1 Special Environments

1-1. Specifications for Special Environments

1. Linear guide

Table 1-1-1 Linear guide specifications

Environment	Condition	NSK linear guide specifications				Technical Explanation Page No.
		Rail, slider	Steel balls	Ball Recirculation component	Lubrication/surface treatment	
Clean	Atmosphere, normal temperature	Standard material	Standard material	Standard material	LG2 Grease	D8
					NSK K1 lubrication unit	D10
		Martensitic stainless steel	Martensitic stainless steel	Austenitic stainless steel	LG2 Grease	D8
					NSK K1 lubrication unit	D10
					Fluoride low temperature chrome plating	D5
	Atmosphere~Vacuum, normal temperature				Fluoride grease	
	Atmosphere~Vacuum up to 200 °C					
Vacuum	Atmosphere~Vacuum, normal temperature	Martensitic stainless steel	Martensitic stainless steel	Austenitic stainless steel	Fluoride grease	
	Atmosphere~Vacuum up to 200 °C					
	Atmosphere~Vacuum up to 300 °C				Molybdenum disulfide	
	High vacuum up to 500 °C				Special sliver film	D7
Corrosion resistance	Vapor, steam	Martensitic stainless steel	Martensitic stainless steel	Austenitic stainless steel		
		Standard material	Standard material	Standard material	Fluoride low temperature chrome plating	D5
	Acid, alkali			Austenitic stainless steel		D5
		Martensitic stainless steel	Martensitic stainless steel			D5
	Acid, alkali, clean				Fluoride low temperature chrome plating	D5
					LG2 Grease	D8
	Strong acid, strong alkali				Fluoride low temperature chrome plating	D5
					Fluoride grease	
	Organic solvent				Fluoride grease	
High temperature	Atmosphere up to 150 °C	Standard material	Standard material	Austenitic stainless steel	ET150 Grease	
	Atmosphere Up to 200 °C	Martensitic stainless steel	Martensitic stainless steel		Fluoride grease	
	Atmosphere Up to 200 °C, Corrosion resistant				Fluoride grease	
Low temperature	-273 °C ~	Martensitic stainless steel	Martensitic stainless steel	Austenitic stainless steel	Solid lubricant	
Radiation resistance	Atmosphere	Standard material	Standard material	Standard material	Radiation resistant grease	
		Martensitic stainless steel	Martensitic stainless steel	Austenitic stainless steel		
Foreign matters	Fine particles, wooden chips	Standard material	Standard material	Standard material	NSK K1 lubrication unit	D10
		Martensitic stainless steel	Martensitic stainless steel	Austenitic stainless steel		D10
	Water, under water		Standard material	Standard material		D10
			Martensitic stainless steel	Austenitic stainless steel		D10

2. Ball screw

Table 1-2-2 Ball screw specifications

Environment	Condition	NSK Ball screw specification				Technical Explanation Page No.
		Screw shaft, ball nut	Steel balls	Ball Recirculation component	Lubrication/surface treatment	
Clean	Atmosphere, normal temperature	Standard material	Standard material	Standard material	LG2 Grease	D8
					NSK K1 lubrication unit	D10
		Martensitic stainless steel	Martensitic stainless steel	Austenitic stainless steel	LG2 Grease	D8
					NSK K1 lubrication unit	D10
					Fluoride low temperature chrome plating	D5
	Atmosphere~Vacuum, normal temperature				Fluoride grease	
	Atmosphere~Vacuum up to 200 °C					
	Atmosphere up to 200 °C, Corrosion resistant	Ceramic	Ceramic	Ceramic	Fluoride grease	
Vacuum	Atmosphere~Vacuum, normal temperature	Martensitic stainless steel	Martensitic stainless steel	Austenitic stainless steel	Fluoride grease	
	Atmosphere~Vacuum up to 200 °C					
	Atmosphere~Vacuum up to 300 °C				Molybdenum disulfide	
	High vacuum up to 500 °C				Special sliver film	D7
Corrosion resistance	Acid, alkali, clean	Standard material	Standard material	Austenitic stainless steel	Fluoride low temperature chrome plating	D5
		Martensitic stainless steel	Martensitic stainless steel			D5
		Precipitation hardening stainless steel	Precipitation hardening stainless steel		Fluoride grease	
	Strong acid, strong alkali, clean, nonmagnetic	Ceramic	Ceramic			
Nonmagnetic	Atmosphere-Vacuum, clean	Special austenitic stainless steel	Ceramic	Austenitic stainless steel	Fluoride grease	
	Atmosphere-Vacuum, up to 200 °C, clean	Ceramic			Fluoroplastic	
High temperature	Atmosphere Up to 200 °C	Standard material	Standard material	Austenitic stainless steel	Fluoride grease	
	Atmosphere Up to 200 °C	Martensitic stainless steel	Martensitic stainless steel		Fluoride low temperature chrome plating	D5
	Atmosphere- up to 500 °C, corrosion resistance	Ceramic	Ceramic		Fluoride grease	
Low temperature	-273 °C ~	Martensitic stainless steel	Martensitic stainless steel	Austenitic stainless steel	Solid lubricant	
Radiation resistance	Atmosphere	Standard material	Standard material	Standard material	Radiation resistant grease	
		Martensitic stainless steel	Martensitic stainless steel	Austenitic stainless steel		
Foreign matters	Fine particles, wooden chips	Standard material	Standard material	Standard material	NSK K1 lubrication unit	D10
		Martensitic stainless steel	Martensitic stainless steel	Austenitic stainless steel		D10
	Water, under water					D10

D 2

1-2. Lubrication and Materials

1. Lubrication

Grease can be used for high rotation and magnetic field. However, grease evaporates or solidifies in special environment such as vacuum, high temperature, and low temperature. Solid lubricant is used when it is difficult to use grease. Functions of solid lubricant differ greatly by condition where it is used. It is important to select the most suitable solid lubrication for the environment.

Fig. 1-2•1 Lubrication in clean environment

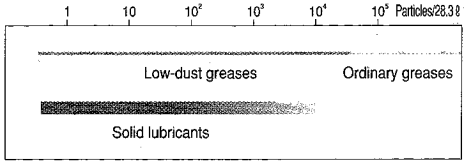


Fig. 1-2•2 Lubrication in vacuum

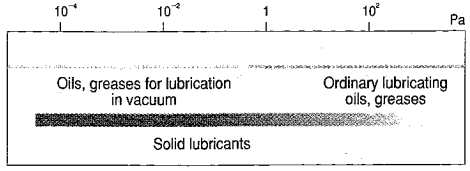


Fig. 1-2•3 Lubrication in corrosive environment

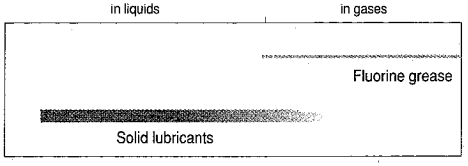


Fig. 1-2•4 Lubrication in high temperature

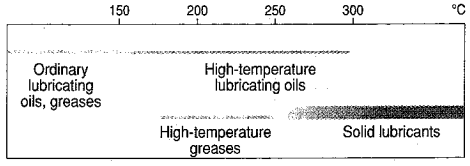


Fig. 1-2•5 Lubrication in low temperature

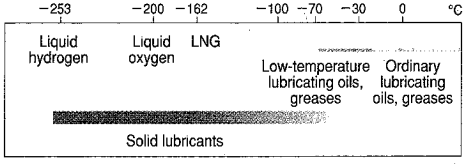


Fig. 1-2•6 Lubrication in radioactive environment

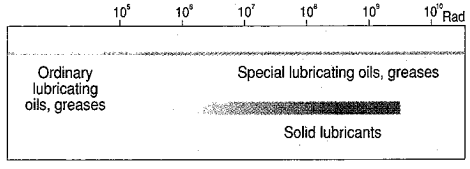
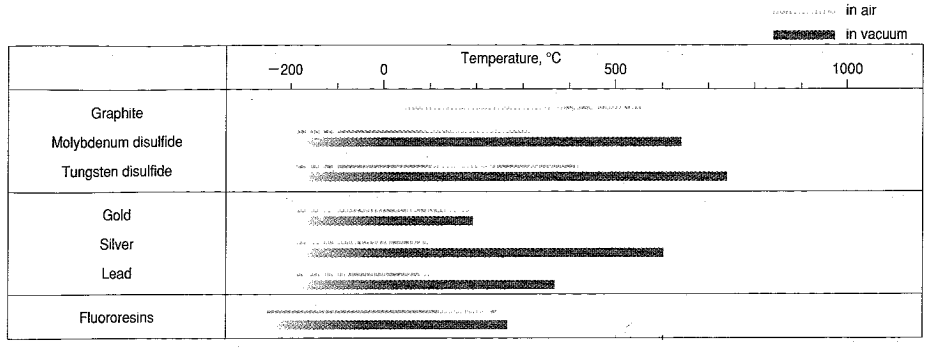


Fig. 1-2•7 Temperature range for using solid lubricants



2. Materials

Iron type metals are used in vacuum, high temperature, and high speed environments as the basic material. Nonmagnetic stainless steel and beryllium copper are used as nonmagnetic materials.

Table 1-2•1 Characteristics of metal materials

Application	Type of steel	Linear expansivity ×10⁻⁶/℃	Young's modulus GPa	Hardness (1) HB
For clean environment, vacuum environment, corrosion resistance, low temperature, high temperature, radioactive resistance	Martensitic stainless steel SUS440C	10.1	200	580
	Austenitic stainless steel SUS304	16.3	193	150
	Precipitation hardening stainless steel SUS630	10.8	200	277~363
Nonmagnetic	Nonmagnetic stainless steel	17.0	195	420
	Beryllium copper alloy	16.3	135	300~380

Note (1) Hardness of steel is usually indicated by Rockwell C Scale. For comparison, these figures are expressed by Brinell number.

1-3. Rust Prevention and Surface Treatment

1. Fluoride low temperature chrome plating

The use of and environment for NSK linear guides and ball screws are expanding from general industrial machines, semiconductor and liquid crystal manufacturing systems, to aerospace equipment.
Among all measures to cope with environment, rust prevention is the most challenging. Such environment includes: Moisture for washers and other equipment; Chemicals used in the wet processing of semiconductor and liquid crystal display manufacturing equipment.
NSK developed electrolytic rust prevention black film treatment (black chrome plating) which is added by fluoro resin impregnating treatment. (hereinafter referred as "Fluoride low temperature chrome plating") This surface treatment methods has proved its superiority as the rust prevention of linear guides and ball screws which are used in above equipment.

● What is "Fluoride low temperature chrome plating ?"

This is a type of black chrome plating which forms a black film (1~2μm) on the metal surface. Fluoroplastic coating is added to the film to increase corrosion resistance.

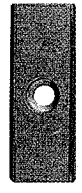
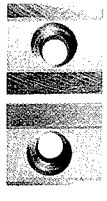
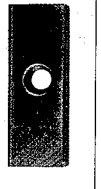
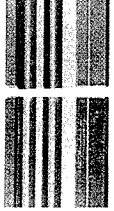
- Accuracy control is easily manageable due to low temperature treatment and to an absence of hydrogen embrittlement.
- Product accuracy is less affected due to the thin film which has high corrosion resistance.
- This method is superior to other surface treatments in durability on the rolling surface.
- Inexpensive compared with products by other surface treatment and stainless steel products.

Do not use organic solvent because it adversely affects antirust property of the plating.

● Characteristics

Humidity cabinet corrosion resistance test

Table 1-3•1 Results of the humidity cabinet test

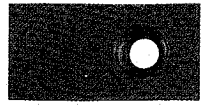
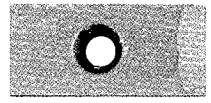
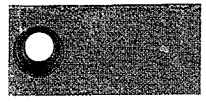
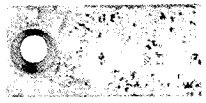
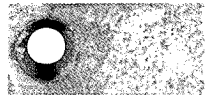
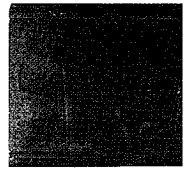
Characteristic	Test sample	Fluoride low temperature chrome plating	Hard chrome plating	Electroless nickel plating	Equivalent to SUS440C material	Standard steel
Rust prevention ability — Rusting	Top	(Ground) B	(Ground) B	(Ground) A	(Ground) C	(Ground) D
	Side	(Ground) A	(Ground) A	(Ground) A	(Ground) C	(Ground) E
	Bottom	(Ground) A	(Ground) A	(Ground) A	(Ground) C	(Ground) E
	End	(Machined) A	(Machined) C	(Machined) A	(Machined) C	(Machined) E
	Chamfer/grinding recess	(Drawn) A	(Drawn) D	(Drawn) A	(Drawn) C	(Drawn) E
Test conditions ● Testing cabinet: High temperature, highly moist cabinet (made by DABAI ESPEC) ● Temperature: 70 deg. C ● Relative humidity: 95% ● Testing time: 96h Time to "reach to" and "falling from" the temperature/humidity conditions Reaching: 5h Falling: 2h						
						
Film thickness		5μm	0.5~7μm	10μm	—	—

Rusting A: No rust B: Not rust, but some discoloration C: Spotty rust D: Light rusted E: Completely rusted

● Corrosion resistance test against chemicals

Table 1-3•2 Result of the corrosion resistance test

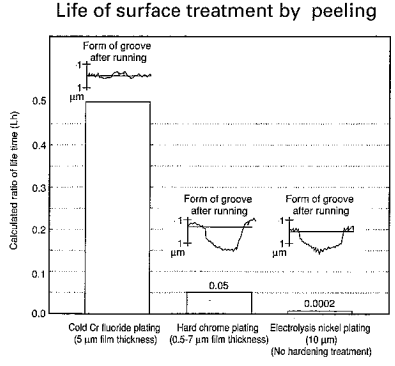
Test conditions Rail base material: Equivalent to SUS440C
Chemical density: 1 mol/ℓ

Fluoride low temperature chrome plating		Hard chrome plating	None surface treatment
	Immersed in solution for 24hrs Nitric acid		
	Immersed in solution for 24hrs Fluoride		
	Exposed to vapor for 72hrs Hydrochloric acid type washing solution $HC\ell : H_2O_2 : H_2O = 1 : 1 : 8$		
○	Hydrochloric acid (immersed)	○	▲
○	Sulfuric acid (immersed)	○	×
○	Ammonia or sodium hydroxide	○	△

○: Normal △: Partial surface damage ▲: Overall surface damage ×: Corroded

● Surface treatment durability test

Fig. 1-3•1 Result of durability test



● Total evaluation

Table 1-3•3 Evaluation

	Available length	Rust prevention ability	Quality stability	Durability	Cost
Fluoride low temperature chrome plating	◎ (4m)	◎	○	◎	◎
Hard chrome plating	△ (2m)	○	×	△	△
Electroless nickel plating	◎ (4m)	◎	△	×	△
Material equivalent to SUS440C	○ (3.5m)	○	◎	◎	△

◎: Excellent ○: Suitable in use
△: Not very suitable in use ×: Problem in use

D 6

1-4. Measures against Special Environments

1. In vacuum

● Silver-film plated ball screw

Ball screws that are plated by soft metal (special silver film) as a solid lubricant are developed the application for vacuum environment such as semiconductor manufacturing equipment and surface modification systems.

● Durability test in high vacuum

Test equipment and conditions

Table 4-1 shows ball screw specifications. Figure 4.1 is a schematic of the testing system in vacuum chamber. Table 4-2 shows testing conditions.

Table 1-4•1 Ball screw specifications

Shaft diameter		12mm
Lead		4mm
Steel ball diameter		2.381mm
Numbers of circuit of balls		2.5 turns, 1 circuit
Axis load (preload)		29.4N (3kgf)
Maximum surface pressure (preload volume)		about 690Pa
Material	Shaft	SUS630
	Nut	SUS440C
	Ball return tube	SUS304
	Steel balls	SUS440C
Solid lubricant		Special silver film

Table 1-4•2 Testing conditions

Rotational speed	300rpm
Vacuum chamber pressure	1.3×10^{-5}~1.3×10^{-6}Pa
Stroke	160mm

Evaluation method

It is understood that the rolling bearing with solid lubrication reaches end of life when the lubrication film deteriorates, resulting in sudden rise of friction torque. In this test, ball screw rotation torque was constantly measured to study durability and operation. Results were then evaluated.

Test results

Fig. 1-4•2 shows two distinctive exanples obtained in the torque characteristic test.

Photo 1-4•1 Vacuum testing system

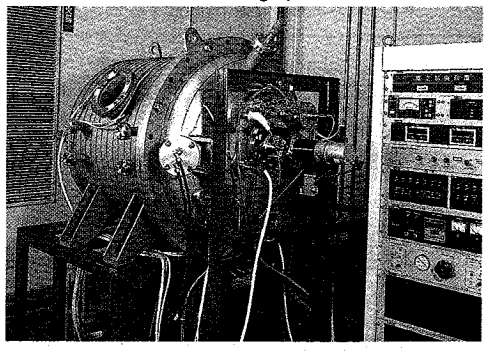
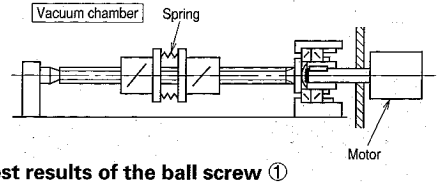


Fig. 1-4•1 Schematic of the testing system



Test results of the ball screw ①

The torque tendency was stable until about 1 x 10^7 rev. Then the torque characteristics slightly deteriorated. At about 1.35 x 10^7 rev, the torque suddenly rose. At this point, it was determined that the ball screw reached the end of its life.

Test results of the ball screw ②

Torque value is little higher than that in test ①. The value is also little unstable. The torque momentarily soared several times during the test (some 10N • cm). It is thought this is attributable to the repeated peeling/sticking of the surface film made of soft metal (silver, etc.).

When the torque finally soared at 1.13 x 10^7 rev., it was determined that the ball screw reached the end of its life.

Fig. 1-4•2 Torque variation

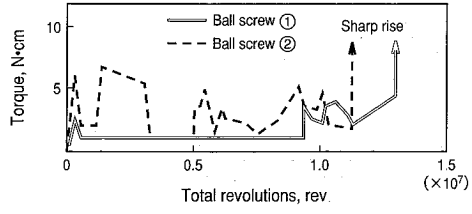


Table 1-4•3 Ball screw durability

	Classification	Ball screw ①	Ball screw ②
Life	Total revolutions (rev.)	1.35×10^7	1.13×10^7
	Total traveling distance (km)	54.0	45.2
	Total traveling hours[1] (h)	750	628

Note: (1) Total traveling hours when operated constantly at 300 rpm

Conclusion

Table 4-3 explains results of the two ball screw durability tests.

From these results and other findings, it is estimated that a life of more than 1 x 10^7rev is possible with a load of about 29.4N.

Torque may soar momentarily before the ball screw reaches its final life due to peeling/sticking of the surface film made of soft metal like silver. For this reason, it is recommendable to select a drive motor with extra torque capacity.

2. Clean environment

● NSK Clean Grease LG2, LGU

NSK Clean Grease LG2 is used in clean room for NSK linear guides, ball screws, Monocarriers, Robot Modules, Megathrust motors, XY tables, etc. with low-dust emitting specifications. For its low dust emitssion and high durability, LG2 earns trust and high reputation of semiconductor equipment manufacturers.

LG2 is superior in many areas to fluorine greases which are commonly used in clean room.

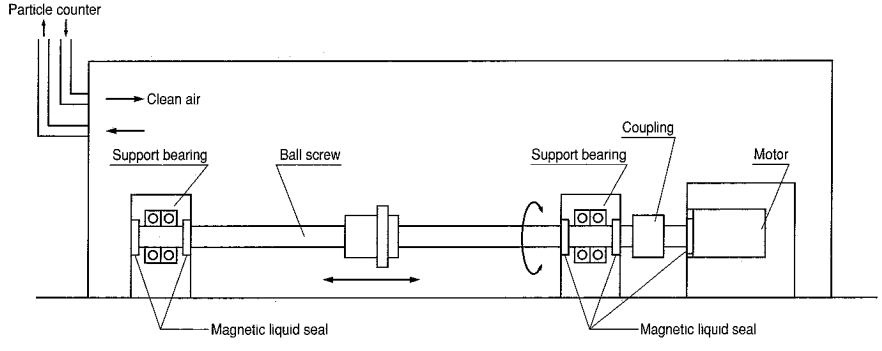
Features

- **Remarkably low dust emission**
- **Long life -- More than ten times longer than fluoride greases, and equivalent to ordinary greases.**
- **Excellent rust prevention -- Significantly higher capacity than fluorine greases.**
- **Low and stable torque -- 20% or less than that of fluorine greases**

Table 1-4•4 Nature of Clean Grease LG2

Name	Thickener	Base oil	Base oil kinematic viscosity mm²/s (40℃)	Consistency	Dropping point ℃
Clean Grease LG2	Lithium soap	Synthetic hydrocarbon oil + mineral oil	30	207	200
Clean Grease LGU	Diurea	Synthetic hydrocarbon oil	100	209	260

Fig. 1-4•3 Setting to measure dust generated by ball screw



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● Feature 1: Remarkably low dust emission

Compared with fluoride greases, dust emission by LG2 is low and stable for long period of time.

Fig. 1-4•4 Comparison in dust emission characteristics

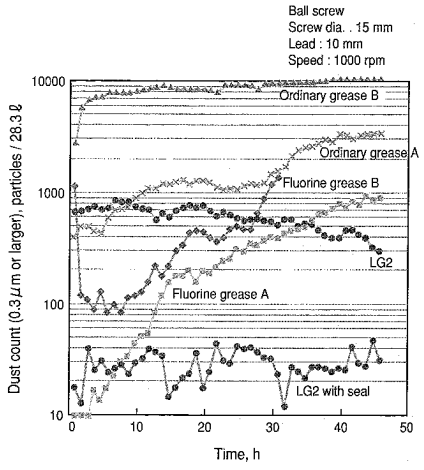
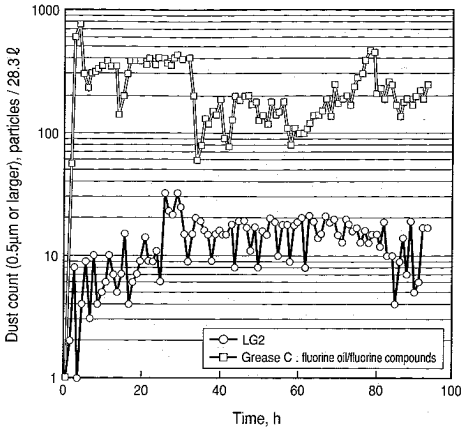


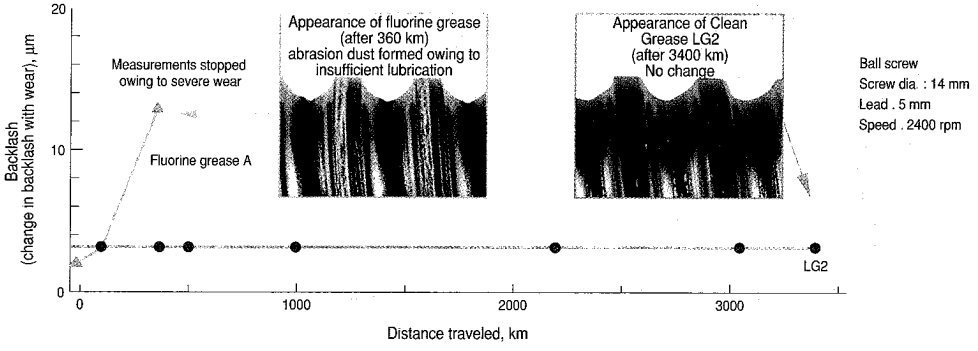
Fig. 1-4•5 Dust emission from linear guide (Linear guide: LU09)



● Feature 2 : Long life

Life is ten times or longer than fluorine greases, and equivalent to ordinary greases. This stretches maintenance intervals.

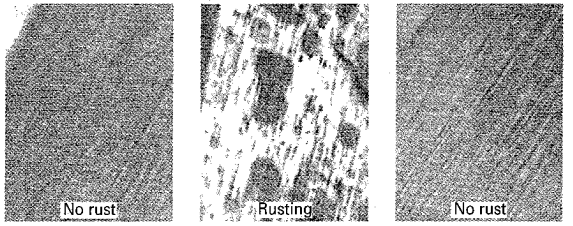
Fig. 1-4•6 Results of ball screw durability test



● Feature 3 : Excellent rust prevention capacity

The rust prevention capacity is significantly higher than fluoride type greases. Handling and preparation for operation are easy.

Photo 1-4•2
Ball screw rust prevention test (test conditions . 96 hr at humidity 95%, temperature 70°C)



Clean Grease LG2 | Fluorine grease A | Ordinary grease A

Table 1-4•5 Rust prevention test on bearing

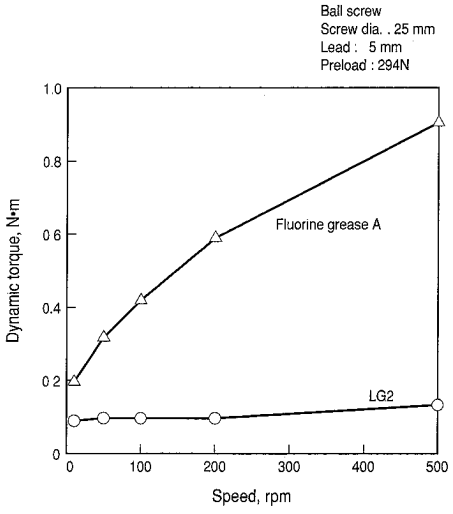
Type	Rusting after 7 days
NSK Clean Grease LG2	No rust
Fluorine grease B	Rusted

Test conditions ●19 mg is sealed in ball bearing 695
●Temp. 90 ℃, Humidity 60%
Evaluation Studied by microscope

● Feature 4 : Stable torque

Torque is 20% or lower than fluorine greases.

Fig. 1-4•7 Comparison of torque characteristics



● Total evaluation

Table 1-4•6 Evaluation

Characteristic	LG2	Fluorine grease	General grease
Dust generation	○	○～△	△～×
Torque	○	×	○～△
Durability	○	△～×	○
Rust prevention ability	○	△～×	○

○ : Suitable
△ : Not very suitable
× : Problem in use

3. Environment with foreign matters

● NSK K1 lubrication unit (linear guide and ball screw)

Molded oil is made of a lubrication oil and polyolefin which has affinity with the lubrication oil. More than 70% of the mass is lubrication oil.
Molded oil which is formed into NSK K1 lubrication unit effectively seals linear guides, continually supplying lubrication oil. NSK K1 lubrication unit has made it possible to use linear guides in water or powder dust.
NSK K1 lubrication unit is available for ball screws.

Features

- **Extend maintenance-free intervals**
- **No contamination of surrounding environment**
- **Prolong life of the products exposed to water**

Refer to Page A117 and B419 for details of NSK K1 lubrication unit.

1-5. Table to Cope with Special Environments

1. Linear guides

Table 1-5•1 Availability of linear guides

Series	Model number	Special environment linear guide can tolerate				
		Clean	Vacuum	Corrosion	High temp.	Foreign matters
LH	LH20AN	○	○	○	○	○
	LH20BN	○	○	○	○	○
	LH20FL	○	○	○	○	○
	LH20HL	○	○	○	○	○
	LH20EL	○	○	○	○	○
	LH20GL	○	○	○	○	○
	LH25AN	○	○	○	○	○
	LH25BN	○	○	○	○	○
	LH25FL	○	○	○	○	○
	LH25HL	○	○	○	○	○
	LH25EL	○	○	○	○	○
	LH25GL	○	○	○	○	○
	LH30AN	○	○	○	○	○
	LH30BN	○	○	○	○	○
	LH30FL	○	○	○	○	○
	LH30HL	○	○	○	○	○
	LH30EL	○	○	○	○	○
	LH30GL	○	○	○	○	○
	LH35AN				○	○
	LH35BN				○	○
	LH35FL				○	○
	LH35HL				○	○
	LH35EL				○	○
	LH35GL				○	○
	LH45AN				○	○
	LH45BN				○	○
	LH45FL				○	○
	LH45HL				○	○
	LH45EL				○	○
	LH45GL				○	○
	LH55AN				○	○
	LH55BN				○	○
	LH55FL				○	○
	LH55HL				○	○
	LH55EL				○	○
	LH55GL				○	○

Table 1-5•2 Availability of linear guides

Series	Model number	Special environment linear guide can tolerate				
		Clean	Vacuum	Corrosion	High temp.	Foreign matters
LU	LU09AL	○	○	○	○	○
	LU09TL	○	○	○	○	○
	LU09AR	○	○	○		○
	LU09TR	○	○	○		○
	LU12AL	○	○	○	○	○
	LU12TL	○	○	○	○	○
	LU12AR	○	○	○		○
	LU12TR	○	○	○		○
	LU15AL	○	○	○	○	○
LE	LE09AR	○	○	○		○
	LE09TR	○	○	○		○
	LE12AR	○	○	○	○	○
	LE15AR	○	○	○	○	○
LW	LW17EL				○	○
	LW21EL				○	○
	LW27EL				○	○
	LW35EL					○
LS	LS15CL	○	○	○	○	○
	LS15AL	○	○	○	○	○
	LS15KL	○	○	○	○	○
	LS15FL	○	○	○	○	○
	LS15EL	○	○	○	○	○
	LS20CL	○	○	○	○	○
	LS20AL	○	○	○	○	○
	LS20KL	○	○	○	○	○
	LS20FL	○	○	○	○	○
	LS20EL	○	○	○	○	○
	LS25CL	○	○	○	○	○
	LS25AL	○	○	○	○	○
	LS25KL	○	○	○	○	○
	LS25FL	○	○	○	○	○
	LS25EL	○	○	○	○	○
	LS30CL	○	○	○	○	○
	LS30AL	○	○	○	○	○
	LS30KL	○	○	○	○	○
	LS30FL	○	○	○	○	○
	LS30EL	○	○	○	○	○
	LS35CL					○
	LS35AL					○
	LS35KL					○
	LS35FL					○
	LS35EL					○

2. Ball screws

Clean
Vacuum
Corrosion
} **KA Series**

Clean
Vacuum
Corrosion
High temp.
Foreign matters
} **Custom made ball screws cope with the special requirement. Please consult NSK for details.**

1-6. Precautions for Handling

Please observe the following precautions to maintain high functions of ball screws and linear motion guide bearings in special environment over a long period.

- Products are washed to remove oil, and wrapped in a way to protect them from moisture. Use the product as soon as possible after opening the package.
- After opening, store the ball slide (interchangeable type linear guide) and ball nut (rolled ball screw) in a clean, air-tight container such as desiccater with desiccating agent (e.g. silica gel). Do not apply rust preventive oil or paper or product that vaporizes rust preventive agent.
- Wear plastic gloves and handle product in clean place.