User Manual

for

A603 Series Tiltmeters

850 Perimeter Road

Manchester, NH 03103

Phone: 603-669-6400

Fax: 603-622-2690

www.jewellinstruments.com

sales@jewellinstruments.com

REVISION HISTORY

Revision	Date	Change Description
A	1/25/2017	Initial Release

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MANUAL ACRONYMS & NOTATIONS

DC Direct Current, typically used in the measurement of voltage.

mV millivolts, 1 mV = $1x10^{-3}$ volts

°C Degree in units of Celsius

µrad microradians, 1 µrad = $1x10^{-6}$ radians

nrad nanoradians, µrad = $1x10^{-9}$ radians

1 OVERVIEW

The 603 High-Precision Platform-Mount Tiltmeters are dual-axis, analog output tiltmeters, designed for high-sensitivity, low power consumption, durability. Suitable for geotechnical and geophysical projects in remote locations, they will also provide years of trouble-free service in industrial and laboratory applications.

The tiltmeter is constructed with a painted white aluminum cover (dome), stainless steel base plate, electrolytic tilt sensors, PC board, connectors, and switches. It has two adjustable worm gear legs making the tiltmeter easy to level when placed on a hard horizontal surface. The switches allow the tiltmeter to change between it's gain settings and enable additional passive filtering.

Figure 1: A603 Tiltmeter

2 TECHNICAL DATA

2.1 TECHNICAL FEATURES

The tiltmeter has the following technical features:

- They sense a change in tilt angle with an electrolytic sensor, similar to a spirit level.
- All electronics reside on a single internal printed-circuit board.
- All circuit board external connections are gold-plated for long life and noise-free operation.
- All resistors are premium quality, 1% tolerance, metal-film type.
- All tiltmeters are hand-assembled, calibrated, and tested at our plant under stringent quality control standards.
- JEWELL maintains complete specifications and test records of every tiltmeter built.

High level function of every tiltmeter is the same: they contain two electrolytic level sensors (one for each tilt axis) that produce changes in resistance in response to a rotation of the sensor. Using a balanced bridge or voltage divider network to sense the resistance change, the tiltmeter electronics amplify, actively rectify and filter the AC sensor output to form a high-level DC signal that is proportional to the tilt angle. This output DC signal can be read by strip chart recorders, digital voltmeters, analog-to-digital converters or any other standard recording device.

Biaxial tiltmeters contain two orthogonal tilt sensors. The vector sum of the outputs of both channels yields the direction and magnitude of rotation with respect to the vertical gravity vector. 600-Series platform and surface mount tiltmeters also contain a temperature sensor that is installed in the base plate beside the tilt sensors. This temperature sensor allows you to record and evaluate the effects of temperature changes on measured structural and ground behavior.

2.2 TILTMETER DIMENSIONS

The dimensions of the tiltmeter are shown in the following figures. Dimensions in [] have units of millimeters, followed by units of inches.

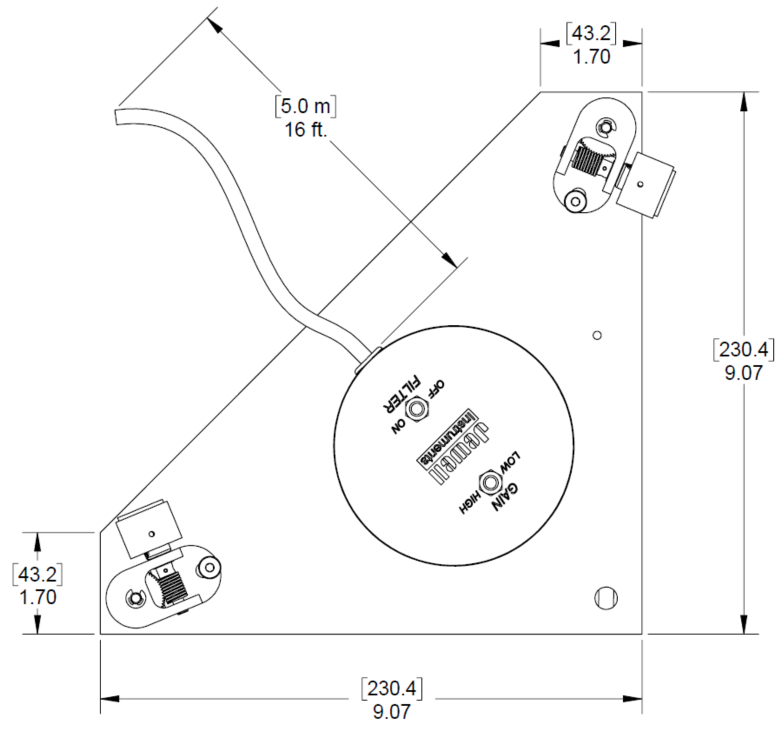

Figure 2: Tiltmeter Top View

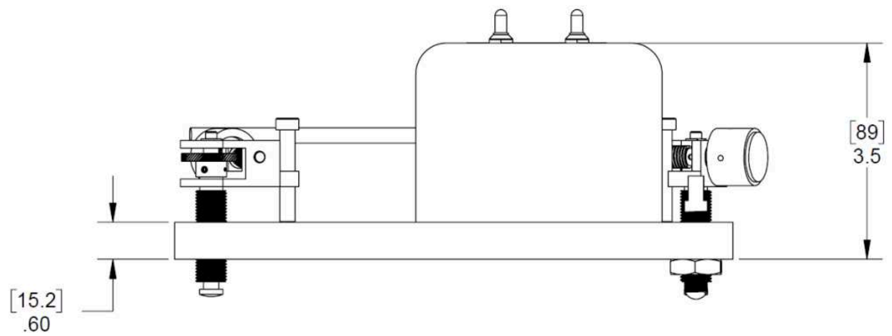

Figure 3: Tiltmeter Side View

2.3 GENERAL SPECIFICATIONS

The general specifications and technical data is listed below. Each tiltmeter is calibrated at the factory and will ship with it's own specific technical data, identified as a Calibration Certificate. Please refer to the Calibration Certificate on the precise scale factors for your tiltmeter.

Table 1: A603 Technical Data

		Model A603-A (High Gain)	Model A603-C (Ultra High Gain)
Angular Range	High-Gain: Low-Gain:	±200 µradians (±0.0115°) ±2000 µradians (±0.115°)	± 20 µradians (±0.00115°) ± 200 µradians (±0.115°)
Scale Factor	High-Gain: Low-Gain::	25 nradian/mV 50 nradian/mV	2.5 nradian/mV 25 nradian/mV
Non-Linearity		2.0%	
Resolution		<25 nradians	<2.5 nradians
Time Constant		Filter on: 7.5 sec; Filter off 0.5 sec	
Kz Temp Coefficient (deg/C)		±3 µradians/°C (typical)	
Ks Temp Coefficient (%/°C)		0.05%/°C (typical)	
Output		±8VDC (single ended); ±16VDC (differential)	
Channels		X-tilt, Y-tilt, Temperature	
Output Impedance		270 ohms	
Temperature Output		0.1°C/mV typical (single ended; 0°C = 0mV)	
Power		±11 to ±15 VDC @ +11 and -6mA, 250 mV ripple max, reverse polarity protected	
Environmental		-25 to +70°C operational; -30 to +100°C storage; IP50 Seal	
Dimensions		9.25 x 9.25 x 5 inches (24 x 24 x 12.7 cm), Weight: (estimated) 6 lbs (2.7 kg)	
Materials		Anodized and painted aluminum dome, Stainless Steel base and hardware	

Specifications subject to change without notice on account of continued product development

Aluminum tiltmeters are protected from light rain and splashes in the field by their domes and seals. However, they are not waterproof and may leak if submerged or exposed to heavy rainfall. If used in wet climates or conditions, they should be protected by a suitable housing or cover. WATER DAMAGE TO THE TILTMETER ELECTRONICS VOIDS THE WARRANTY!

3 INSTALLATION

3.1 CONNECTIONS TO EXTERNAL DATA MEASUREMENT EQUIPMENT

The tiltmeter has an attached 5m shielded 10 conductor, 24 AWG cable with PVC Jacket. The leads are stripped and tinned and the cable drain is provided for easy connection to measurement equipment and grounding. The electrical connections to the tiltmeter cable are provided in Table 2 below.

Table 2: Tiltmeter Cable Wire Color & Functions

Wire Color	Function
Red	+DC Power
Black	Power Ground
Violet	-DC Power
Blue	+Y tilt out
Brown	-Y tilt out
Green	+X tilt out
Gray	-X tilt out
Yellow	Temperature
White	Signal Ground

The power supplied to the tiltmeter must be bi polar and fall within the limits specified in Table 1. The low-impedance analog output of the tiltmeter (X-tilt, Y-tilt, and Temperature) can be readily measured by a variety of external devices, including digital voltmeters, oscilloscopes and digital data loggers. Ensure the DC power supply is OFF when making any electrical connections.

When routing the tiltmeter cable from the tiltmeter to the data recording equipment, do not route the cable along the floor where it may be subject to foot traffic and/or compression and abrasion. Doing so will prematurely wear the PVC jacket and may cause premature cable conductor failure.

3.2 PHYSICAL PLACEMENT

600-Series platform tiltmeters are built on a triangular stainless steel base. This base has one finely threaded invar leg, and two adjustable worm gears. Install on a hard, clean, and smooth horizontal surface, such as ceramic tile, a concrete floor, or a smooth rock. Careful surface preparation is important in achieving stable, low-noise measurements. Every site has different installation requirements.

Most importantly, it is strongly recommended that the tiltmeter be installed in a location where the ambient temperature is very stable. Due to the Coefficient of Zero Shift (Kz) small changes in temperature can result in large reported measurements of tilt. Please reference section 4.1 for additional information.

You may wish to consult with a Jewell Instruments engineer concerning the optimum site preparation for your particular project.

3.3 BASIC LEVELLING

A small bulls-eye or carpenter's level can be used to perform very rough initial leveling of the tiltmeter. Due to the very high sensitivity of the tiltmeter, however, it would be easiest to connect the tiltmeter to field data recording equipment. The initial leveling should be performed in Low Gain with the Filter Off. Due to the high capacitance in the signal conditioning unit and the high sensitivity of the sensor, allow the tiltmeter to stabilize for 20 seconds before committing to a reading. Levelling is accomplished by adjusting the worm screws slowly in sequence while observing the readout to obtain level (readings of approximately zero volts on both X and Y axes). It is generally a good idea to install the tiltmeter at the middle of its sensing range, i.e., with the output nulled on both channels, so that you will have the maximum dynamic range available for subsequent operational readings.

If you intend to operate the tiltmeter in high gain, turn the GAIN switch to HIGH after you have leveled the tiltmeter in low gain. Continue the leveling procedure until the X and Y outputs are as close to zero as possible. Now, turn the filter on if you want low-pass-filtered data.

3.3.1 WORM GEAR NOTES

The tiltmeter is shipped with two adjustable worm gears at the corners of the base. To level the X- and Y-axes of the, the user turns a knob that raises or lowers an invar screw by means of a worm gear assembly. One complete 360° turn of the knob turns the screw by 6°, or 1/60 of a revolution. The ½-inch diameter screw has a pitch of 40 threads per inch, so that one revolution of the knob raises or lowers the screw by: 1/60 x 1/40 inch = 1/2400 inch = 0.0106 mm.

The invar screw on each axis is exactly 200 mm from the stationary pivot point in the corner of the tiltmeter. The tilt change produced by a full revolution of the knob is therefore: 0.0106 mm/200 mm = 0.000053 = 53 microradians.

The user easily can adjust the knob in steps of 10° or smaller. A 10° turn of the knob is equal to: 53 microradians x 10°/360° = 1.47 microradians.

Conversion factor: 4.848 microradians = 1 arc second

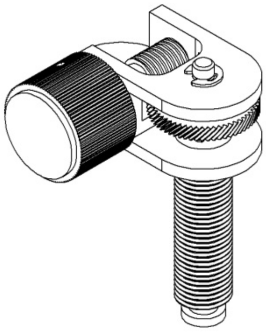

Figure 4: Worm Gear

3.4 GROUNDING AND TRANSIENT PROTECTION

Your tiltmeter has a common power and signal ground on its internal circuit board. However, there are separate signal and power ground pins in the tiltmeter cable (reference section 3.1). In general, the single-ended X, Y, and temperature outputs should be referenced to signal ground at the location where you are reading the data. Because current flows in the power ground wire and because the wire has some resistance, Ohm's law indicates that the potential at opposite ends of this wire will be slightly different. Thus, signals measured at opposite ends of your cable will be different when power ground is used as the reference. No current flows in the signal ground wire, so the potential in this wire is the same at both ends.

Your tiltmeter has an earth ground circuit that provides protection from high-voltage surges caused by nearby lightning strikes, unstable power sources and other transients carried on your signal/power cable. High-voltage transients are the most common cause of failure of geotechnical field instruments. In a typical occurrence, a high-voltage transient from a lightning strike travels along the cable until it encounters the instrument's electronic circuitry, where the delicate, low-voltage components are overloaded and fail. To help avoid such an occurrence, each tiltmeter input and output circuit is connected to the tiltmeter case through variable resistance type surge absorbers (Figure 5). To activate this surge protection, connect the tiltmeter base plate to earth (e.g. a water pipe or grounding rod). Make this connection at the grounding screw in the base plate shown by the arrow in Figure 6.

Transient protection and noise reduction can also be enhanced by earthing the shield (drain wire) of the tiltmeter cable at one end only.

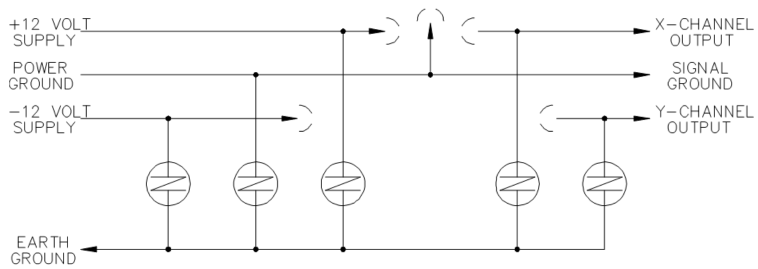

Figure 5: Earth Ground Circuit

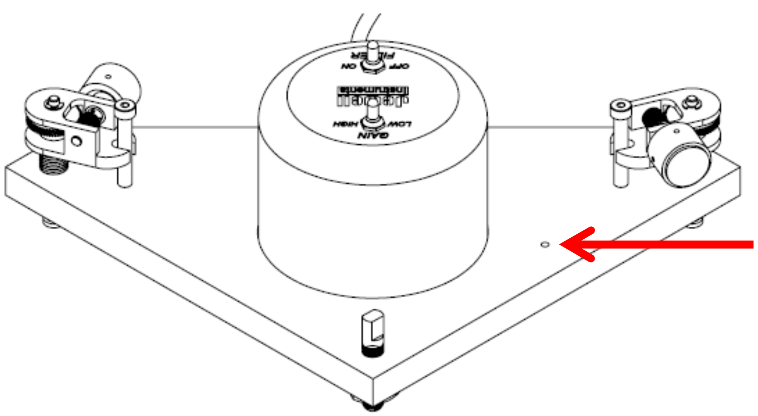

Figure 6: Baseplate Ground Screw Location

4 OPERATION

Once installed and levelled, the tiltmeter may be used for monitoring angular changes against the gravity vector. Each tiltmeter is shipped with a Calibration Certificate from the factory which is separate from this User Manual. To convert the tiltmeter output voltages to angular and temperature measurements, utilize the scale factor provided on the Calibration Certificate. Each axis will have its own scale factor for Low or High Gain and for single ended or differential. The temperature scale factor is fixed.

4.1 TILTMETER SENSITIVITY

The A603 tiltmeter is a very tilt sensitive device and as a result very small changes can result in large output voltage changes. Further, due to the highly amplified signal of the small angular range, small changes in temperature can have large effect on the output voltage. A typical ±0.25 arc degree sensor has a Coefficient of Zero Shift (Kz) value of ±3 µradians/°C. Thus for a 5°C change in ambient temperature along the tiltmeter may report a 15urad change tilt.

It is strongly recommended that the tiltmeter be installed in a location where the ambient temperature is very stable.

4.2 TILT (DC) TO TILT (RADIAN) EQUATIONS

The general equation to convert DC voltage to angular radians is as follows:

$$Tilt\ Output\ [nrad] = TiltmeterOutput\ [mV] x\ Scale\ Factor [nrad/mV]$$

Example: to convert a single ended Low Gain measurement of 50mV from the tiltmeter's X-output multiply 50mV by the X-Axis Single Ended Scale Factor reported on the Calibration Certificate, 23.860 nradians/mV.

$$Tilt\ Output\ [nrad] = 50\ [mV] x\ 23.860 [nrad/mV] = 1193\ nrad$$

4.3 TEMPERTATURE (DC) TO TEMPERTATURE (°C) EQUATION

The general equation to convert DC voltage to temperature in units of Celsius is as follows:

$$Temperture\ Output\ [°C] = TiltmeterOutput\ [mV] x\ Temperture\ Scale\ Factor [°C/mV]$$

Example: to convert a measurement 184mV from the tiltmeter's X-output multiply 184mV by the temperature sensor scale factor, 0.1°C/mV.

$$Temperature\ Output\ [°C] = 184\ [mV] x\ 0.1 [°C/mV] = 18.4\ °C$$

5 MAINTENANCE & TROUBLESHOOTING

5.1 ROUTINE MAINTENANCE

Keep all tiltmeters away from extremes of heat and cold. Extreme temperatures shorten the life of the seals, and unnecessarily stress the electronic components. Keep tiltmeters out of direct sun because the internal temperature can reach levels considerably greater than the ambient temperature.

Aluminum tiltmeters have been sealed in the factory with silicone rubber cement. This is intended to protect the tiltmeter against splashes or occasional light rainfall. However, aluminum tiltmeters are not fully waterproof and should NEVER BE SUBMERGED in water or any other liquid. WATER DAMAGE TO INTERNAL COMPONENTS VOIDS THE WARRANTY!

In addition to providing a seal, the cement between the dome and the base plate of aluminum tiltmeters provides the mechanical bond between these two parts. In normal use the cement will provide a strong and secure attachment. To maximize the bond life and reduce the possibility of separation, lift the tiltmeter by holding the base plate and not the dome. If the dome should separate from the base plate, it can be reattached by 1) cleaning off the old cement, 2) applying new silicone rubber cement and 3) holding the two sides firmly together until the cement has dried.

5.2 DETERMINING THE CAUSE OF MALFUNCTIONS

If there is no output when you have connected the tiltmeter to data recording equipment first check that bipolar DC power is provided to the tiltmeter and/or that the recording equipment is functioning properly. Then be sure that all connections are securely attached. Failure to obtain an output signal from the tiltmeter normally is the result of lack of power or a broken wire or connection.

If one or more tiltmeter outputs are firmly "pegged" at either end of the output range, the tiltmeter is probably tilted off scale. If this is not the case, be sure to carefully inspect the tiltmeter cable for nicks and cuts through the PVC jacket to identify possible electrical opens. Also re-inspect the tinned leads and repair as necessary.

The A603 tiltmeters cannot be opened without special tools. If you have conclusively established that the problem is internal to the tiltmeter, these tiltmeters should be returned to JEWELL for repair. The A603 tiltmeters are not field serviceable. Please do not attempt to remove the aluminum dome from the baseplate. Doing so will void the warranty.

APPENDIX A: Angle Conversion Chart

Table D1. Angle Conversion Chart						
	degrees	**arc minutes**	**arc seconds**	**µradians**	**mm/meter**	**inches/ft.**
degree=	1	60	3600	17453	17.453	0.2094
arc minute=	0.016667	1	60	290.89	0.29089	$3.4907E^{-3}$
arc second=	$2.7778E^{-4}$	0.016667	1	4.8481	$4.8481E^{-3}$	$5.8178E^{-5}$
µradian =	$5.7297E^{-5}$	$3.4377E^{-3}$	0.20626	1	0.001	$1.200E^{-5}$
mm/meter=	0.057297	3.4377	206.26	1000	1	0.01200

APPENDIX B: Warranty & Limitation of Liability

Standard goods (those listed in Jewell Instruments' published sales literature, excluding software) manufactured by Jewell Instruments LLC are warranted against defects in materials and workmanship for twelve (12) months from the date of shipment from Jewells' premises with the following exceptions: Series 900 analog or digital clinometers are warranted against defects in materials and workmanship for 90 days from the delivery date. Jewell will repair or replace (at its option) goods that prove to be defective during the warranty period provided that they are returned prepaid to Jewell and:

(a) that the goods were used at all times for the purpose for which they were designed and in accordance with any instructions given by Jewell in respect of them,

(b) that notice is received by Jewell within 30 days of the defects becoming apparent, and

(c) that return authorization is received from Jewell prior to the goods being sent back.

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