficient	0.002% F.S./°C
Wheel Base	0.5 m, 1 m or 2 ft
Length × Diameter[3]	700 × 25 mm, 1200 × 25 mm or 32 × 1 in
Casing Size I.D.[4]	51 to 89 mm (2 to 3.5 in)
Weight (with case)	7.5 kg (16 lb)
Shock Survival[5]	2000 g

[1]±10 arc seconds. The resolution shown is only true in the range of ±5 degrees from vertical. Beyond this, the resolution is diminished (by the cosine of the angle from vertical). Resolution also depends on readout instrument used.
[2]Within 3° of vertical. This takes into account the accumulation of the error inherent with each reading, and normal placement errors in positioning the probe inside the casing; also the effect of debris in the casing, or casing damage.
[3]The cable connector adds 150 mm to the length of the probe.
[4]The probe is designed for use in all standard inclinometer casing up to a maximum diameter of 89 mm (3.5 inches).
[5]The Inclinometer Probe is a highly sensitive device and should be treated with great care at all times in order to maintain calibration. Particular attention should be given to preventing the probe from hitting the bottom of the casing with any impact.

Model 6005 Spiral Indicator

Model 6005 Spiral Indicator.

The Model 6005 Spiral Indicator is designed to measure the orientation of the grooves in inclinometer casing at any depth. Twisting or spiraling of the casing can occur during installation, especially if the casing is long; also the grooves in inferior extruded casing can become twisted during manufacture.

The Model 6005 is used in conjunction with the standard inclinometer cable and the Model GK-603 Readout Box. In use the probe is lowered down the casing with its wheels engaging the casing grooves, pausing at any depth to take a reading. A flux-gate magnetometer inside the probe measures the compass bearing of the wheel assemblies. The compass bearing is displayed on the Model GK-603 Readout Box screen and can be stored for later analysis.

Note that, unlike some spiral indicators, where the orientation of the grooves requires a complete survey of the entire borehole, so that incremental values of twist can be summated, the Model 6005 Spiral indicator can measure the orientation directly at any depth and thus gives the required information much more quickly and accurately.

Due to the magnetic influences caused by steel, the Model 6005 is not suitable for use inside steel casing or near heavy rebar cages.

Technical Specifications

Standard Range	360°
Sensor	Flux gate compass
Output	0.1 to 1.9 VDC
Resolution	0.1°
Repeatability	±0.5°
Total System Accuracy	±1.0°
Temperature Range	–20°C to +80°C
Wheel Base	610 mm
Length × Diameter[1]	686 × 51 mm
Casing Size I.D.[2]	61 to 89 mm
Weight (with case)	8 kg
Shock Survival	MIL-STD-810

[1] *The cable connector adds 150 mm to the length of the probe.*
[2] *The probe is designed for use in all standard inclinometer casing up to a maximum diameter of 89 mm.*

System Components and Accessories

The Portable Inclinometer System consists of the probe, carrying case, cable and Model GK-603 Readout Box (see back page for GK-603 details).

Model 6000-3 Carrying Case – A stainless steel case, with padded interior, is used to protect the probe from shock during transportation.

Model 6000-4 Cable – The inclinometer cable is designed to be strong. The cable has a central Kevlar® strand, with a breaking strength of 350 kg which effectively prevents the cable from stretching and allows for a heavy pull on the inclinometer should it become jammed in the casing. It should be noted that this Kevlar® strand is firmly attached to the lower cable connector so that the cable can not pull out of the connector.

The cable is also designed to serve as a depth marker and has markers crimped to the polyurethane jacket at intervals equal to the wheelbase of the inclinometer probe (0.5 meters or 2 feet).

A screw cap is provided to protect the cable connector when not in use.

The upper cable connector is a Lemo connector which plugs into the Model GK-603 Readout Box.

Model 6000-5 Cable Reels – Cables are supplied on wooden spools. Manual cable reels with hand cranks are also available. The reels are useful for storing the cable neatly when not in use. When reels are used, it is normal to pull off sufficient cable from the reel before commencing a survey.

For deeper boreholes and casings, where the weight of the cable becomes too heavy to manage manually, special motorized reels with slip ring contacts are used.

Where no reels are used, the operator frequently uses an open top box or carton in which to loosely coil the cable so that it dispenses easily without tangling during a survey.

Model 6000-6 Pulley Assembly – The pulley assembly attaches to the top of the casing and facilitates the survey process.

Model 6000-10 Dummy Probe – The dummy probe is geometrically identical to the standard Model 6100 Probe but does not contain any sensors. It is used to check that installed inclinometer casings are free of obstructions or distortions that might prevent removal of the standard probe. The dummy probe is lowered and raised using coated stainless steel aircraft cable.

Model GK-603 Readout Box

Model GK-603 Readout Box LCD / control panel.

Operating Principle

The Model GK-603 Inclinometer Readout Box is an easy-to-use, portable and rugged instrument for reading inclinometer probes, spiral indicators and tiltmeters, and for analyzing the resultant data. It is housed in a weather-resistant aluminum case to withstand the rigors of field operation. A large (15 row by 20 column) backlit LCD provides exceptional viewing under nearly all lighting conditions. A 12 volt 7.0 Ahr rechargeable battery will power the unit for up to 12 hours with a probe or tiltmeter plugged in. An internal lithium battery retains the configuration and data files of the readout for up to four years should the main battery fail or be disconnected.

In use, the inclinometer probe is connected to the readout and lowered to the bottom of the hole. Readings are stored by pressing a button on the face panel (or the remote switch). An audible in the Model GK-603 indicates the completion of the reading storage.

When the survey is complete, the readings are saved in the solid state memory under an eight-character file name which can be analyzed using the built-in capabilities of the Model GK-603, or transmitted to a host computer via RS-232 for archival purposes or further data reduction using spread sheets or GTilt Software[1].

The data reduction features of the readout allow for the direct printing of instrument check sums, deflection and profile reports, and the creation of three plot types: change in reading, deflection and profile. Plots may also be viewed on the LCD screen prior to printing to check the scales or to quickly determine if movement has occurred and at which depth.

System Components

The Model GK-603 is supplied complete with battery charger, remote switch with audible, and RS-232 interface cable. Optional accessories include a cold weather option, external power cable (12 VDC), and serial printer.

[1]GTilt is manufactured by Mitre Software Corporation. Please visit www.mitresoftware.com for more information.

Technical Specifications

▾ Analog Measurement	
Input Range	±10 VDC
Resolution	1 part in 40,000
Input Bias Current	10 µA
Input Impedance	> 1 MΩ
Input Bandwidth	20 Hz
A to B Channel Isolation	–92 db
Accuracy[1]	0.15% F.S.
Probe Supply	±12 VDC @ 50 mA
▾ Digital Measurement	
Resolution	16 bit (1 part in 65,536)
▾ Memory	
RAM / ROM	128K Static / 64K EPROM
Configuration File Storage	16 files
Data File Storage	96 files
Max Levels Per Data File	255
Total Data Point Storage	26,880
▾ Clock	
Features	Full calendar
Time Format	24 hour
Oscillator	32.768 kHz
Accuracy	±1 minute per month
▾ Serial Interface	
Interface Speed	300, 1200 or 9600 baud
Communication Parameters	8 databits, 1 stop bit, no parity, full duplex
Software Handshake	XON / XOFF
Data Output Format	ASCII text
▾ Power	
Quiescent Current Draw	< 0.2 mA
Operating Current	≈ 175 mA (≈ 225 mA with probe)
Battery	Sealed lead-acid, 12 Volt, 7.0 Ahr
Operating Time	≈ 12 hours
Backup Battery	Lithium, 3.5 volt, 1.8 Ahr
▾ Physical	
Dimensions (L × W × H)	210 × 165 × 203 mm
Weight	3.6 kg
Operating Temperature[2]	0°C to 50°C
Humidity	95% (non-condensing)

[1]Over specified temperature range.
[2]Low temperature versions (to –30°C) available on request.

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