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IW-700/710

INCHWORM MOTOR

INSTRUCTION MANUAL

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1. INTRODUCTION

Burleigh Instruments Inc. thanks you for choosing an IW-700 or 710 Series Inchworm® Motor. It's design has been optimized to meet your most rigorous micropositioning needs. These products are the culmination of over a decade of development in Inchworm technology, and incorporate significant improvements over earlier motors in smoothness of operation, speed under load, mechanical step resolution, reliability, and versatility. When operated by Burleigh control electronics they provide the highest mechanical resolution of any commercially available positioning systems.

Should any questions or problems arise with the Inchworm Motor please contact Burleigh's Customer Service Department at (716) 924-9355 or your local representative.

CAUTION: High voltages are present during normal operation of Inchworm Motors, even when they are not in motion. Do not disassemble the Motor or remove any covers. There are no user serviceable areas or parts inside. Also, use care not to damage the cables and plugs.

CAUTION: Inchworm Motors contain piezoelectric ceramics and their encoders contain glass scales, both of which can be damaged by rough handling or physical shock.

2. INITIAL INSPECTION

A. VISUAL

Inchworm Motors are packed in a special carton designed to provide maximum protection during shipment. Notify your shipping department if the outside of the shipping carton is damaged. They may wish to notify the carrier at this point.

If the shipping carton is undamaged externally remove the Inchworm Motor from the carton. If any damage is evident visually or if rattling can be heard when it is gently shaken notify your shipping department and Burleigh Instruments, Inc. or your local representative. Please save the special carton for future storage and transportation.

B. OPERATIONAL

Refer to section 4 for a discussion of normal operation of the IW-700 and 710 Series Inchworm Motors. If an Inchworm Motor fails to operate correctly contact the Burleigh Customer Service Department or your local representative at once.

CAUTION: Do not attempt to use an Inchworm Motor until you are familiar with the operation of the Controller. Refer to the Controller Manual for details.

C. QUALITY CONTROL

Inchworm Motors undergo several stages of inspection, test, and calibration before shipment including an extended run-in. They are designed to provide years of trouble-free operation. In the unlikely event that problems occur please contact Burleigh for instructions. Our Customer Service Department is ready to help with advice, parts, and repair services.

3. DESCRIPTION

The Burleigh Inchworm Motor is a compact linear actuator. Its patented piezoelectric construction allows precise positioning with low compliance (high stiffness) and none of the backlash inherent in gear driven stepper or dc motor systems. Unlike magnetic motors the Inchworm Motor does not dissipate power when stopped. They have a mechanical resolution of 0.004 microns with a speed range of 0.004 μm/sec to greater than 2 mm/s. The shaft can generate a linear force of 1.5Kg. Construction for vacuum operation is available.

Inchworm Motors are available with nominal travel distances of 6.3, 25 and 50mm, with or without integral 0.5μm resolution encoders. Applications requiring longer travel or different mounting geometries may be satisfied with Burleigh LTO and LTS Series Motors. Contact Burleigh or your local representative for more information.

Burleigh IW-700 and IW-710 Series Inchworm Motors have identical motor components and positioning specifications. The IW-710 Series include an integral 0.5μm resolution encoder which is described in section 3-B.

For your convenience, a glossary of micropositioning terms is found in Section 11 of this manual.

NOTE: Although designed for operation by Burleigh 6000, 7000 and 7010 Series Controllers, IW-700 and 710 Series Motors may be operated with certain restrictions by CE-1000 and CE-2000 Controllers. Refer to Section 10 for details.

CAUTION: An electrical shock hazard can exist if an IW-700 or 710 Series Inchworm Motor is connected directly to a CE-1000 or CE-2000 Controller. If you have any questions, please contact the Burleigh Customer Service Department or your local representative.

A. INCHWORM MOTION

The principle of Inchworm motion is described below. See Figure 1.

Both outer elements, numbered 1 and 3 in the figure, contract when voltage is applied and firmly clamp onto the shaft. The center element, numbered 2, expands along the shaft with increasing voltage. All three elements operate independently.

The Controller sequences the clamp and center element voltages to generate Inchworm motion as follows:

- actuate clamp element 3
- extend center element 2, moving shaft to the right
- actuate clamp 1, release clamp 3
- contract center element, moving shaft further to the right
- actuate clamp 3, release clamp 1
- repeat sequence

Reverse travel is achieved by reversing the sequence for actuating the clamp elements.

Forward and reverse limit switches automatically halt further travel when either extreme of travel is reached. Extension or contraction of the center element causes about 2 microns of shaft movement between clamp changes.

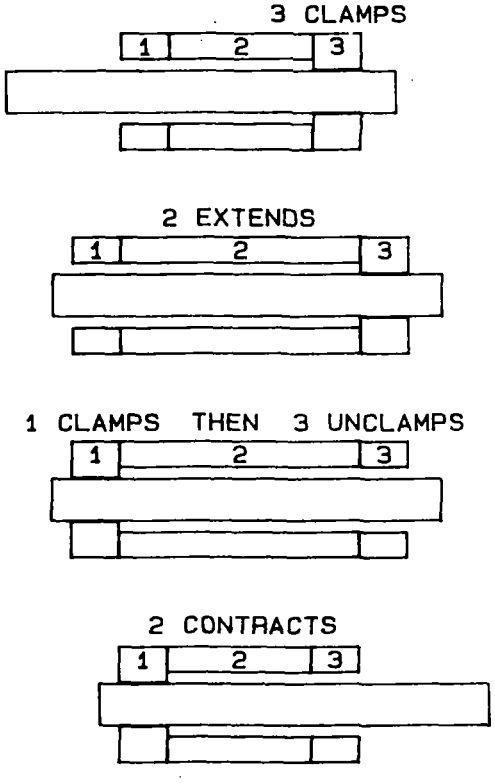


FIGURE 1
INCHWORM MOTION

The voltage applied to the clamp elements has two levels: On (clamped) and Off (unclamped). The center element receives a 512 step voltage staircase for smooth motion. The slope of these ramp signals, coordinated with the clamp change frequency determines translation speed. Between clamp changes the voltage staircase may be halted at any level to achieve mechanical resolution of about 0.004 microns. See Figure 2.

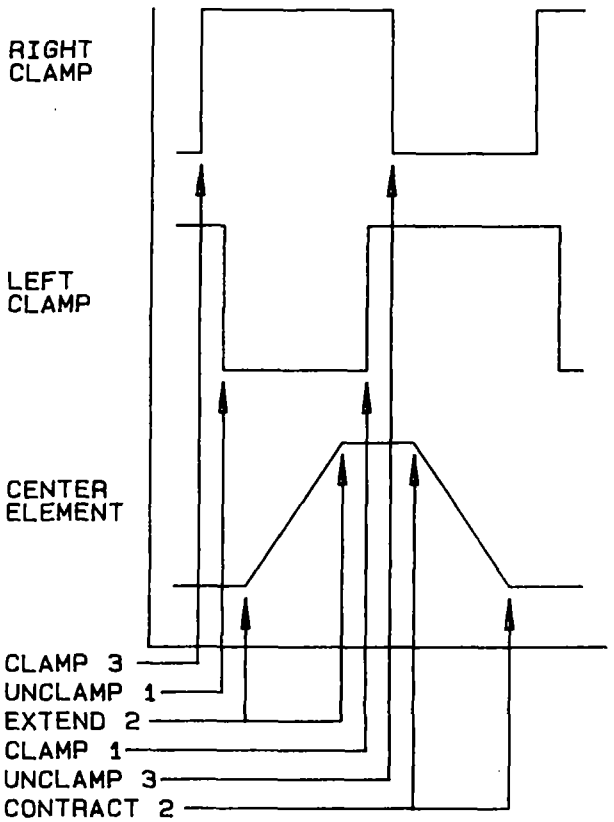


FIGURE 2
VOLTAGE SEQUENCE

The clamping and unclamping process generates a "discontinuity" in the motion which will vary slightly from motor to motor with a typical magnitude of less than 0.05μm under no-load conditions and 0.2μm with a 1.5Kg load. See Figure 3.

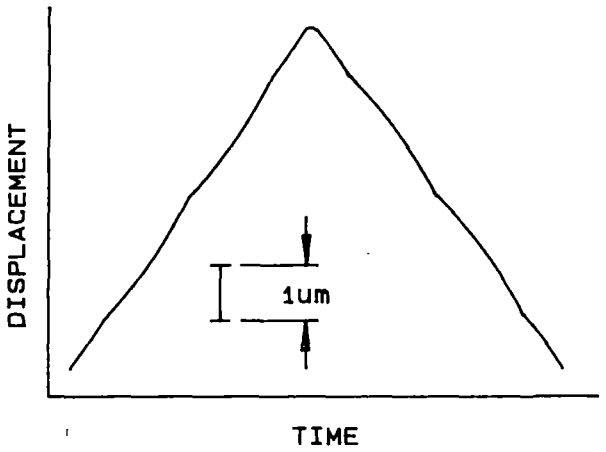


FIGURE 3
MOTION PROFILE

In applications where accurate, repeatable positioning is required best results are obtained by using the Inchworm Motor in closed-loop mode with a linear encoder providing position feedback. The IW-710 Series feature integral 0.5μm resolution encoders which are described in the following section. Alternatively, an IW-700 Series can be used with an externally mounted 0.1μm resolution encoder also available from Burleigh.

B. ENCODER

The IW-710 Series Inchworm Motor features an integral Moire fringe counting linear optical encoder mounted on the rear of the Motor shaft. It directly detects movement of the spindle and shaft with 0.5μm resolution and $\pm$1μm accuracy. The encoder provides feedback (direction and amount of motion) to the Controller for position display and closed-loop operation. Burleigh 0.5μm encoders do not have a reference mark.

The encoder is calibrated and aligned at the time of assembly and requires no user adjustment.

Refer to section 9-A for information on EN Series externally mounted 0.1μm resolution encoders.

4. OPERATION

A. INCHWORM MOTOR

IW-700 and 710 Series Motors are designed for use with Burleigh 6000, 7000 and 7010 Series Controllers. Refer to section 10 for information on using these motors with Burleigh CE-1000 or CE-2000 Controllers.

Before connecting an Inchworm Motor to a Controller be sure that the Controller power is turned off. Plug the Inchworm Motor cable connector directly into the High Voltage Driver Output located on the rear of the Controller. For IW-710 Series Motors refer to the following section for connecting the encoder cable.

If the motor must be located beyond its standard six foot cable length from the Controller Burleigh Model 7011 Extension Cables must be used for the Motor. Although extension cables can be connected in series, do not exceed 50 feet in total length.

The novel piezoelectric construction of the Inchworm Motor results in unique operating characteristics. As the Motor moves a buzzing at high speeds and clicking at low speeds can be heard. This is due to the opening and closing of the clamp elements and is normal. When the Inchworm Motor is stopped one clamp firmly holds the shaft so the shaft is very stable and does not exhibit any vibration. In addition, since piezoelectric materials do not draw current when held at constant voltage Inchworm Motors do not dissipate heat when stopped. The fast response of piezoelectric materials give the Inchworm Motor very high acceleration and deceleration.

Some lateral motion occurs in the spindle when the piezoelectric clamps change, typically $\pm 1\mu$m or less at the tip of the spindle. For critical applications such as intracellular probing the Lateral Stability Option is of value. With this feature lateral motion at the spindle tip is reduced to approximately 0.2-0.4 micron. Refer to section 8.

Refer to the Controller manual for more information on using Inchworm Motors.

In any application:

- Make sure the Motor is protected from dust, dirt and debris.
- Avoid excessive relative humidity that may condense causing electrical arcing.
- Avoid shock loads which may damage the encoder glass scales and/or the Inchworm Motor.
- In operation any side loading (perpendicular to the direction of travel) of the spindle must be kept below 0.1Kg.
- Damage can result if the Inchworm Motor stalls repeatedly against a mechanical stop for periods greater than 5 minutes.

B. INTEGRAL ENCODER

The integral encoder of an IW-710 Series Inchworm motor has a separate cable for direct connection to the Encoder Input on the back of the Controller. If the encoder is located beyond its standard 6 foot cable length from the Controller a model 7006 Remote Encoder Box must be used. The encoder cable connects directly into this box. Burleigh Model 7007 Extension Cables are available in 10, 25,and 50 foot versions and connect the box to the Controller. Extension cables can be connected in series but should not exceed 50 feet in total length.

CAUTION: Use care in handling the Inchworm Motor, specifically avoiding shocking the motor/encoder body. Misalignment and/or breakage of the encoder reader and reticle scales could result.

NOTE: When routing cables from Inchworm Motors and encoders to the Controller be sure to separate the encoder and motor cables. Avoid coiling the cables together when cables are longer than necessary since unwanted signals can be generated resulting in incorrect encoder position readings.

The mechanical resolution of the Inchworm Motor is approximately 0.004μm. Since this is much smaller than the 0.5μm encoder measurement resolution the motor may be operated within this range ($<0.5\mu$m) without the encoder detecting any change in position.

Some applications may require externally mounted encoders, the choice based upon the need for a reference mark, higher resolution, or the need for a more direct measurement of the motion of interest. Externally mounted encoders may be used with IW-700 Series Inchworm Motors.
Refer to section 9-A.

C. MOUNTING THE INCHWORM MOTOR

Important considerations:

- Use a rigid mount.
- Do not apply side loads greater than 0.1Kg

There are three methods for mounting IW-700 and IW-710 Series Inchworm Motors.

i. Mount the threaded front section of the Inchworm Motor through a clearance hole in a plate. For best results use a .500" diameter hole with a plate thickness less than or equal to .375". Use the retaining nut and spanner wrench supplied to secure the Inchworm Motor in place.

Under some conditions the retainer nut may bind and become difficult to turn. A few drops of isopropyl alcohol applied to the threads as a lubricant will alleviate the problem.

ii. Use a mount which threads onto the .5 × 40 pitch thread on the front housing. Thread the mount onto the Inchworm Motor. DO NOT thread the Inchworm Motor into the mount as there is a risk of loosening the housings.

iii. Insert the Inchworm Motor front housing into a 1.000" diameter clamp. Be careful to not over tighten the clamp. This method of mounting can provide the best stiffness.

NOTE: The rear housings do not provide a stable mounting surface and should not be used to mount Inchworm Motors.

The Burleigh IW-450 Mount was designed specifically for use with the Lateral Stability Option (LSO) Inchworm Motor but also provides a versatile mount for other applications. See Figure 4.

D. MOUNTING LOADS TO INCHWORM MOTORS

Important considerations:

- Couple loads to the spindle with care as lateral forces on the spindle (perpendicular to the travel direction) must be less than 0.1Kg.

- It is best to operate Inchworm Motors with as light a direct load as possible. This leads to smoother motion and minimizes differences in forward and reverse speeds. Spring loading does nothing to improve the stability of Inchworm Motors since they are very rigid and stable when stopped. In addition Inchworm Motors are clamped only when the controller is turned on. Rigid mounting provides less chance of slippage when power is turned off.

- Shaft-to-body axial alignment is very important. Misalignment can lead to motor damage and failure. Use Burleigh's Model LTO-H Alignment Hardware Kit to compensate for minor misalignments. See Figures 5 and 8.

- When power is turned off the Inchworm Motor holding force can momentarily drop to .5Kg or lower. It is best to remove any direct load (i.e. vertical mass, spring load, etc.) from the spindle before turning the power off.

Inchworm Motors are supplied with a rounded spindle tip. This can be used to couple to a load or can be removed to access the 6-32 tapped hole in the end of the spindle.

Several coupling methods can be used:
See Figure 5.

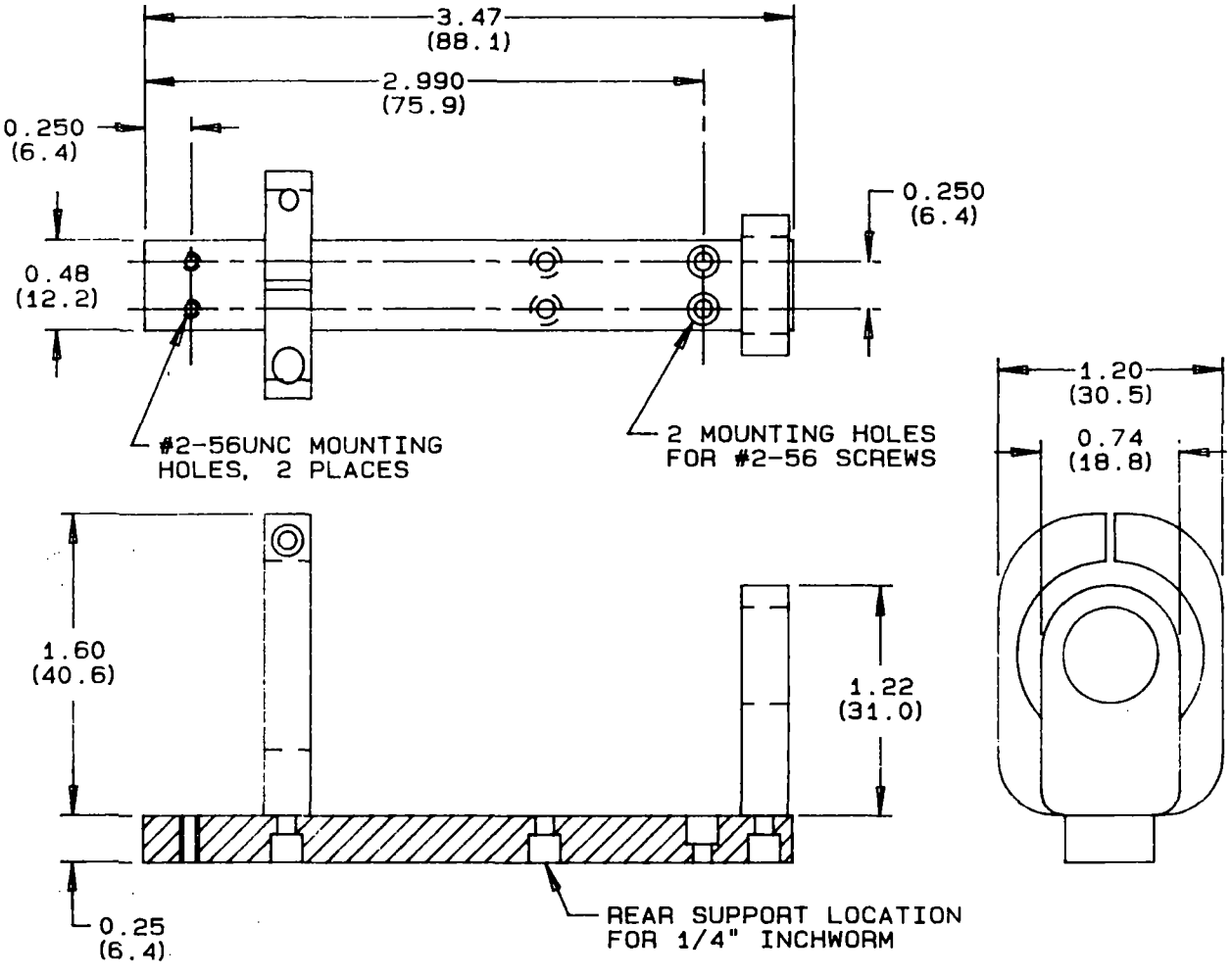
i. The rounded spindle tip is used for pushing against a spring loaded flat surface. This is often the simplest method, but may not yield the best performance.

ii. Light objects may be mounted directly to the tapped hole in the spindle.

iii. Coupling may be accomplished by magnetic attraction by removing the non-magnetic spindle tip and replacing it with either a magnetic tip or a tip of ferromagnetic material that contacts a magnetic load.

iv. Burleigh's model IW-475 Electrode Mounting Kit may be used to attach small electrodes, pipettes, or other small loads to the spindle. It mounts directly to the spindle tip with a supplied 6-32 screw.

CAUTION: NEVER tighten or loosen the spindle tip (or any threaded object) on the spindle while holding the housing. This could damage the Inchworm Motor. Hold the spindle at the wrench flats located near the end of the spindle.



DIMENSIONS IN PARENTHESES ARE IN MILLIMETERS

FIGURE 4
IW-450 MOUNT

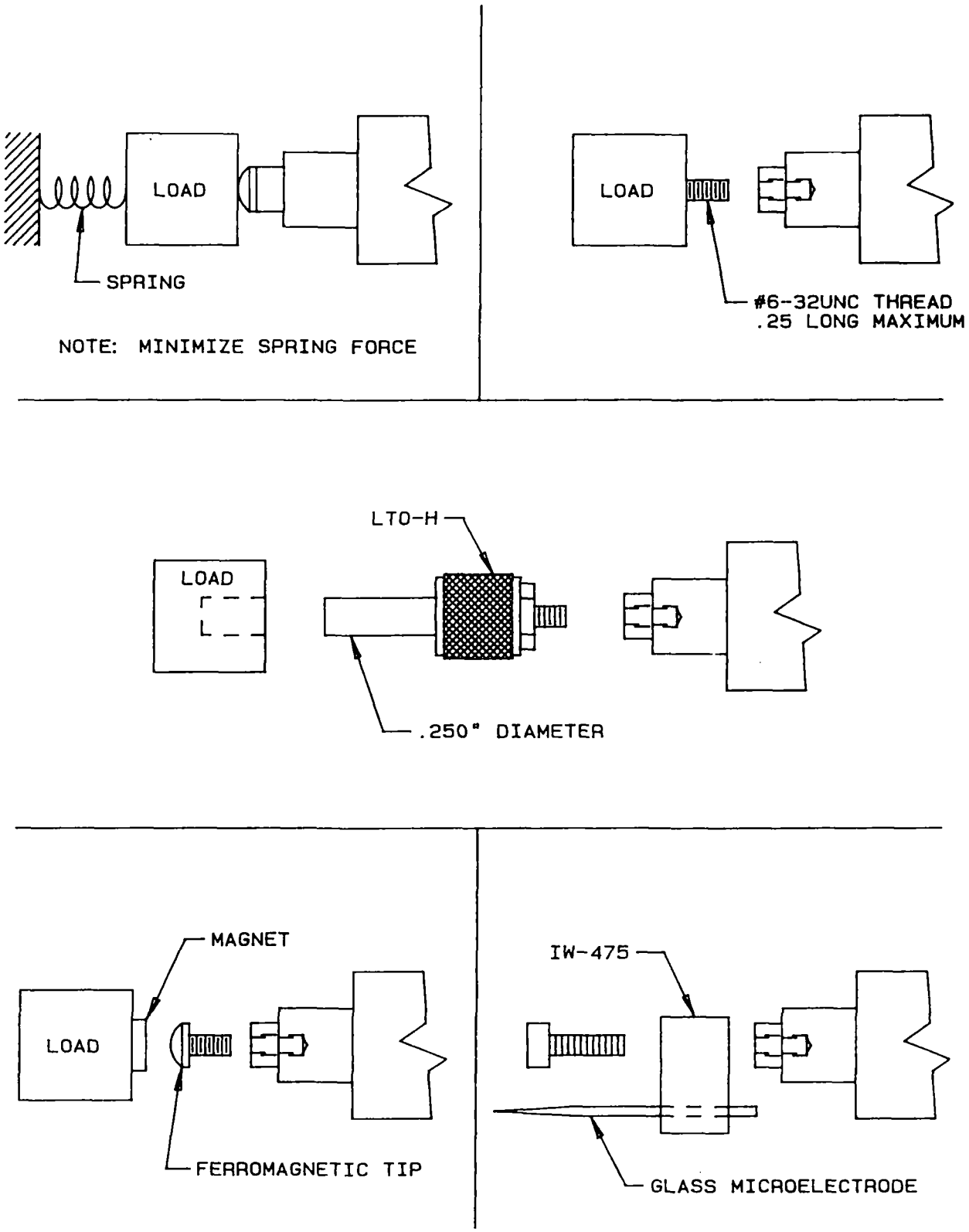


FIGURE 5
COUPLING METHODS

5. SERVICE

Clearance Compensation is a bias level that sets the Off, or unclamped voltage for the clamp elements and determines the clearance between the clamp elements and the shaft. Burleigh sets this operating level at the factory. In normal use no adjustment should be necessary. However, under certain conditions the clearance between the shaft and clamps will change slightly resulting in a loss of push force. These conditions include:

- high ambient temperature
- large load combined with high duty cycle
- motor wear over a long period of time.

Please refer to your Inchworm Motor Controller Manual for instructions on adjusting the Clearance Compensation.

CAUTION: Excessive wear and damage to the Inchworm Motor can result if the Clearance Compensation is set too low.

There is no other user service or maintenance that can be done for the IW-700 or 710 Series Inchworm Motors. When any problems or questions arise please call the Burleigh Customer Service Department at:

Burleigh Instruments, Inc.
Burleigh Park
Fishers, New York 14453
Tel. (716)924-9355
Tlx. 97-8379
Fax. (716)924-9072

Or contact your local representative.

CAUTION: Do not open up an Inchworm Motor or remove any housing parts. High voltages may be exposed and the warranty will be voided!

6. SPECIFICATIONS

All Models:

Travel Distance	0.25(mm)	IW-700, IW-710
	25.0	IW-701, IW-711
	50.0	IW-702, IW-712
Speed	(minimum)	.004 micron/sec
	(maximum)	>2mm/sec.
Load	(maximum)	1.5Kg in direction of motion
		0.1Kg perpendicular to motion
Mechanical Resolution		4nm (typical)
Lateral Motion (maximum)		±1 microns at tip (6.25 and 25mm models)
		±2 microns at tip (50mm models)
Discontinuity at clamp change (typical)		<0.05 microns at no load
		<0.2 microns at 1.5 Kg. load
Temperature Range	Operation	+10 to +50 degrees C.
	Storage	0 to +70 degrees C.
Force to move shaft (typical)		1.0to 1.5Kg Controller power off
		0.0 to 0.7Kg Power on (Free mode)

Encoder models:

Encoder Resolution	0.5μm
Encoder Accuracy	±1.0μm
	±2.0μm with LSO

Refer to Figure 7 for IW-700 and 710 Series outline dimensions.

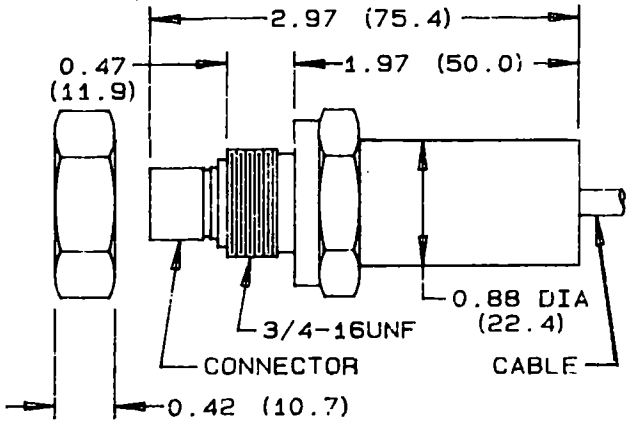
7. VACUUM OPERATION

A. DESCRIPTION

IW-700 and 710 Series Inchworm Motors are available with special assembly for vacuum use.

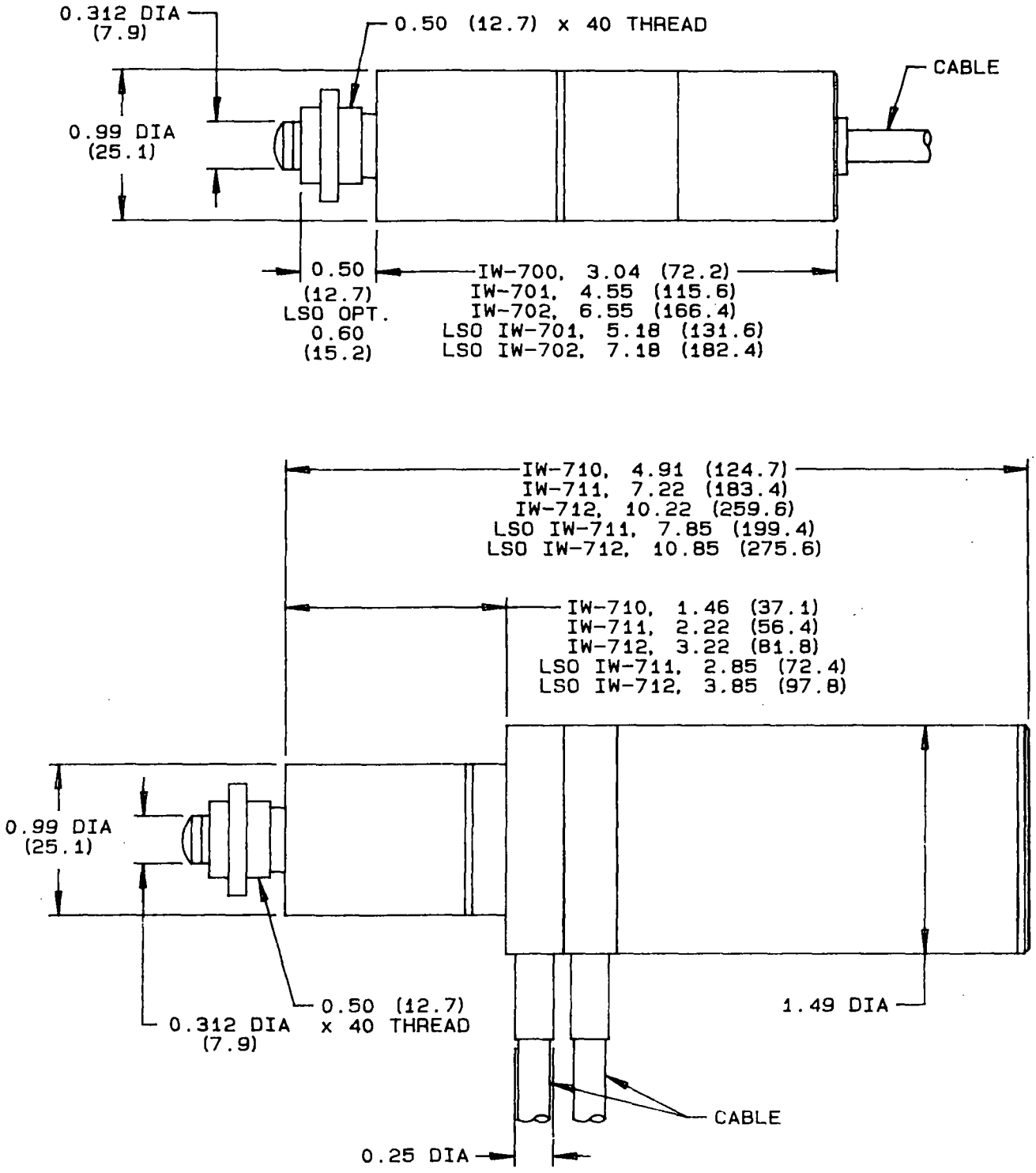
Important features are:

- Teflon motor and encoder cables.
- Bulkhead mount O-ring vacuum feedthroughs supplied for both Motor and encoder cables. (See Figure 6)
- Special cleaning in Freon to remove residual contaminants.
- All cavities vented to prevent trapping air.



DIMENSIONS IN PARENTHESES ARE MILLIMETERS

FIGURE 6
VACUUM FEEDTHROUGH



DIMENSIONS IN PARENTHESES ARE IN MILLIMETERS

FIGURE 7
IW-700/710 OUTLINE DIMENSIONS

B. OPERATION

Excess heat generation during Inchworm Motor operation places a limitation on the product of duty cycle and speed. For vacuum use the recommended maximum is .25 × 100% duty cycle × 2mm/sec. In all cases the actual Motor temperature must be kept at or below 60^{O}C during operation.

When an Inchworm Motor is first run in vacuum self heating may cause some excess degassing which will result in a higher initial outgassing rate. The system will then return to outgassing rates listed below. The ultimate pressure obtainable depends on the pumping rate and background outgassing rate of the user's vacuum system. For ultra high vacuum applications contact Burleigh Instruments for information on UHV Series Inchworm Motors.

WARNING: The controller must be turned OFF when pumping through the corona region (.001 to 100 Torr). Failure to turn off the controller will result in permanent damage to the Inchworm motor, cabling, and controller. Inchworm motor replacement will likely be required. It is Burleigh's strongest recommendation that vacuum/power interlocks be installed to help prevent this type of damage.

CAUTION: The vacuum Inchworm uses a vented spindle tip. The threaded spindle hole is NOT vented. If the spindle tip is replaced, a vented screw design must be used.

C. SPECIFICATIONS

With the exception of the maximum product of duty cycle and speed as described above all positioning specifications are identical for vacuum and non-vacuum Inchworm Motors.

Vacuum range	10^{-6} to 10^{-7}Torr (typical)	
Bakeout temperature	- 70 C (maximum)	
Outgassing (typical)	Model	Outgassing rate
	IW-700	<1.0 (X10^{-6} T-L/s)
	IW-701	1.0
	IW-702	1.5
	IW-710	3.0
	IW-711	3.5
	IW-712	4.0

NOTE: (T-L/s = Torr-Liters/sec)

8. LATERAL STABILITY OPTION (LSO)

A. DESCRIPTION

The Lateral Stability Option reduces the sideways (lateral) motion of the Inchworm Motor spindle that occurs during a clamp change. This option is primarily of interest to neuroscientists who use the Inchworm Motor to probe or penetrate small cells (<20μm diameter).

The LSO is available for 25 and 50mm travel models only and is compatible with the encoder and vacuum options. The LSO adds approximately .63" to the length of the front housing of the Inchworm Motor. All other dimensions remain the same. Refer to Figure 7.

B. OPERATION

Cell penetration:

When the Inchworm Motor is moving there may be some vibration transmitted to the microelectrode, even with with LSO. Some Neuroscientists find this vibration or "ringing" helpful in making successful cell penetrations. Since this vibration is not a lateral motion of the spindle tip, but a resonant effect of the microelectrode it can be adjusted by varying the length of the pipette. Contact the Burleigh Customer Service Department or your local representative for more information.

Stability:

Due to its piezoelectric construction the Inchworm Motor is intrinsically very stable, showing little drift over many hours in a stopped condition.

For correct operation and to prevent unintended motions the Controller should be operated with the Maintenance function turned OFF. Refer to the Controller manual for further details.

C. SPECIFICATIONS

With the exception of encoder accuracy all positioning specifications are identical for LSO and non-LSO Inchworm Motors.

Lateral motion	<.2μm at clamp change (typical)
Lateral hysteresis	3μm maximum (see definition below)
Encoder accuracy	±2μm (IW-711 and IW-712 only)

Lateral hysteresis is the net sideways motion of the spindle occurring when the Inchworm Motor reverses travel direction. This is a gradual motion with a sideways translation of 1-3μm occurring in a travel distance of 5-30μm. It is measured at the end of an approximately 3" long glass microelectrode mounted on the end of a fully extended Inchworm spindle.

D. ACCESSORIES

IW-475 ELECTRODE MOUNTING KIT

This kit provides the user a stable mount for 1mm diameter glass microelectrodes. The insulating Delrin block mounts to the threaded spindle end with a supplied 6-32 screw. See Figure 5.

IW-450 INCHWORM MOUNT

This mount is designed for use with LSO Inchworm Motors and provides a stable versatile platform for connecting to user supplied apparatus. The mount is provided with two tapped and two countersunk holes for mounting, or the user can tap or drill holes in the base as required. See Figure 4.

9. OPTIONS

A. EN SERIES ENCODERS

The EN Series encoders have travel distances of 12, 25 and 60mm, with 0.1μm resolution and $\pm$.5μm accuracy ($\pm$1μm accuracy for 60mm version). All three versions have an absolute reference position and are compatible with 6000, 7000, and 7010 Controllers. Hardware is available for mounting them to TS-100 Series stages. Contact the Burleigh Sales Department or your local representative for further details.

B. TS-100 TRANSLATION STAGES

The TS-100 Series offers a lightweight aluminum, high precision, crossed roller bearing stage designed for used with IW-700 and 710 Series Inchworm Motors. The basic stage has a 4" × 4" (101.6mm × 101.6mm) footprint with 50mm travel and is offered with or without a 1.75" diameter central through-hole, each in a standard or vacuum version. Counterbalanced vertical (Z-axis) versions are also available. Hardware is available for mounting EN Series encoders. Contact the Burleigh Sales Department or your local representative for further details.

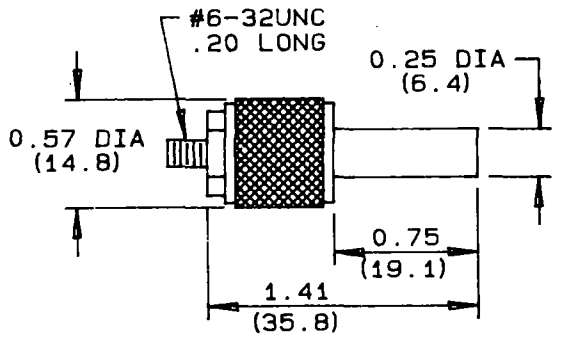
C. NON-MAGNETIC INCHWORM MOTOR

The standard IW-700 and 710 Series Motors use ferromagnetic shafts and screws. For applications requiring non-magnetic construction a ceramic shaft and stainless steel or brass screws can be substituted. For the IW-710 Series there are additional magnetic encoder parts that can be replaced depending on the degree of magnetism which can be tolerated. Contact the Burleigh Sales Department or your local representative for further details.

D. ACCESSORIES

LTO-H HARDWARE KIT

Burleigh's LTO-H Hardware Kit provides spring coupling directly to the spindle and provides a 0.25 inch diameter shaft for connection to the load. Each Kit has two spring loaded couplings. See Figures 5 and 8.



DIMENSIONS IN PARENTHESES ARE MILLIMETERS

FIGURE 8
LTO-H

CE-7 CABLE

This cable permits use of Inchworm Motors with CE-1000 & CE-2000 Controllers. See section 10.

10. OPERATION WITH CE-1000 AND CE-2000 CONTROLLERS

Restrictions:

i. A CE-7 Cable must be used (see below).
ii. Mechanical resolution is .01μm (typical).

As part of a design to improve noise immunity, Inchworm Motors designed for use the 6000, 7000 and 7010 Controllers use a different ground and

shield pin configuration than those designed for use with the CE-1000 or CE-2000 Controllers. Thus the IW-700 and 710 Series are not directly compatible with Burleigh Model CE-1000 or CE-2000 Controllers, but require use of a CE-7 Adapter Cable between the Controller and the Inchworm Motor cable.

CAUTION: An electrical shock hazard can exist if a CE-1000 or CE-2000 Controller is used without a CE-7 cable. If you have any questions please contact the Burleigh Customer Service Department or your local representative.

EN Series 0.1μm resolution encoder operation:

A model EXE-710 interface box must be used. Contact the Burleigh Customer Service Department or your local representative for details.

Extension cables:

Motor: Use Model 7011 Extension cables. The maximum allowable length is 50 feet. First connect the CE-7 cable to the Controller then connect the extension cable.

Encoder:

0.5μm resolution - No extension cables permitted

0.1μm resolution - Use Model 7007 Extension cables. The maximum allowable length is 50 feet.

11. GLOSSARY

Accuracy - The veracity with which an instrument can determine the true value of a quantity measured.

Backlash - An error in gear trains and lead screw systems arising from mechanical tolerances. It is the "dead band" where no motion occurs when the direction of travel is reversed.

Closed loop control - Operation of a positioning system with position feedback. Positioning accuracy is dependent upon the encoder.

Encoder - A measuring device which outputs signals corresponding to position or change in position. Rotary or shaft encoders measure angles. Linear encoders measure distance along a straight line.

Feedback - In closed loop positioning systems this refers to the signals used by the controller to measure and maintain position.

Lateral motion - The rapid sideways net motion of the spindle which occurs during a clamp change.

Open loop control - Operation of a positioning system without position feedback. Accuracy depends on the drive system, stage and load.

Piezoelectric - A term used to describe a class of materials which expand or contract upon application of an electric field.

Repeatability - The variability experienced when a positioning system is repeatedly moved to some nominal location. Note that a system can be inaccurate, but very repeatable.

Resolution: measurement - The smallest increment of motion that the encoder or sensor can detect. In a closed-loop system this is also the smallest position step that can be taken under feedback control.

Resolution: mechanical - The smallest motion that an actuator can achieve.

12. WARRANTY

Burleigh 700 and 710 Series Inchworm Motors, when operated by Burleigh Control Electronics, are warranted against defects in material and workmanship for a period of one year after date of delivery. Burleigh's warranty card must be returned within 30 days after date of delivery. During the warranty period, Burleigh will repair or, at its option, replace parts which prove to be defective when the motor is returned prepaid to Burleigh Instruments, Inc. The warranty will not apply if the motor has been damaged by accident, misuse, or as a result of modification by persons other than Burleigh personnel.

It is important to call Burleigh or your local representative for a Return Authorization Number (RA#) before returning any product. This will insure the prompt handling of the repair.

The liability of Burleigh (except as to title) arising out of supplying of said product, or its use, whether under the foregoing warranty, a claim of negligence, or otherwise, shall not in any case exceed the cost of correcting defects in the product as herein provided. Upon expiration of the warranty period specified herein, all liability shall terminate. The foregoing shall constitute the sole remedy of the buyer. In no event shall the seller be liable for consequential or special damages.

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