PRODUCT: LINEAR Σ SERIES: SGLGW, SGLFW, SGLTW

SUBJECT: LINEAR MOTOR DESIGN TIPS AND ASSEMBLY INSTRUCTIONS

Linear motors will greatly improve automated machinery by producing higher speeds, faster response, higher accuracy, increased stiffness and longer life. This will be apparent with proper assembly of the linear motor components. A linear motor actuator design is similar to a ball screw actuator in that both use linear guide rails, bearing blocks, an actuator base, carriage and encoder. The main difference is that a linear motor coil and magnet track provides non-contact thrust rather than a mechanical ballscrew coupled to a rotary servomotor. Also, the encoder readhead measures actual load position from a linear scale rather than reading the position of the motor on a ball screw actuator. The design considerations that are specific to linear motor assemblies will be explored in further detail. The SGLFW-50A200A coil in the FW series is shown as an example below, even though the design considerations apply to all three Yaskawa series; FW, GW, and TW. This document is intended as a supplement to the Yaskawa technical manuals, third party technical manuals, and the Yaskawa product CD. The details that follow are meant to be guidelines that will help a project engineer get started designing a linear motor assembly. This is meant to be a guide and not a textbook on machine design for linear motors.

Carriage

Bearing Block / Truck

Primary Linear Guide Rail Shoulder

Primary Linear Guide Rail

Linear Slide Base / Machine Base

Readhead Bracket

Readhead

Linear Scale

Magnet Track
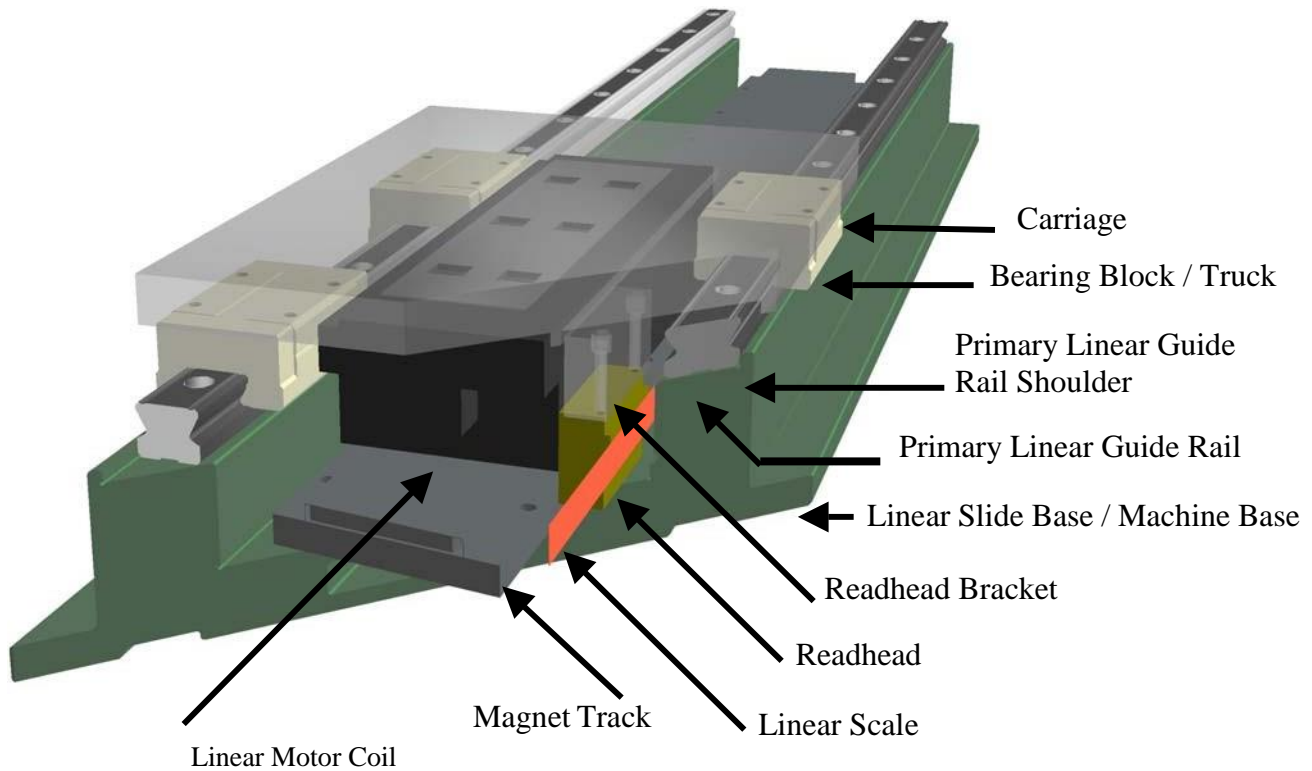
Linear Motor Coil

1. Linear Motor Design Considerations

1.1. Linear Motor Coil Selection

Yaskawa offers three types of linear motor systems. Each type provides specific features and advantages depending on the application.

The FW series is an iron-core linear motor system ideal for most general automation applications. The iron-core maximizes the generated thrust force but also creates a magnetic attraction force. The magnetic attraction force between the coil and magnets can be used to effectively increase the rigidity of the linear guidance system by preloading the linear motion bearings. The magnetic preloading can help increase the system's frequency response, improving its deceleration and settling performances. The compact profile of the FW linear motors result in low profile positioning systems.

The GW series is a coreless (no iron in moving coil) linear motor system ideal for applications requiring low velocity ripple and/or high acceleration. The velocity ripple is minimized due to the zero-attraction force and zero-cogging nature of the coreless construction.

The TW series is also an iron-core linear motor system with a unique balanced construction that negates the effects of magnetic attraction forces while delivering the highest force per cross-sectional area. The balanced design allows for the use of smaller linear motion bearings without the major concerns for bearing life. The TW linear motors have very little cogging due to its optimized internal magnetic circuit design.

The size of the linear motor coil should be selected based on the application requirements. The applied load, desired move profile, duty cycle, required accuracy and precision, life, and environment are all important factors necessary in selecting the proper linear motor.

1.2. Magnet Track Selection and Stroke Length Considerations

Magnet tracks come in several discrete sizes. Choosing the longest possible sections to make up a total length is recommended. If multiple tracks are combined to make up a travel length, make sure the threaded mounting holes on the receiving base are dimensioned to a +/- 0.1 mm tolerance. Make sure the magnet track is within 50 microns of parallel to the linear guide rails.

The magnet track for the FW and TW series coil are parallelogram shaped. The angled sections should not be considered in the magnet tracks useful length.
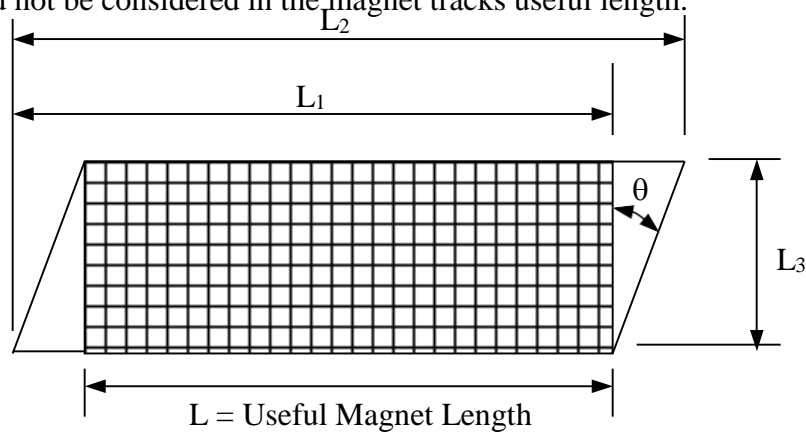
$$UsefulMagnetTrackLength, L = L_1 - [L_2 - L_1] = L_1 - [L_3 \tan\theta]$$

The length of the coil and the emergency stopping distance must be considered when determining the useful stroke length.

The available stroke length equals the useful magnet track length minus the coil length, hall sensor length, and emergency stop distance. Depending on the mechanical design, check for clearance for the hall sensor and the cables. Note the hall sensor should never protrude from the edge of the magnet track otherwise an alarm may occur.

Conservative designs will allow a stopping distance from the over travel switch to a point short of the mechanical hard stop. (See example calculations in Appendix A)
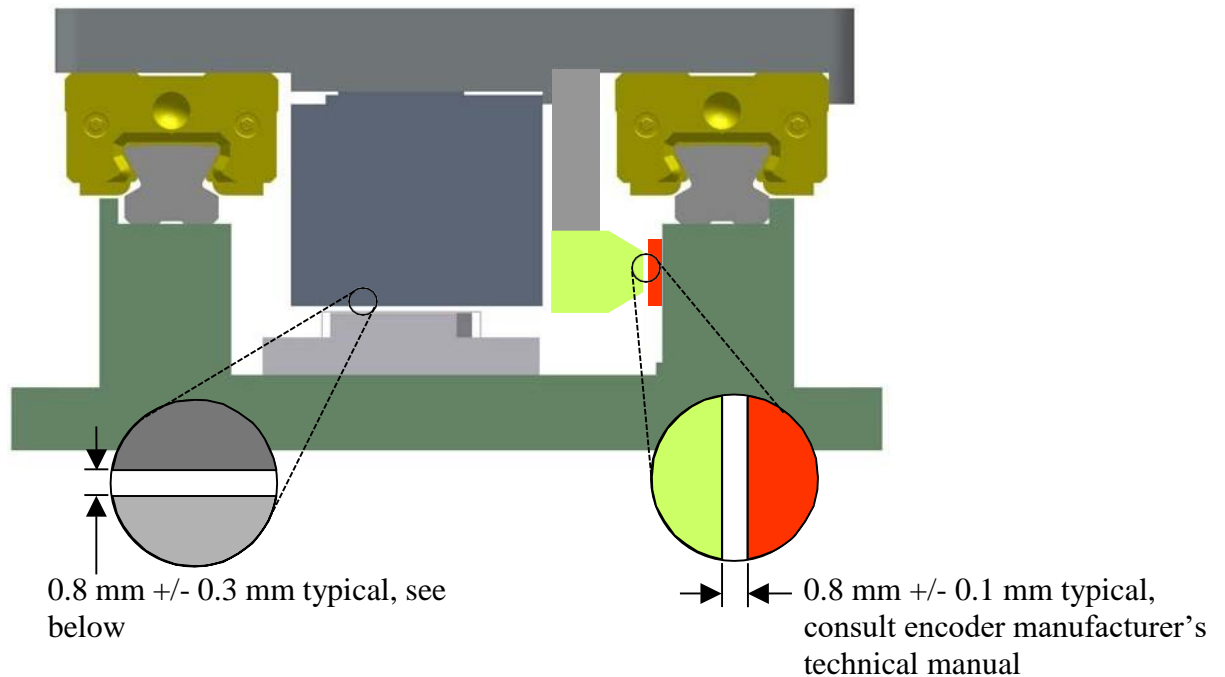
Dynamic braking on an over travel switch is a feature available in the Yaskawa SGDH Sigma II amplifier. This feature allows the carriage to be stopped without power applied to the amplifier. However, this method requires more stopping distance than if peak force was applied. Yaskawa recommends measuring the actual stopping distance on the prototype machine at a point where the carriage is least likely to contact a mechanical hard stop.

1.3.   Material Selection

The majority of linear motor assemblies are produced with aluminum components. Specifically 6061-T6 and MIC-6 aluminum provide excellent rigidity and ease of machining. The linear motor base is used to average out surface discontinuity of the machine base as well as provide a non-magnetic surface for trouble free mounting of the magnet track. Be cautious when using extruded aluminum, since it contains internal stresses that can cause dimensional changes after machining.

1.4. Mechanical Precision

There are two important alignments in linear motor assemblies, the gap distance between the coil and the magnet track and the gap distance between the encoder readhead and the linear scale. These are the only alignments that are necessary in a linear motor system. The critical alignment of a ballscrew is eliminated with a linear motor system.

0.8 mm +/- 0.3 mm typical, see below

0.8 mm +/- 0.1 mm typical, consult encoder manufacturer's technical manual

The following tables and diagrams show the required gap dimensions for the linear motors. Consult encoder manufacturer for gap dimensions on the encoder.

Table 1. G-Series Position of Moving Coil & Magnet Track

Moving Coil Type: SGLGW-	Size	
	G1 (mm)	G2 (mm)
30A050ϒϒ	0.85 ± 0.3	1 ± 0.3
30A080ϒϒ	0.95 ± 0.3	1 ± 0.3
40A***ϒϒ	0.8 ± 0.3	1 ± 0.3
60A*** ϒϒ	0.8 ± 0.3	1 ± 0.3
90A***ϒϒ	1.1 ± 0.3	2 ± 0.3
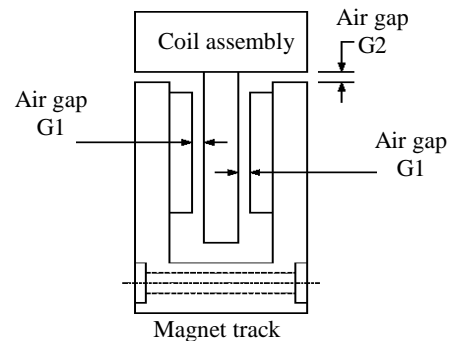
Table 2. F-Series Position of Moving Coil & Magnet Track

Moving Coil Type: SGLFW-	Size		
	H (mm)	P (mm)	G (mm)
20AⲨⲨⲨAⲨ	45 ± 0.1	22 ± 0.2	0.8 ± 0.3 (1)*
35AⲨⲨⲨAⲨ	45 ± 0.1	21 ± 0.2	
50AⲨⲨⲨAⲨ	58 ± 0.1	25.8 ± 0.2	
1ZAⲨⲨⲨAⲨ	58 ± 0.1	27 ± 0.2	

The value in parentheses is the dimension when the magnet cover is not used.
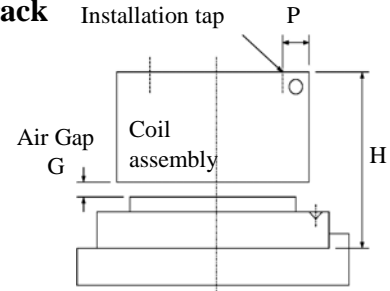
Linear servomotor side
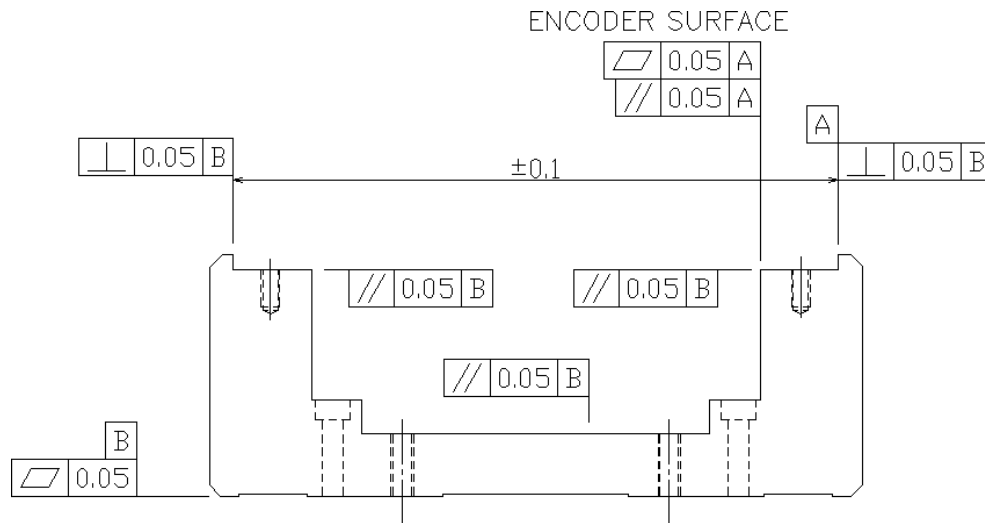(Diagram viewed from the side where the cable extends from the coil assembly.)

Table 3. T-Series Position of Moving Coil & Magnet Track

| Moving Coil Type: SGLTW-	Size		
	H (mm)	A (mm)	G1 & G2 (mm)
20AⲨⲨⲨAⲨ	55 ± 0.3	15 ± 0.1	0.8 ± 0.3 (1)*
35AⲨⲨⲨAⲨ	70 ± 0.3		
40AⲨⲨⲨAⲨ	83 ± 0.3	19.1 ± 0.1	1.2 ± 0.3 (1.4)*
80AⲨⲨⲨAⲨ	120 ± 0.3		

∗ The value in parentheses is the dimension when the magnet covers are not used.
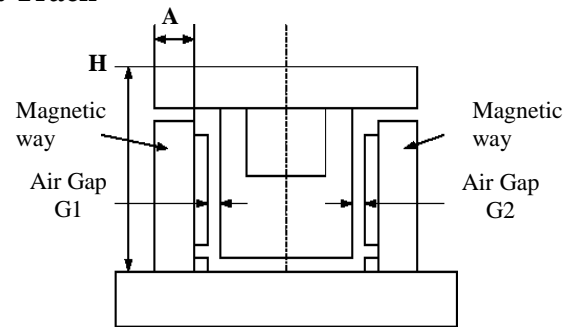
Linear servomotor side view
(Diagram viewed from the side where the cable extends from the coil assembly)

ENCODER SURFACE

```
�  0.05  A
//    0.05  A
```

A

```
⊥  0.05  B                    ±0.1                    ⊥  0.05  B
```

```
//  0.05  B        //  0.05  B
```

```
// 0.05 B
```

B
```
� 0.05
```

The above diagram shows the cross section of a base designed for an FW series coil. The diagram shows typical surface tolerances that will help achieve these two important dimensions.

**Base for FW coil**

B
```
⌁ 0.05
```
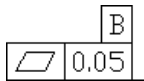
The B datum line defines the bottom surface of the linear motor assembly base. The surface flatness should be 50 microns. Any point measured by an indicator should be less than 50 microns from any other point.

A
```
⊥ 0.05 B
```
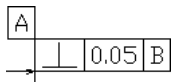
The A datum defines the shoulder for the primary linear guide rail. Any point on this surface must be with in 50 microns of perpendicular from the B datum.

ENCODER SURFACE
```
⌁ 0.05 A
// 0.05 A
```
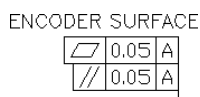
The surface for the linear encoder scale must be with in 50 microns of parallel from the A datum. All points must also be with in 50 microns of any other point. (50-micron flatness) Always reference the surface for the scale to the primary guide rail shoulder.

```
//  0.05  B
```
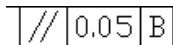
The surface for the linear guide rails and the magnet track surface must be parallel to the B datum. All points should be less than 50 microns from parallel to the B datum. The distance from the magnet track surface to the linear guide rail surface should take into account the deflection of the carriage if the FW series coil is used. See the example deflection calculation in Appendix A.

⟂ 0.05 B
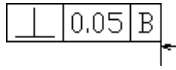
The secondary linear guide rail shoulder must be perpendicular to the B datum. Any point on this surface must be less than 50 microns from perpendicular to the B datum

±0.1

The distance between the linear guide shoulders must not deviate more than 100 microns.

1.5. Linear Bearings

Always use a grade of linear guide rail and bearing block, which provide sufficient precision to meet the coil to magnet track air gap tolerance and the readhead to scale gap tolerance. Specifically check the tolerance for the bearing height. The height is the distance between the bottom of the rail and the top of the bearing block. Also check the tolerance of the rail-to-block lateral distance. Rail-to-block lateral distance is the distance from the linear guide rail shoulder to the side surface of the bearing block. In general, a precision grade bearing will be sufficient, albeit the term precision varies among manufacturers.

Special Note on FW series coils. The configuration of the FW series results in a magnetic attraction force between the coil and the magnet track. This force will produce a considerable deflection in the carriage in some cases. Make sure this deflection is taken into account in the distance from the magnet track surface to linear guide rail surface. An example deflection calculation is shown in Appendix A

1.5.1. Bearing Force and Life Considerations

Nominal life of the bearing is important in both ball screw and linear motor assemblies. There are three considerations that are specific to linear motors.

First, the bearing manufacturer's life calculation usually results in a total distance. Since linear motors can accelerate faster and travel at higher speeds, the cycle rate is much higher than a ballscrew actuator. Make sure to calculate the bearing life in hours taking into account the higher cycle rates.

Second, the bearing loads during acceleration, traverse, and deceleration must be considered. The higher acceleration capacity of the linear motor can produce higher radial and lateral bearing loads during acceleration. If only one rail is used, a significant moment load will arise in the yaw, pitch and roll directions. In the case of the FW series coil, the magnetic attractive force must be added to the weight of the carriage and load. The magnetic attractive force is five to six time the motor's peak force. Make sure the nominal life of the bearing is sufficient to handle these extra loads. Four bearing blocks

are always recommended for the FW series to reduce moment loading. Preloaded bearings are not recommended for the FW series coil. Refer to section 1.5.2 Magnetic Attraction Force for specifications on magnetic attraction forces.
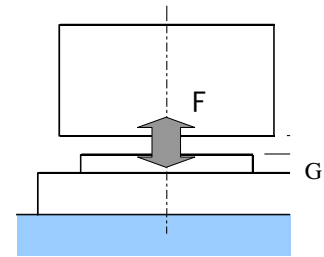
Third, make sure to check the maximum speed allowed by the bearing manufacturer since the Yaskawa motor/drive system is capable of speeds up to 5 m/sec.

1.5.2. Magnetic Attraction Force

The SGLFW/SGLFM type linear motor is constructed of an opposing coil assembly and magnet track. Therefore, the coil assembly is subject to magnetic attraction as shown in the following table (calculated maximum values). (Refer to Table 4). Consider the magnetic attraction when designing the linear motor actuator.

Table 4. FW-type Magnet Attraction Force (Calculated Value)

Moving Coil Type: SGLFW-	Gap: G^{*1} (mm)	Attraction Force: F^{*2} (N)	Nominal Attraction Force: F_1^{*3} (N)
20A090Aϒ	.5 mm (0.7 mm)^{*4}	410	314
20A120Aϒ		600	462
35A120Aϒ		1100	809
35A230Aϒ		2100	1586
50A200Aϒ		2700	2095
50A380Aϒ		5200	4144
1ZA200Aϒ		5300	4190
1ZA380Aϒ		10400	8289

Conditions:
*1. Gap G: Air gap value of -0.3mm relative to the design value.
*2. Attraction Force F: Maximum magnetic attraction force.
*3. Attraction Force F_1: Nominal magnetic attraction force (air gap = design value).
*4. The value in parentheses is the dimension when the magnet cover is not used.

The SGLTW/SGLTM type linear motor is constructed of a coil assembly and two opposing magnetic ways. Therefore, magnetic attraction is offset when the air gap between the coil assembly and both magnetic ways is even.

However, achieving an even air gap is difficult due to the accuracy of the linear servomotor itself and the machine, and error in the assembly of the linear servomotor at installation. Consider the magnetic attraction values shown in the following table when designing the linear motor actuator to account for the effect of magnetic attraction (calculated maximum values). (Refer to Table 5).

Table 5. TW-type Magnetic Attraction Force (Calculated Value)

| Moving Coil Type: SGLTW-	Gap: G1[*1] (mm)	Gap: G2[*1] (mm)	Attraction Force: F1[*2] (N)	Attraction Force: F2[*2] (N)	Difference Between F1 & F2: ΔF (N)
20A170Aϓ	1.1 (1.3)[*3]	.5 (0.7)[*3]	760	1030	270
20A320Aϓ			1510	2040	530
20A460Aϓ			2260	3050	790
35A170AϓΎ	1.1 (1.3)[*3]	.5 (0.7)[*3]	1330	1800	470
35A320AϓΎ			2650	3570	920
35A460AϓΎ			4000	5400	1400
40A400Aϓ	1.5 (1.7)[*3]	.9 (1.1)[*3]	4700	5900	1200
40A600Aϓ			7000	8700	1700
80A400Aϓ	1.5 (1.7)[*3]	.9 (1.1)[*3]	9200	11400	2200
80A600Aϓ			13600	16900	3300

Conditions:

*1. Gap G1 & G2: Air gap value when one side is +0.3mm and the other side is -3mm relative to the design values.

*2. Attraction Force F1 & F2: Maximum magnetic attraction force.

*3. The value in parentheses is the dimension when the magnet cover is not used.
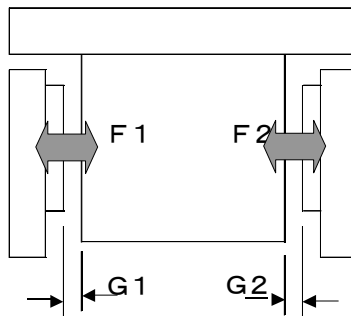
1.6. Thermal Considerations

One obvious difference in a linear motor design is the placement of the motor coil. In a ball screw application the heat produced by the motor is somewhat isolated from the load by the length of the ball screw. In a linear motor assembly the heat is generated at the coil mounted on the carriage. The heat generated is conducted through the carriage and readhead bracket (assuming that the readhead bracket is mounted to the carriage) and can cause the temperature to rise in the bearing blocks and readhead. Take precautions to ensure the temperature rise in the coil does not lead to temperatures exceeding those recommended by the bearing and readhead manufacturer. The temperature rise in the coil will be less if a heat sink is used. Less heat will be conducted to the bearings and readhead if cooling fins are employed (see drawing below). In general, excessive bearing or readhead temperature is not a problem if the coil temperature is held under 60°C. Yaskawa application engineering is available for coil temperature calculations.

Cooling fins
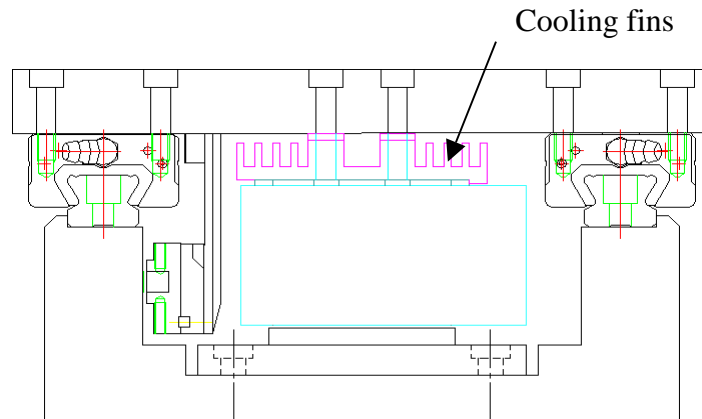
In some applications, the heat from the coil can cause the carriage to expand and contract. This movement can cause the read head gap to change. In these cases, consider steel or another material with a lower coefficient of thermal expansion than aluminum.

1.7.   Environmental Considerations

Precautions should be taken to prevent particles from entering the gap between the coil and the magnet track and the gap between the readhead and the scale. Keep all liquids from the readhead, the scale, and the coil.

1.8.   Vertical Applications

When the linear motor is intended for use in a vertical orientation, well-designed counter balancing or mechanical braking mechanisms must be provided in order to prevent free fall in a servo off condition.

1.9.   Feedback System Considerations

The feedback system controls the accuracy, resolution, and repeatability of the linear motor system as well as the mechanical precision of the system. The position feedback system in a linear motor assembly includes several components. The linear scale, readhead, hall sensors, home and end-of-travel sensors, serial converter, and cables all must be considered. The linear scale provides small gratings that allow the readhead to measure position. The readhead is a sensitive electronic device that uses an LED and an array of photo detector's to convert light signals from the scale to electronic signals. Only readheads with 1-V_{p-p} sinusoidal analog outputs are compatible with the Yaskawa linear servomotor system. The hall sensors are used to detect the orientation of the magnetic field from the magnet track and provide feedback for commutation of the coil. The serial

converter takes in the analog $1V_{p-p}$ signals from the readhead and the signals from the hall sensor and converts them to a serial signal accepted by the Sigma II amplifier. Yaskawa supplies the serial converter and hall effect sensors as an integral part of the motor coil.

1.9.1.   Linear Scale

Linear scales can be made of glass or metal and fall into two categories; sealed or exposed. Sealed scales are designed and primarily used on machines that operate in harsh environments. On the other hand, sealed scales typically consist of an internal low-friction guide and seals that introduce additional mechanical wear components to the system. In addition, the sealed encoder housing may be cumbersome to design in a small package.

Exposed linear scales are mounted directly to the linear motor assembly base. Recent improvements in exposed scale technology have made them suitable for many industrial environments. The diagram on the next page from Renishaw shows how the exposed linear encoders have overcome the problem of contamination and slight mechanical damage.

Renishaw Optical Scheme
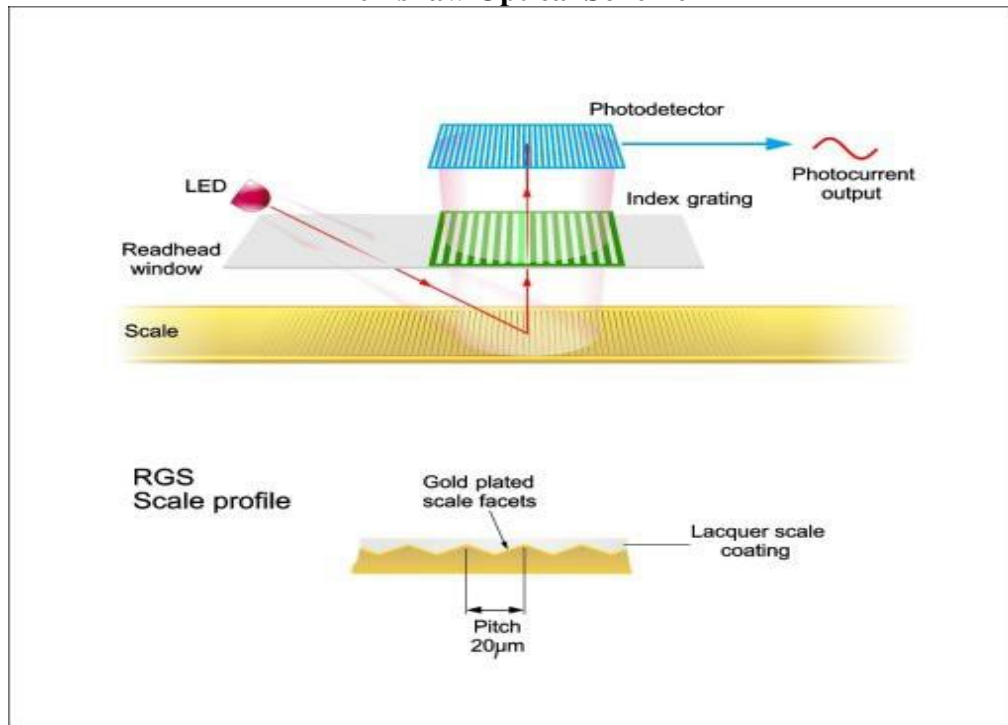
In current systems the scale grating reflects the LED light. The light travels through an index grating that produces a sinusoidal pattern on the photo detector as the carriage moves. The photo detector is actually several photo-receivers that average the light over 80 scale graduations. Any contamination or physical damage to the scale is effectively filtered out of the signal.

Heidenhain uses single-field scanning that results in relative insensitivity to contamination. The dust, toner, water and oil droplets produce only a 0.1 um position error.

Heidenhain Resistance to Contamination
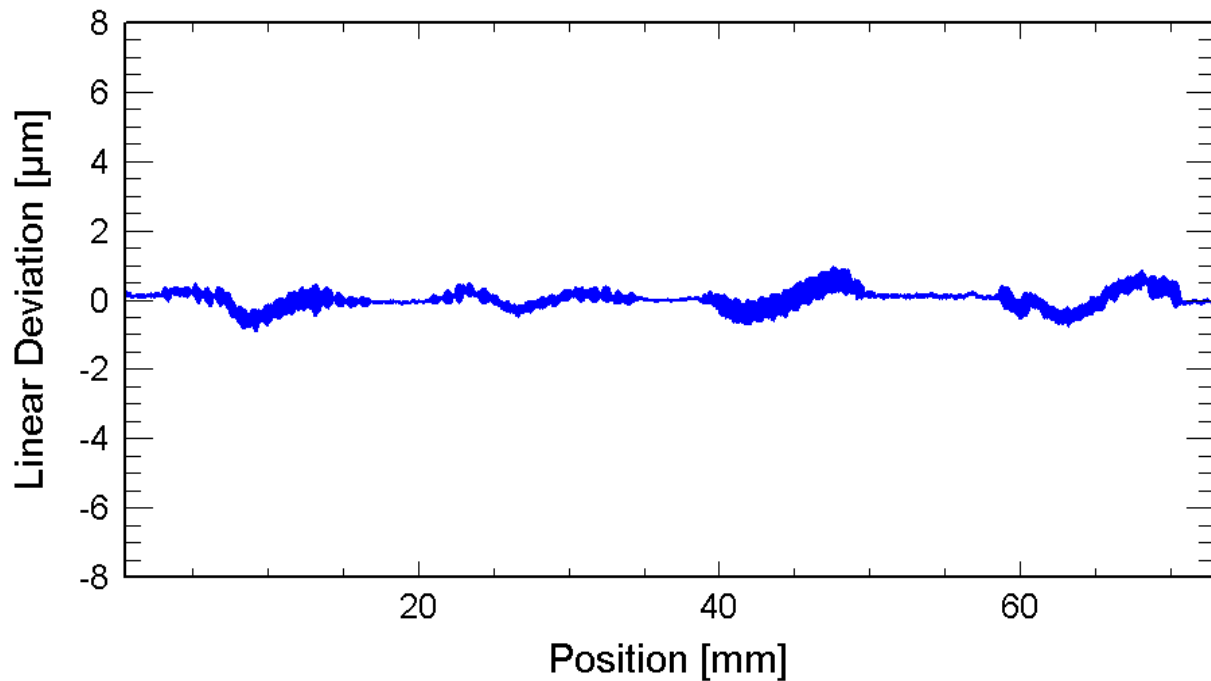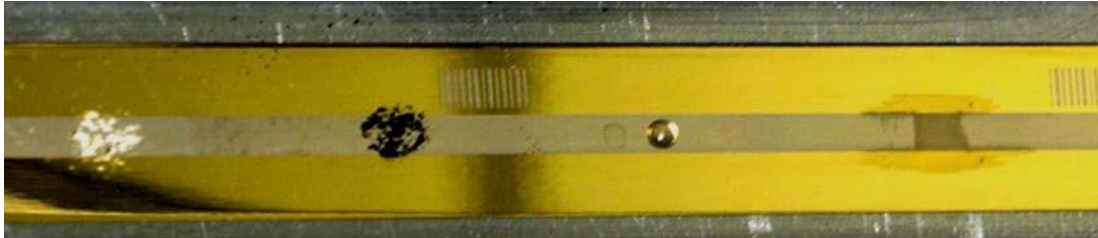
Adhesive and mechanical fastening are the two main methods of mounting an exposed linear scale. In the adhesive method, a backing from the scale is removed, exposing an adhesive that attaches directly to the base of the linear motor assembly. In the mechanical method, the scale is inserted into an aluminum extrusion and the extrusion is mechanically fastened to the base.

Both methods are suitable for most applications. The two methods should be further investigated if thermal expansion or field service is critical in the application. In general the adhesive method allows the scale to expand and contract with the base and will average out the effect of dissimilar metals in the base. The adhesive method can require

machine disassembly for replacement. The mechanical mounting method pins the scale in the middle and allows the scale to expand and contract according to its thermal expansion coefficient. In this method, the scale is selected so that the scale expansion coefficient matches the material in the linear motor assembly base. The mechanical mounting method is easier to service since the scale slides in and out of the extrusion.

Make sure the scale is mounted parallel to the linear guide rails. As the diagram illustrates, small angular misalignments can cause linear errors.

SIDE VIEW

α = **angular offset of the scale**
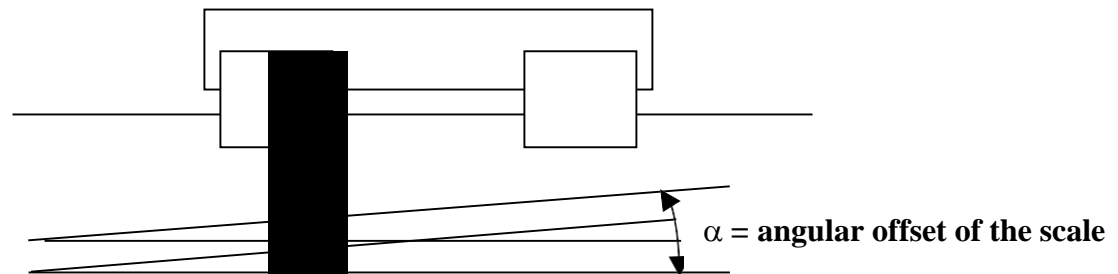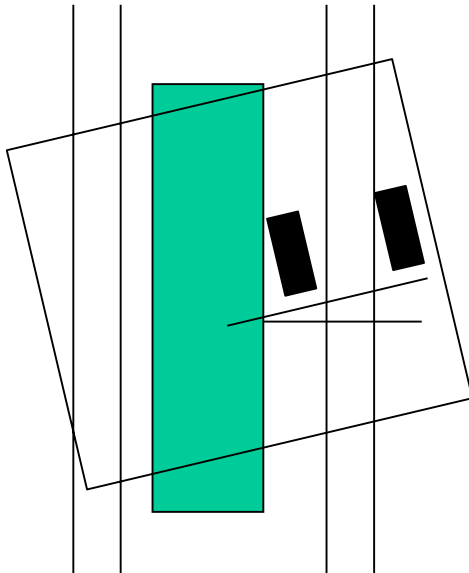
1.9.2. Readhead

TOP VIEW

Place the readhead as close as possible to the coil. Always place the readhead on the side of the primary linear guide rail. The readhead should withstand the heat produced from the motor coil. As the diagram below illustrates, small angular deflections will cause larger linear errors, as the read head gets farther away from the coil.

1.9.3. Yaskawa Serial Converters

Yaskawa provides serial converters that work with the Renishaw RG2 and RG4 and many Heidenhain analog output linear encoders. The Renishaw encoder cable connector (15-pin D-sub) can be directly connected to the serial converter, whereas, a conversion cable is required and available from Yaskawa to connect the Heidenhain encoder cable

connector (15-pin D-sub). Renishaw provides adhesive backed scales with a unique device for mounting the scale to the base. Heidenhain offers the adhesive scale and the mechanically mounted scale. The Heidenhain mechanically mounted scale includes a built in reference mark, while the Renishaw offers a reference mark with an install-to-suit location.

The following websites provide more information on the two companies.

Renishaw plc.
http://www.renishaw.com/client/product/UKEnglish/PGP-1114.shtml
http://www.renishaw.com/UserFiles/acrobat/M-9531-1281.pdf
http://www.renishaw.com/userfiles/acrobat/m-9531-2050.pdf

Heidenhain GmbH.
http://www.absolutencoder.com/linear

1.9.4.   Cabling and Cable Carrier

Cable carriers are necessary to guide and protect cables in a linear servomotor system. Depending on the location of the serial converter, the power cable, encoder (readhead) cable, hall sensor cable, and/or encoder (serial converter) cable will need to be routed through the cable carrier. These cables are available from Yaskawa, and it is recommended that only these cables be used with the linear servomotor system. These cables are designed for high-flexing applications. The recommended bend radius is 60mm at which the cable life is 10 million cycles. A smaller bend radius will reduce the cable life while a larger bend radius will increase the life.

When routing cables through the cable carrier, cables must always be clamped at each end with strain reliefs to ensure proper cable length at all times within the carrier. Cables should also be placed next to one another and should never be able to climb over one another. In general, the faster or more frequent the cable moves, the more important it is to properly install cables in the carrier. Consult the cable carrier manufacturer for specific details.

Linear Servo Motor Installation Procedure

2.1. Safety Precautions

Install the linear servomotor according to the following precautions.

- <u>Any person having electronic medical devices such as a pacemaker must not approach the magnet track of the linear servomotor.</u>

  Failure to observe this warning may result in malfunction of the medical devices.

<CAUTION>

- <u>When unpacking and installing the magnet track, check that no metal fragments or other magnetic objects are present considering the magnetic attraction of the magnet track.</u>

  Failure to observe this caution may result in injury or damage to the magnets track.

- <u>Do not place the magnet track near metal or other magnetic objects.</u>

  Failure to observe this caution may result in injury.

- <u>Do not place any electronic devices such as clocks, magnetic cards, floppy disks, or measuring instruments close to the magnet track.</u>

  Failure to observe this caution may result in malfunction or damage to these items by the magnetic force.

- When handling the magnet track with the magnetic cover, do not grab the cover. (Refer to the photograph)
  Failure to observe this caution may result in injury caused by the edge of the cover or deformation of the cover.

Cover
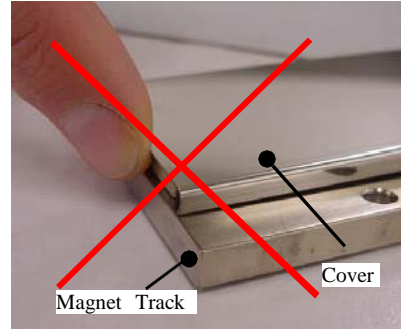
Magnet Track

- Keep fingers away from the gap between magnet tracks when connecting multiple magnet tracks together.

  Otherwise fingers may become jammed due to the magnetic attraction between magnet tracks, resulting in injury. When joining magnet tracks together, place the second magnet track temporarily in line and at least 30 mm apart from the first magnet track.

- When using linear servomotors with hall sensors, make sure that the hall sensor does not protrude from the servomotor's magnet track.

  Otherwise, the linear servomotor may not operate properly. The hall sensor is built into the coil assembly in SGLGW-30 and SGLGW-90 linear servomotor. For other models, the hall sensor is mounted on the side.

2.2. SGLGW and SGLGM Linear Servomotor Installation Procedure (Coreless Type)

2.2.1. SGLGM Magnet Track Installation

The SGLGM magnet tracks are U-channel steel tracks with opposing magnets attached to the inner surfaces. (Refer to the Figure 1).
Make sure that no foreign particles (magnetic objects) are caught between the magnets when installing them.
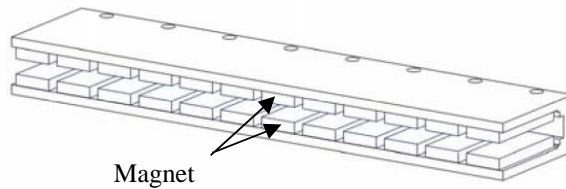

Magnet

Figure 1

Use the following procedure to install SGLGM magnet tracks.

(1) After checking the magnet track's two mounting surfaces, place the magnet track on the reference surface of the machine base. (Refer to Figure 2). Be careful to keep hands clear from getting jammed.
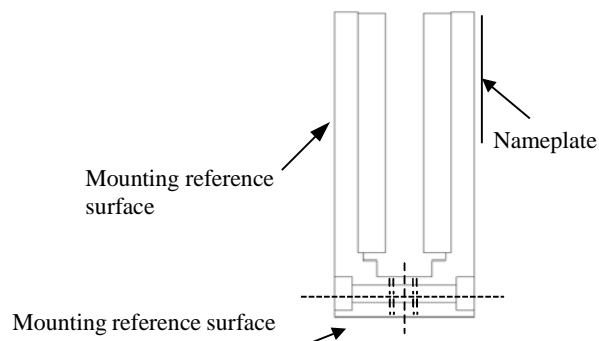

Nameplate

Mounting reference surface

Mounting reference surface

Figure 2

(2) Press the magnet track down closely onto the reference surface of the machine and secure it with bolts. (Refer to Table 6).

Table 6. Recommended Tightening Torque for SGLGM Magnet Track

Magnet Track Type: SGLGM-	Bolt Size:	Tightening Torque: (N.cm)
30 ΥΥΥΥ	M4	360 to 500
40 ΥΥΥΥ	M5	720 to 1010
60 ΥΥΥΥ		
90 ΥΥΥΥ	M6	1220 to 1710

Note: Use hexagonal socket head bolts (tensile strength Class 10.9)

(3) When joining magnet tracks together, place the second magnet track temporarily in line and at least 30 mm apart from the first magnet track. Next, while pressing the second magnet track down closely on the machine's reference surface, push the second magnet track against the first magnet track. After confirming the mounting position, secure the second magnet track using bolts. Make sure that fingers do not get jammed due to the magnetic attraction between the magnet tracks. (Refer to Figure 3).
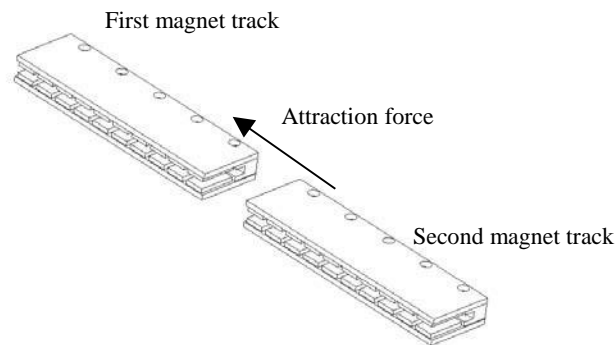
First magnet track

Attraction force

Second magnet track

Figure 3

(Note)
Since the magnetic attraction force of magnet track type "SGLGM-90" etc. is large, the following method is recommended for larger thrust magnet tracks. Rotate the second magnet track to join the first magnet track after aligning the angles of the bolt holes on the magnet track's connecting surfaces. After confirming the mounting position, secure the second magnet track using bolts. Make sure that fingers do not get jammed due to the magnetic attraction between the magnet tracks. (Refer to Figure 4).
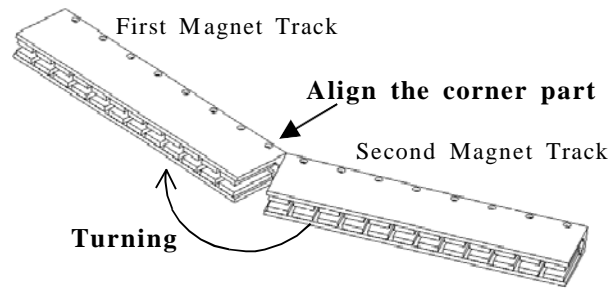
First Magnet Track

Align the corner part

Second Magnet Track

Turning

Figure 4

2.2.2. SGLGW Coil Assembly Installation

The coil assembly of SGLGW linear servomotor is constructed of an aluminum base and a resin-coated coil winding section. Handle the coil assembly with care and do not subject the coil winding section to shock. Doing so may cause injury or damage to the coil assembly.

Use the following procedure to install the coil assembly of SGLGW linear servomotor.

(1)   Insert the coil winding section of the coil assembly between the magnets of the magnet track that have already been installed. (Refer to Figure 5). Next, install the moveable table supported by the coil assembly's linear guide. Make sure that the air gap between the coil assembly's coil winding section and magnet track's magnets is the specified distance. (Refer to Table 1 in section 1.2 Mechanical Precision).
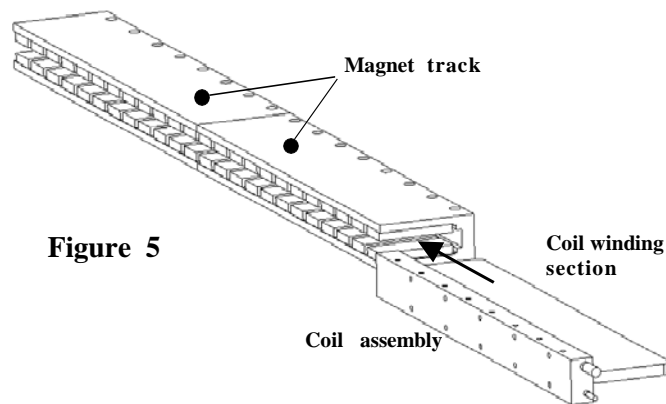
Magnet track

Figure 5

Coil winding section

Coil   assembly

(2) Move the coil assembly back and forth several times from end to end over the magnet track(s). Make sure that the coil assembly and magnet track are not touching each other and that no foreign objects such as magnetic particles are present.

2.3.   SGLFW and SGLFM Linear Servomotor Installation Procedure (F Type with Iron Core)

2.3.1.   SGLFM Magnet Track Installation

The SGLFM magnet track is packed with a cardboard sheet covering the magnetic surface, above which is a thin, rectangular steel plate. (Refer to Figure 6)

The steel plate is a dummy plate used to reduce the influence of magnetic force on the surrounding environment. When removing the plate, make sure that fingers are kept clear and handle with care to prevent damaging the magnet and magnet cover.
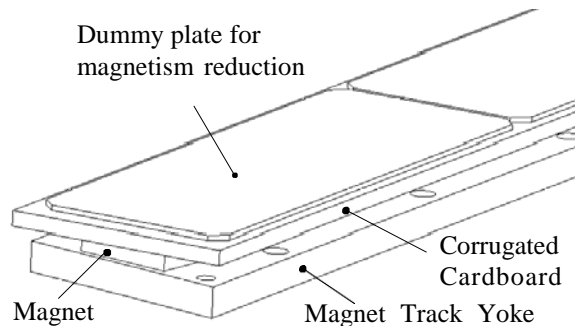

Figure 6

Use the following procedure to install the SGLFM magnet track.

(1)   Remove the dummy plate used to reduce the magnetic force and the cardboard sheet from the magnet track surface.

(2)   Align the side of the magnet track with the standard marks (approx. 4-mm dia. indentations) with the reference surface of the machine base. Keep fingers clear to prevent from being jammed. (Refer to Figure7).
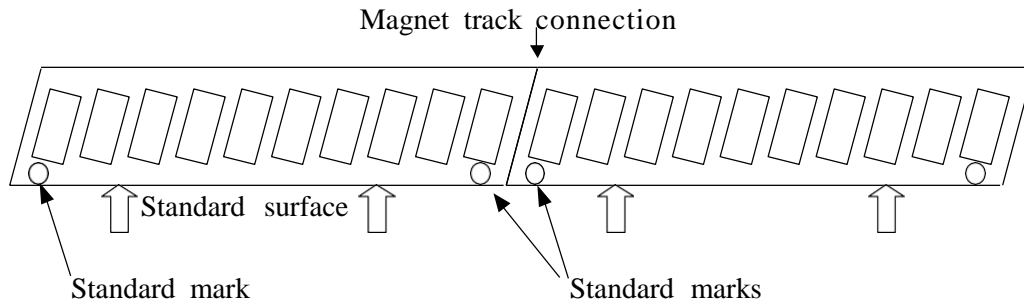
Magnet track connection

Standard surface

Standard mark

Standard marks

Figure 7

(3)   While pressing the magnet track down closely on the machine's reference surface, secure with bolts. (Refer to Table 7).

Table 7. Recommended Tightening Torque for SGLFM Magnet Track

Magnet Track Type: SGLFM-	Bolt Type:	Tightening Torque: (N-cm)
20 ΥΥΥΥ	M4	360 to 500
35 ΥΥΥΥ		
50 ΥΥΥΥ	M5	720 to 1010
1Z ΥΥΥΥ	M6	1220 to 1710

Note: Use hexagonal socket head bolts (tensile strength Class 10.9)

(Note)
A strong attraction force generates from the magnets of the magnet track. Work carefully when using steel bolts and wrenches. Always use bolts with a head height according to the dimensions as shown in the following table.

Magnet Track Type: SGLFM-	Bolt Type:	Screw Head Height: K	
20 ΥΥΥΥ	M4	4.2mm or Less	Figure 8
35 ΥΥΥΥ			
50 ΥΥΥΥ	M5	5.2mm or Less	Figure 9
1Z ΥΥΥΥ	M6	6.7mm or Less	

Note: Use hexagonal socket head bolts (tensile strength Class 10.9)

Magnet			↕ K

Magnet Track Yoke

Figure 8

Magnet			↕ K

Magnet Track Yoke
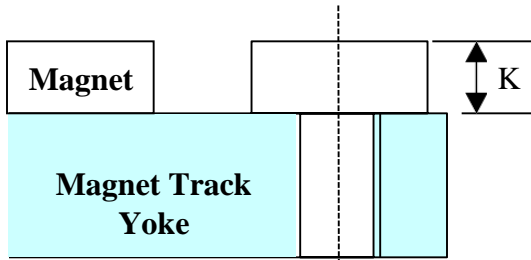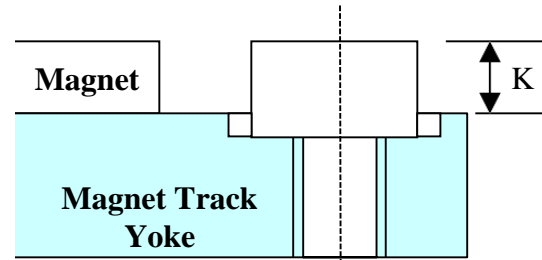
Figure 9

(4) When joining magnet tracks together, place the second magnet track temporarily in line with and at least 30 mm apart from the first magnet track. Match the direction of the magnet tracks (standard marks: approx. 4-mm indentation). [Refer to Figure 7 in step (2)].

Next, while pressing the magnet track down closely on the machine's reference surface, push the second magnet track against the first magnet track and secure with bolts. Keep fingers clear to prevent them from being jammed between the magnet tracks due to the magnetic attraction pulling the magnet tracks together. (Refer to Figure 10).
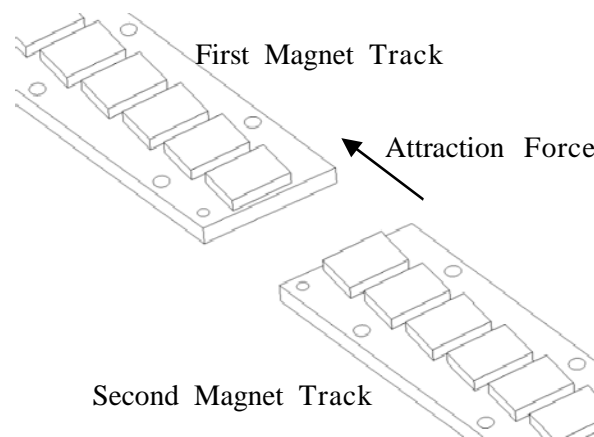
First Magnet Track

Attraction Force

Second Magnet Track

Figure 10

(Note)
For safety, install the coil assembly before installing the second or subsequent magnet track. Refer to "2.3.2 SGLFW Coil Assembly Installation" for details.

2.3.2. SGLFW Coil Assembly Installation

The SGLFW coil assembly is constructed of an aluminum or steel base and iron core with a resin-coated coil winding section. Make sure that the coil winding section is not subjected to shock during installation. Shock may cause injury or damage to the coil assembly.

Use the following procedure to install the SGLFW coil assembly.

(1) Install the coil assembly on the movable table supported by the linear guide in line with the previously installed magnet track. (Refer to Figure 11).

Make sure that the air gap between the coil assembly and the magnet track is the specified distance and that the coil assembly and magnet track do not interfere during the stroke. (Refer to Table 2 in section 1.2 Mechanical Precision).
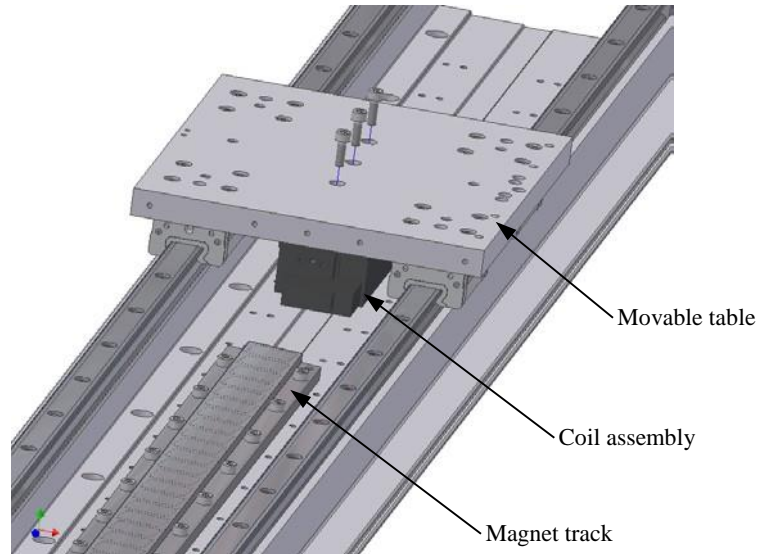

Movable table

Coil assembly

Magnet track

Figure 11

(Note)
When two or more magnet tracks are used, first secure the first magnet track, and then install the coil assembly in the available space. [Refer to Figure 11 in 3.2 step (1)]. If using only one magnet track with insufficient space to extend the linear guide up to the position of the coil assembly, temporarily mount a dummy linear guide in line with the magnet track's linear guide.

[Simplified Diagram of Dummy Linear Guide Installation]

Standard linear guide

Dummy linear guide

Magnet track

Coil assembly

Movable table

Block
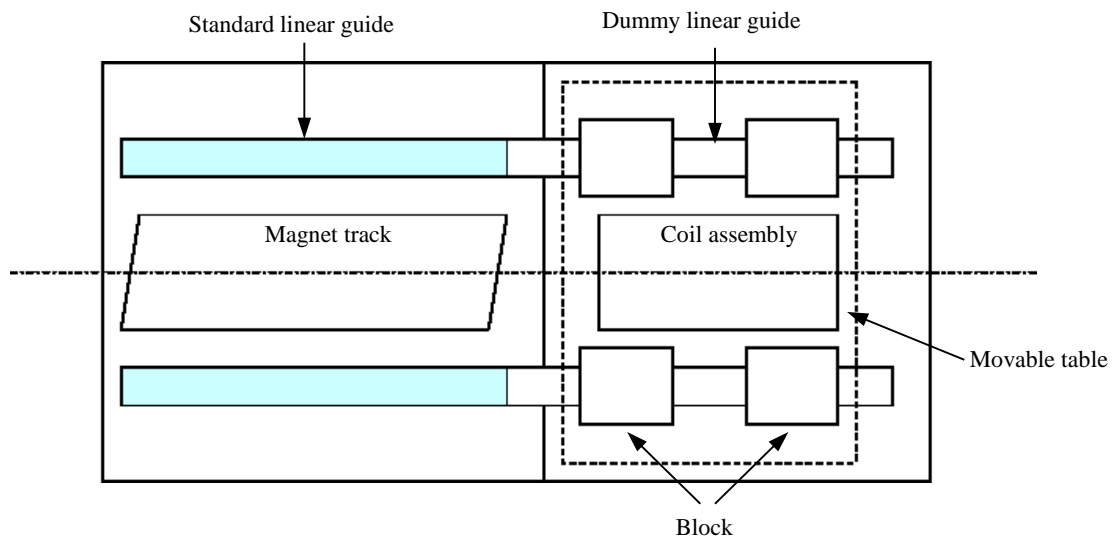
(2) Insert a thin non-magnetic (preferably resin) sheet (thickness: approx. 0.5-mm thick) in the air gap between the coil assembly and magnet track, and then slowly move the coil assembly toward the magnet track. (Refer to Figure 12).
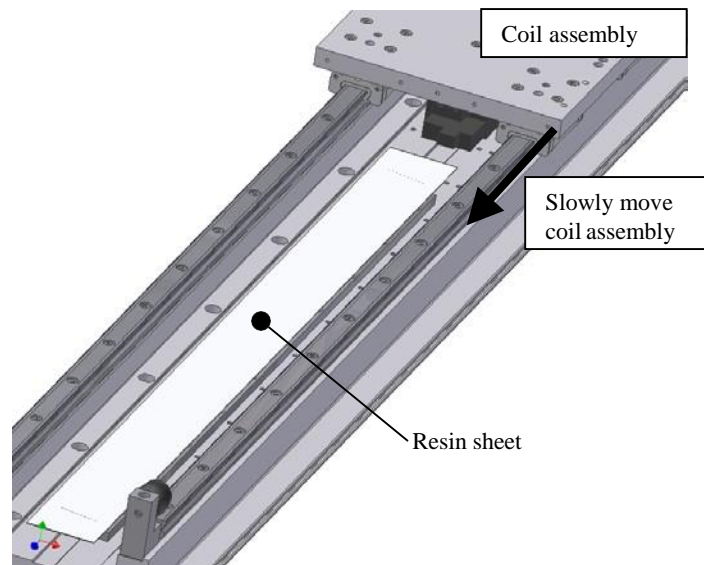
Coil assembly

Slowly move coil assembly

Resin sheet

Figure 12

(Note)
Make sure that hands or tools are not jammed due to the magnetic attraction from the magnet track when the coil assembly approaches the end of the magnet track. When the air gap between the coil assembly and the magnet track is fixed, the nonmagnetic sheet is not required.

(3) Move the coil assembly back and forth several times from end to end over the magnet track, making sure that the coil assembly does not touch the magnet track and that no foreign objects (such as magnetic particles) are present. Use a nonmagnetic (brass or stainless steel) gap gauge to check that the air gap between the coil assembly and the magnet track is uniform

2.4. SGLTW and SGLTM Linear Servomotor Installation Procedure (T Type with Iron Core)

2.4.1. SGLTM Magnet Track Installation

The SGLTM magnet track is packaged with two magnetic ways secured to a base and two installation handles for transport. (Refer to Figure 13).
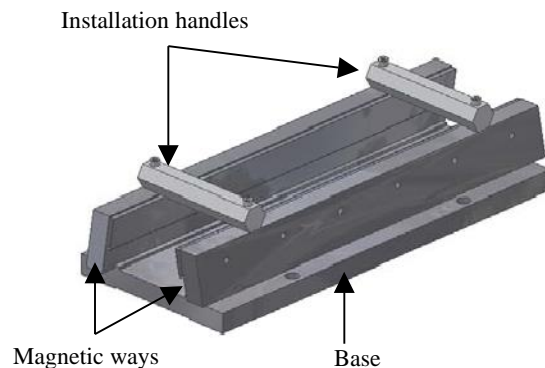

Installation handles

Magnetic ways

Base

Figure 13

(1) Align one side of the magnet track base with the standard surface of the machine base; keeping fingers clear to prevent from being jammed.

(2) While pressing the magnet track base down closely onto the machine's reference surface, secure with bolts. (Refer to Table 8).

Table 8. Recommended Tightening Torque for SGLTM Magnet Track

Magnet Track Type: SGLTM-	Bolt Type:	Tightening Torque (N-cm)
20ΥΥΥΥ	M8	2970 to 4150
35ΥΥΥΥ		
40ΥΥΥΥ	M10	
80ΥΥΥΥ		

Note: The following conditions apply to these values.
- Machine side material: Steel
- Hexagonal socket head bolts (tensile strength Class 10.9)

(3) Fully remove the installation handles used for transport from the magnet track.

(4) When joining magnet tracks together, place the second magnet track temporarily in line with and at least 30 mm apart from the first magnet track. Next, while pressing the magnet track down closely on the machine's reference surface, push the second magnet track against the first magnet track and secure with bolts. Keep fingers clear to prevent them from being jammed between the magnet tracks due to the magnetic attraction pulling the magnet tracks together. (Refer to Figure 14).
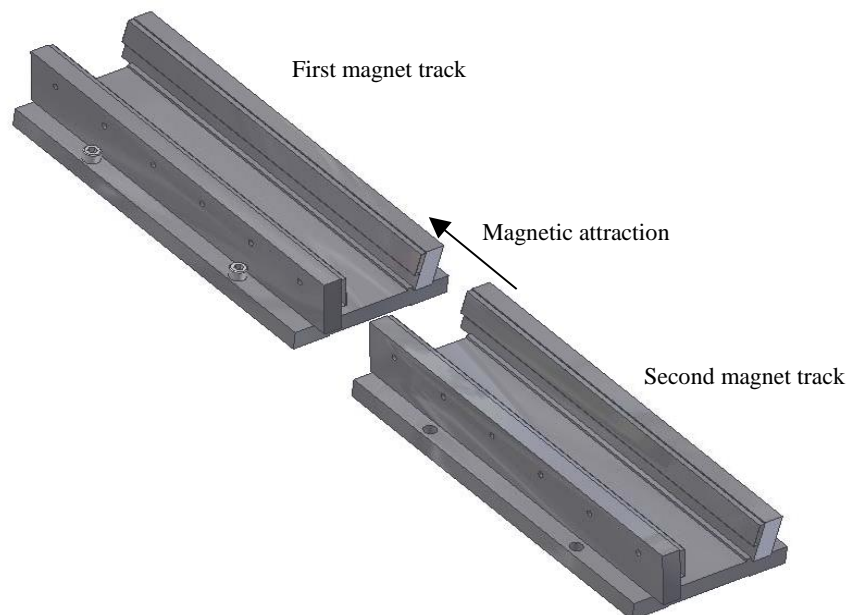

First magnet track

Magnetic attraction

Second magnet track

Figure 14

(Note)
For safety, install the coil assembly before installing the second or subsequent magnet track. Refer to "2.4.2 SGLTW Coil Assembly Installation" for details**.**

2.4.2. SGLTW Coil Assembly Installation

The SGLTW coil assembly is constructed of an aluminum or steel base and iron core with a resin-coated coil winding section. Make sure that the coil winding section is not subjected to shock during installation. Shock may damage the coil assembly.

Use the following procedure to install the SGLTW coil assembly.

(1) Install the coil assembly on the movable table supported by the linear guide in line with the previously installed magnet track. (Refer to Figure 15).

Make sure that the air gap between the coil assembly and the magnet track is the specified distance and that the coil assembly and magnet track do not interfere during the stroke. (Refer to Table 3 in section 1.2 Mechanical Precision).
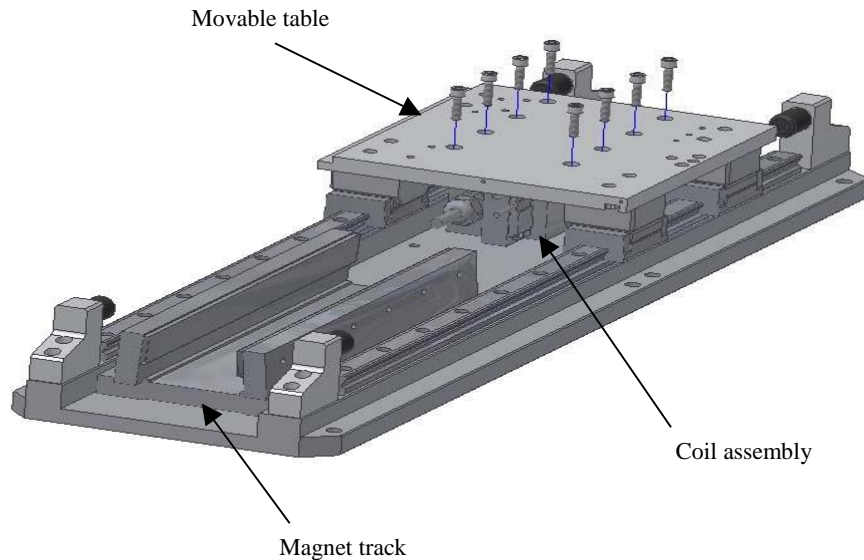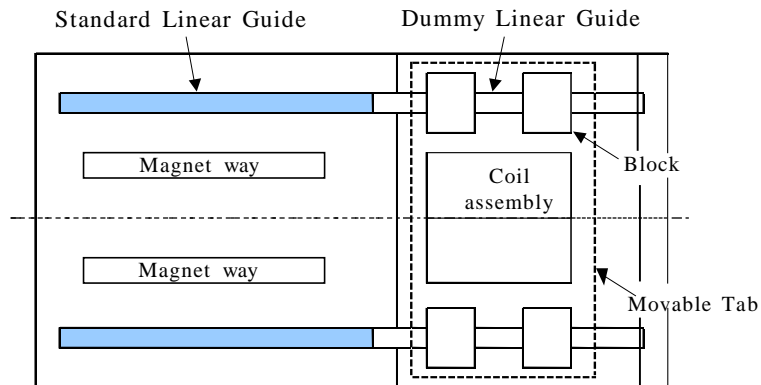

Figure 15

(Note)
When two or more magnet tracks are used, first secure the first magnet track and then install the coil assembly in the available space. [Refer to Figure 15 in 4.2 step (1)]. If using only one magnet track with insufficient space to extend the linear guide up to the position of the coil assembly, temporarily mount a dummy linear guide in line with the magnet track's linear guide.

[Simplifier Diagram of Dummy Linear Guide Installation]

(2) Insert a thin nonmagnetic (preferably resin) sheet (approximately 0.5-mm thick) in the air gap between the coil assembly and magnet track, and then move the coil assembly slowly toward the magnet track. (Refer to Figure 16).
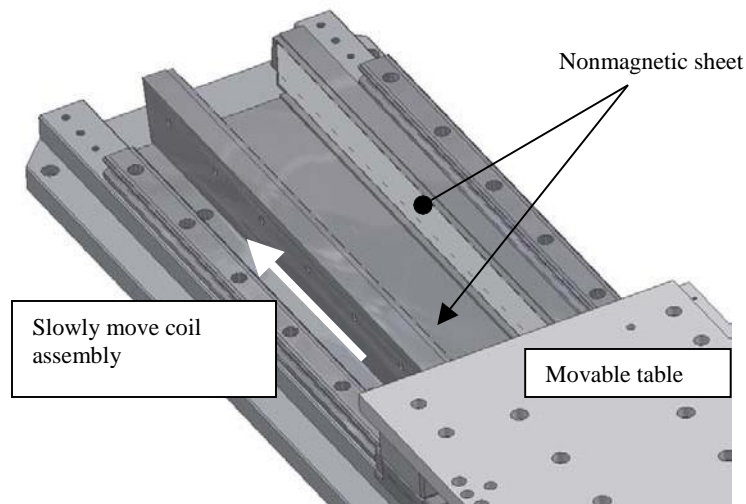

Figure 16

(Note)
Make sure that hands or tools are not jammed or caught due to the attraction of the magnet track when the coil assembly approaches the end of the magnet track. When the air gap between the coil assembly and the magnet track is fixed, the nonmagnetic sheet is not required. [Refer to Table 8 in 4.2 step (1)].

(3) Move the coil assembly back and forth several times from end to end over the magnet track, making sure that the coil assembly does not touch the magnet track and that no foreign objects (such as magnetic particles) are present. Use a nonmagnetic (brass or stainless steel) gap gauge to check that the air gap between the coil assembly and the magnet track is uniform and according to specifications (estimated gap: +/-0.3mm).

Appendix A

Deflection calculation example:

The 3-D cut-away drawing shown on page 1 has a carriage that is 240 mm in the direction of travel, 174 mm wide and 14.5 mm high. The distance between the linear guide rail centers is 127 mm. The SGLFW-50A200A coil produces a 2095 Newton (471 lb) force toward the magnet track when the air gap is at the specified design value. The deflection is defined by the following equation.

$y = \dfrac{PL^3}{48EI}$, Where P is the magnetic attraction force in Newton (2095 N), L is the distance between the linear guide rails in meters (0.127 m), E is the Modulus of Elasticity (69 x 10^9 Pa or N/M^2 for 6061-T6 Al), I is the area moment of inertia, $I = \dfrac{bh^3}{12}$ for a square cross section, where b is the base of the beam cross section (0.240 m), and h is the height of the beam cross section (0.0145 m), so y = 0.000021 m or 21 um. Note [1]

Note: The maximum magnetic attraction force is 2700N when the air gap is at the minimum value (design value - 0.3mm).

Stopping Distance calculation example:

A rough estimate for stopping distance when the linear motor provides full peak force to stop the carriage is as follows.

Acceleration, $A = \dfrac{F}{M}$ where F is the peak force in Newtons and M is the mass in Kg

Stopping Distance, $D = \dfrac{V^2}{2A}$ where V is the maximum velocity in meters/second.

If the carriage and load have a mass of 20 kg, the Peak Force of the linear motor is 600 N, and the top speed of the carriage is 4 m/s then the Deceleration = 600/20 = 30 m/s^2, and the stopping distance = 4^2/(2 x 30) = 0.267 meters (10.5 inches).

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[1] "Mechanics of Materials", p. 598, Beer and Johnston, McGraw-Hill Inc, 1981.