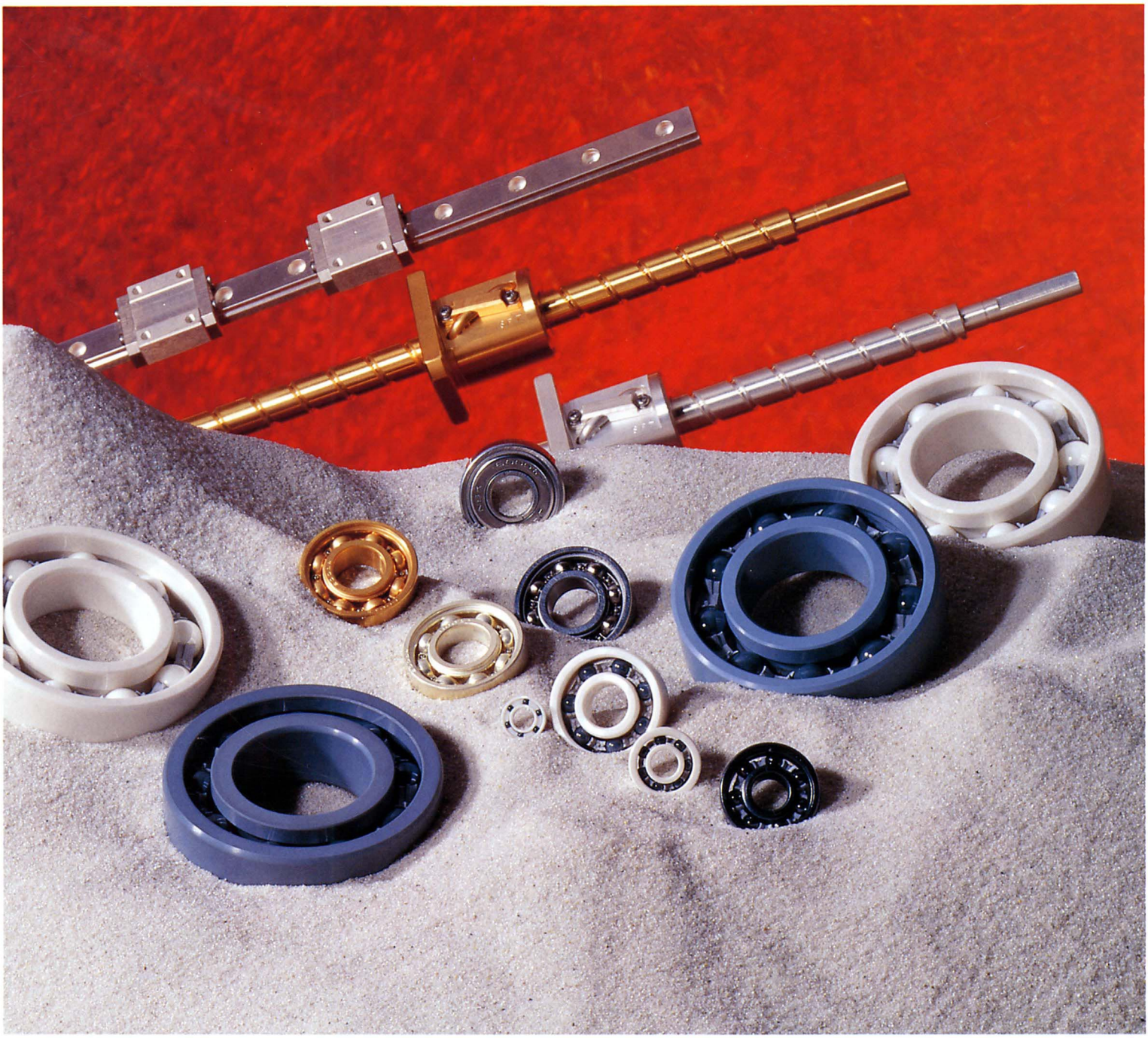
MOTION & CONTROL
NSK

Bearings, Ball Screws and Rolling Guides for Special Environments

The SPACEA™ Series

Outstanding performance in special environments



Bearings, Ball Screws & NSK Linear Guides® for Special Environments

The SPACEA™ Series

The NSK SPACEA Series is a range of bearings, ball screws and NSK Linear Guides designed for special operating environments such as clean environments for semiconductor production, water environments for food processing, environments where corrosive substances are present, and vacuum conditions where conventional methods of lubrication are unsuitable.

This brochure presents the new expanded SPACEA Series lineup and includes examples of the applications and performance of SPACEA products under demanding conditions .

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The SPACEA™ Series

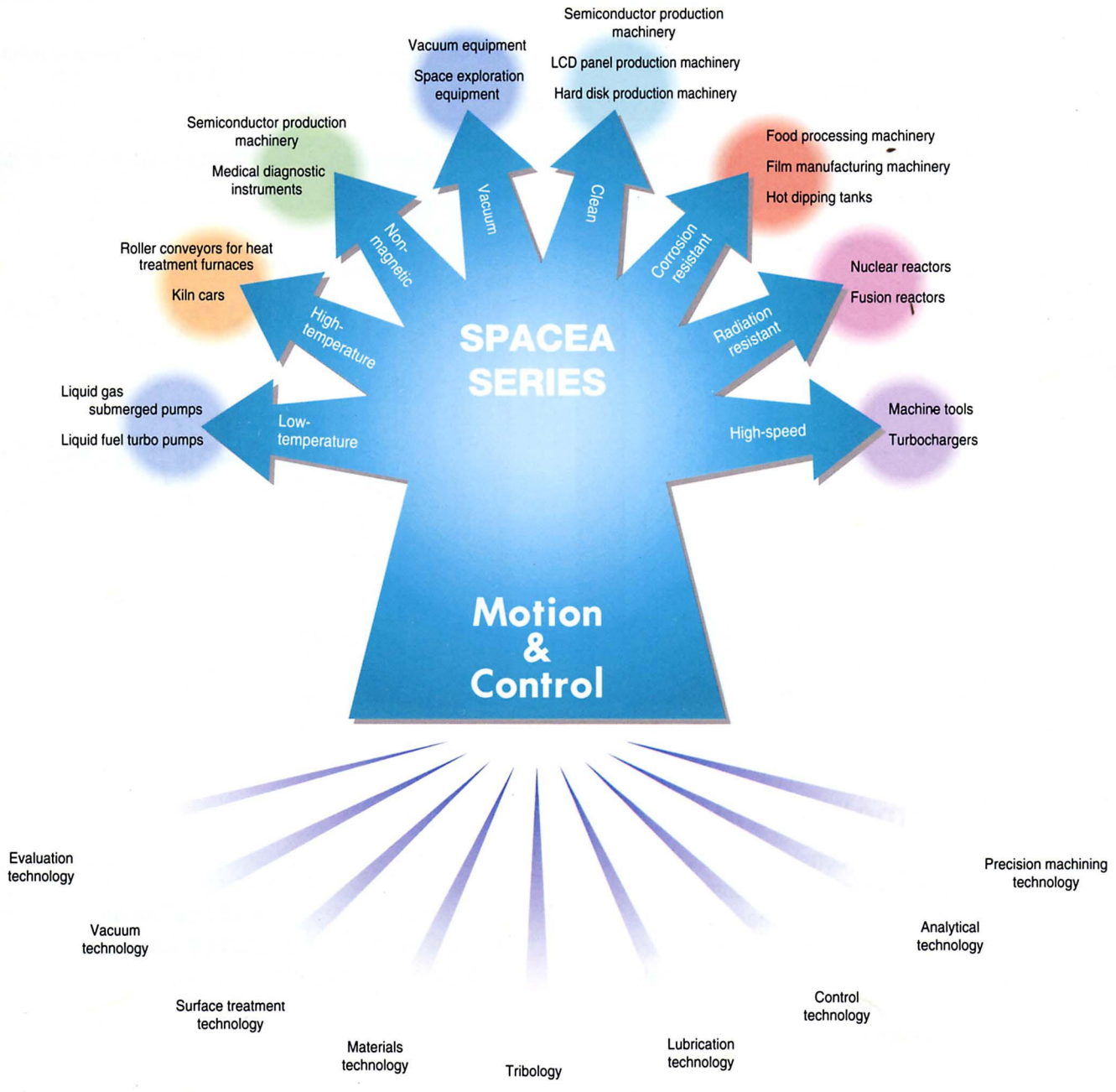
NSK's response to the ever-increasing demands of high-tech industry

For the past ten years, NSK has been designing advanced motion & control products to support the increasingly sophisticated needs of high-tech industry. Over this period, we have developed unique material, lubrication and surface treatment technologies to suit the demanding conditions under which our products must perform. These efforts have resulted in the creation of the SPACEA Series, a range of bearings, ball screws and NSK Linear Guides for special operating environments.

SPACEA Series products are ideally suited for use in clean rooms for the production of semiconductors, environments where corrosive substances are present, or vacuum conditions where conventional methods of lubrication are unsuitable. The SPACEA Series is being expanded and improved on a constant basis to incorporate new technology and keep pace with the needs of science and industry.

The diagram below shows the range of technologies incorporated in SPACEA Series products and their applications. For more information on applications see the individual product sections or the list on page 33 of this brochure.

Fig. 1 The SPACEA Series



New technology used in the SPACEA Series

NSK strives constantly to improve the SPACEA Series lineup. This section outlines some of the latest technology incorporated in the series.

THE SPACEA SERIES USES NSK'S LATEST LUBRICANT TECHNOLOGY

New lubricant technology

NSK Clean Grease LG2

Created for use in air conditions, NSK Clean Grease LG2 is a special grease which reduces dust generation in bearings, ball screws and linear guides to a minimum. NSK Clean Grease LG2 is used to lubricate many SPACEA Series. It outperforms fluorine greases across the board and has drawn widespread acclaim from our customers.

NSK Clean Grease LG2 features

- **an extremely low dust count,**
- **low and stable torque (less than 20% of that of fluorine greases),**
- **long service life (10 times longer than fluorine greases), and**
- **superior rust prevention.**

Table 1 Characteristics of NSK Clean Grease LG2

Product name	Thickener	Base oil	Base oil dynamic viscosity (mm^2/s at 40°C)	Consistency NLGI No.	Dropping point (°C)
Clean Grease LG2	Lithium soap	Mineral oil + synthetic hydrocarbon oil	30	3	200

Fig. 2 Dust count: Clean Grease LG2 with bearing

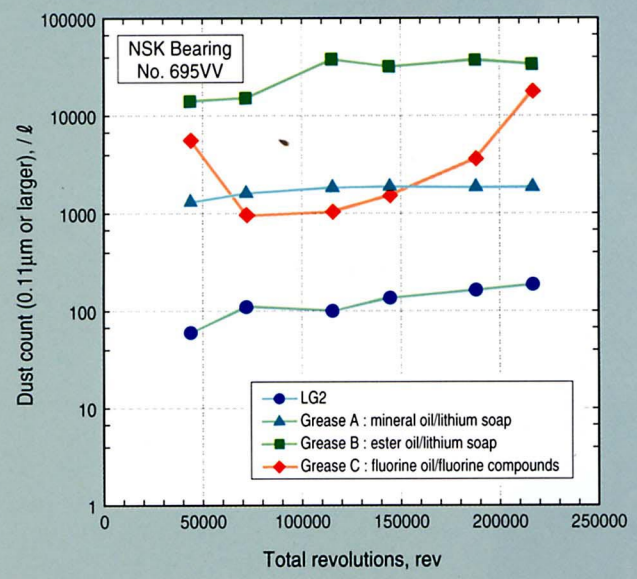
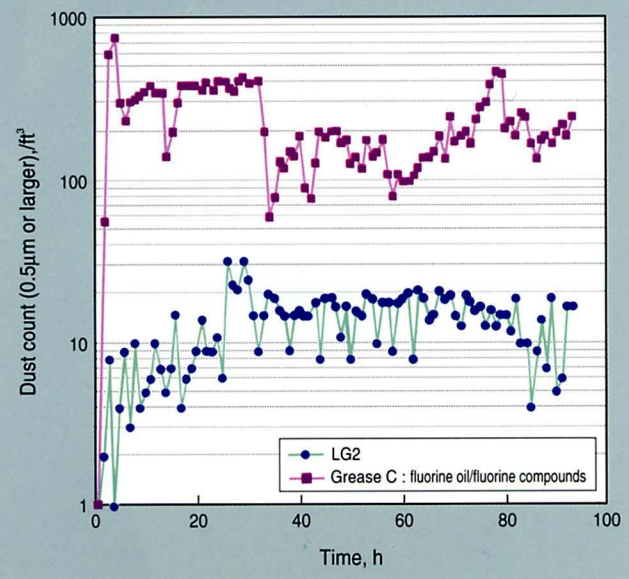


Fig. 3 Dust count: Clean Grease LG2 with linear guide



Note: For data on performance of LG2 with ball screws, see pages 23-24.

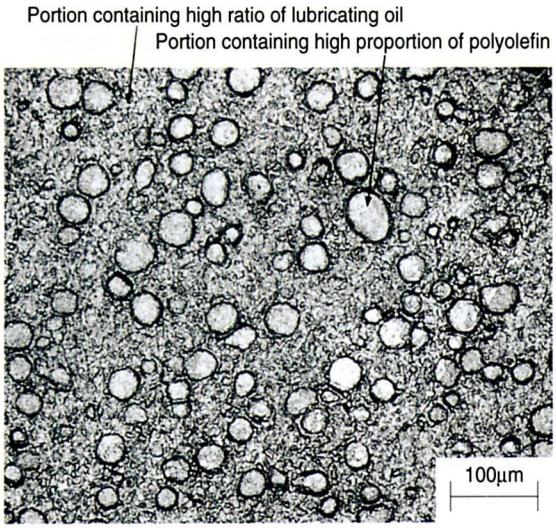
NSK K1 Seal (molded oil)

"Molded oil" is a solid material consisting of at least 50% lubricating oil by weight combined with a compatible polyolefin resin. NSK's K1 Seals for linear guides are made of molded oil and the combination of their excellent sealing properties and continuous supply of lubricating oil has made it possible to use linear guides in wet or dusty conditions where lubrication is otherwise difficult.

NSK K1 Seals features

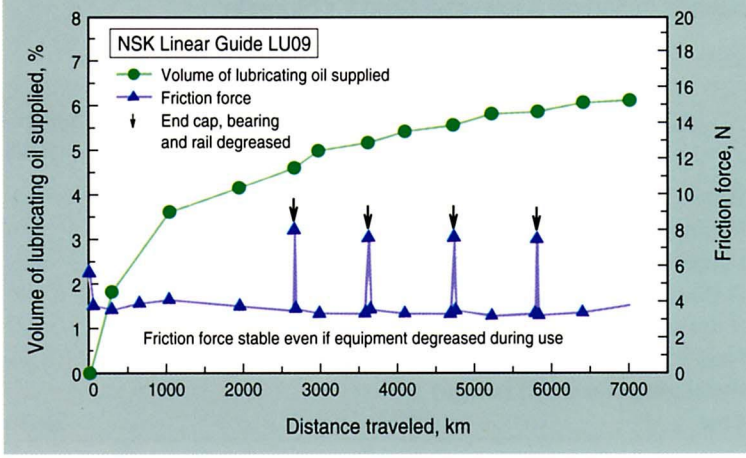
- **continuous supply of lubricating oil,**
- **superior sealing properties, and**
- **long endurance life.**

Fig. 4 Structure of molded oil



Note: For data on performance of K1 Seals with linear guides, see pages 29-30.

Fig. 5 Change in volume of lubricating oil supply and friction force:



Surface treatment technology

NSK has developed a range of advanced surface treatments to meet a wide range of technical needs. SPACEA Series products can be coated with a range of solid lubricants such as lead, silver, gold, and molybdenum disulfide for use in vacuum conditions, with NSK Special Fluororesin Coating for lubrication in clean environments, or Cold Cr Fluoride Coating or Nickel Alloy Coating for corrosive environments.

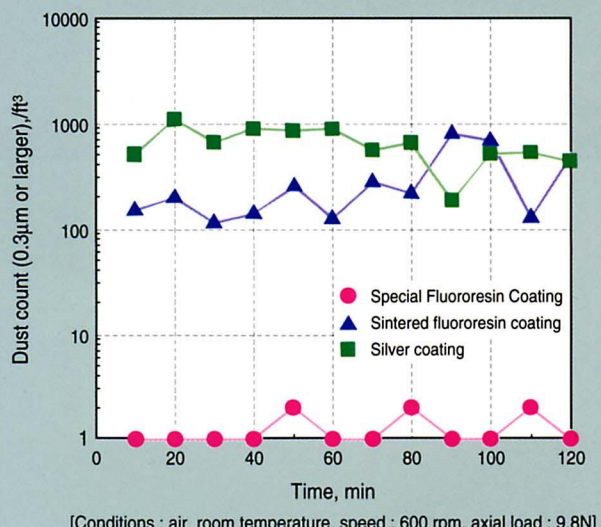
NSK Special Fluororesin Coating

NSK Special Fluororesin Coating combines low dust count and gas evaporation with long endurance life and is the ideal coating for clean environments, whether in air or vacuum conditions.

NSK Special Fluororesin Coating features

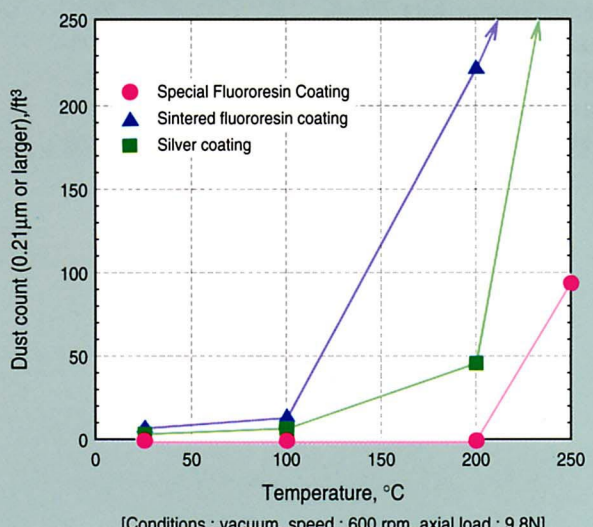
- **low dust count in air or vacuum,**
- **outstanding heat resistance,**
- **long endurance life, and**
- **low gas evaporation.**

Fig. 6 Dust count: NSK Special Fluororesin Coated Bearing



[Conditions : air, room temperature, speed : 600 rpm, axial load : 9.8N]

Fig. 7 Dust count: NSK Special Fluororesin Coated Bearing



[Conditions : vacuum, speed : 600 rpm, axial load : 9.8N]

New technology used in the SPACEA Series

Corrosion resistant coatings

NSK has developed a range of corrosion resistant coatings including a low-cost Cold Cr Fluoride Chrome Coating and a highly corrosion resistant Nickel Alloy Coating.

Table 2 Performance of NSK corrosion resistant coatings

	Stainless steel SUS440C	Hardened Chrome Coating	Cold Cr Fluoride (Low cost)	Nickel Alloy Coating (High corrosion resistance)
Water	×	△	○	○
Hydrochloric acid (1 normal)	×	○	○	○
Hydrochloric acid (5 normal)	×	○	△	○
Sulfuric acid (5 normal)	×	×	○	○
Nitric acid (10 normal)	○	○	○	○
Fluoric acid (1 normal)	×	△	△	○
Hydrogen peroxide (1 normal)	○	○	○	○
Cost	—	Moderate	Low	Moderate

Key: ○ no corrosion △ some corrosion × extensive corrosion

Notes: Nitric acid at 5 normal destroys the corrosion resistant coating. For more information on Cold Cr fluoride plating, see page 31.

Corrosion resistant ceramic materials

The ceramic material, silicon nitride, is highly resistant to corrosion and offers excellent protection against substances other than hydrogen fluoride and molten metal. NSK has also developed a number of ceramic materials offering even greater protection, including High Corrosion Resistance Ceramics and Low-Cost Ceramics.

Table 3 Characteristics and performance of ceramics v. bearing steel

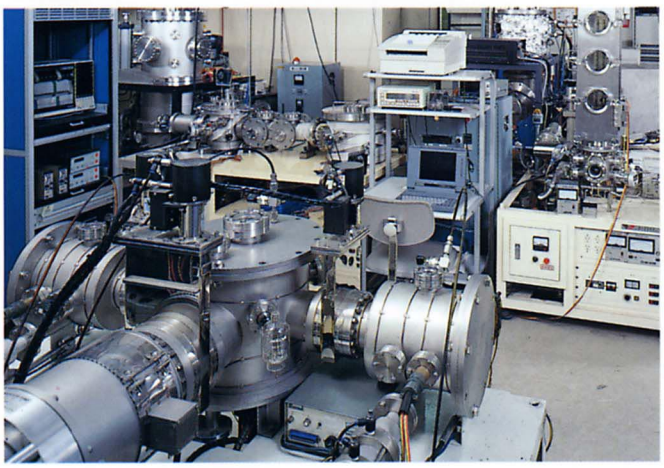
	Bearing steel	High-reliability Ceramics (silicon nitride)	High Corrosion Resistance Ceramics (carbide based)	Low-cost Ceramics (oxide based)
Density, g/cm^3	7.8	3.23	3.14	5.9
Young's modulus, GPa	208	330	390	210
Poisson ratio	0.3	0.27	0.14	0.31
Fracture toughness, MPa•m$^{1/2}$	18	6.0	2.5	7.5
Vickers hardness (HV)	700	1500	≧2000	1300
Ratio of linear expansion, x 10^{-6}/°C	12.5	2.8	4.3	10.5
Thermal conductivity, W/m•k	50	31	60	3
Flexural strength, MPa	≧2500	900	600	1100
Ease of rotation in water	Poor	Excellent	Moderate	Good
Ease of rotation in acidic solution	Poor	Moderate	Excellent	Good
Cost	Very low	Moderate	Moderate	Low

Endurance tests

SPACEA Series bearings are used in a wide range of applications. By evaluating the performance of bearings under simulated conditions as close as possible to those found in actual use, NSK has earned the trust of its customers. For instance, the range of equipment used to test bearings for vacuum conditions alone includes devices for testing bearings for X-ray tube applications, space exploration applications and ordinary vacuum applications, as well as, devices for testing ball screws, dust counting machines, and gas emission measuring devices.

Fig. 8 Tests rigs for ceramic bearings

Fig. 9 Tests rigs for bearings for vacuum conditions



Endurance life of SPACEA Series bearings

NSK carries out extensive tests of the endurance life of SPACEA Series bearings. On the basis of these tests, we have devised the following formulae for the endurance life of SPACEA Series bearings using solid lubricants and ceramic materials.

Endurance life formula for bearings using solid lubricants

The formula below gives an approximate indication of the endurance life of a SPACEA Series bearing in which the raceway surface and rolling elements have been coated with silver (Ag), lead (Pb) or molybdenum disulfide (MoS_2). In this context, endurance life is defined as the number of revolutions of the inner ring before the coating is worn away and torque increases.

$$L = a_{SL} \cdot a_{SV} \cdot (C_r/P)^d$$

- L : Rated life (90% of reliable life), x 10^6 rev
- C_r : basic load rating of steel bearing of same dimensions (x 0.85 for stainless steel bearing), N
- P : equivalent load, N
- a_{SL} : lubricity coefficient (Ag= 1, Pb=0.7, MoS_2=0.0005)
- a_{SV} : speed coefficient (Ag, Pb= 2 where speed is 100 rpm or less, 3 where speed over 100 rpm, MoS_2=1)
- d : Ag, Pb=0.5, MoS_2=2

Endurance life formula for ceramic bearings

The endurance life of ceramic ball bearings (hybrid bearings and all-ceramic bearings) depends on the operating conditions, but can be estimated using the following formula.

Lubrication conditions	a_{CL}	Type of bearing[1]	a_{CM}
Oil or grease	1	Hybrid bearings	4
		All-ceramic bearings	1
Water	0.02	Hybrid bearings	0.1
		All-ceramic bearings	1

Note: Hybrid bearings have steel innèr and outer rings and ceramic balls. In all-ceramic bearings, inner and outer rings and balls are all made of ceramic materials.

$$L = a_{CL} \cdot a_{CM} (C_r/P)^3$$

- L : Rated life (90% of reliable life), x 10^6 rev
- C_r : basic load rating of steel bearing of same dimensions, N
- P : equivalent load, N
- a_{CL} : lubricity coefficient
- a_{CM} : materials combination coefficient

Important : The effects of temperature, speed, rotation mode, loading, and foreign particle contamination mean that the endurance life of SPACEA Series bearings may not conform to these formulae. Please contact NSK for more accurate data on endurance life.

Bearing lubrication and materials

Bearing lubrication

Grease can be used as a lubricant in applications where bearings turn at high speeds or in magnetic fields. In special environments such as vacuums, or at high and low temperatures, however, grease can easily evaporate or harden and is therefore unsuitable as a lubricant. In such conditions, it is better to use solid lubricants. The lubricating performance of solid lubricants varies considerably according to operating conditions, and care should therefore be exercised in the choice of a solid lubricant.

Fig. 10.1 Lubrication in clean environments

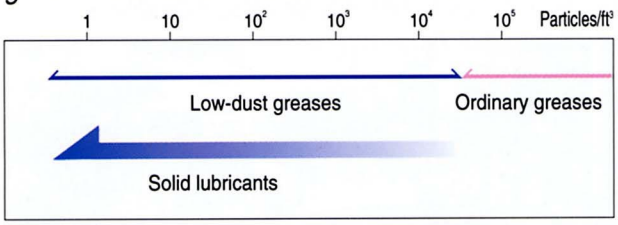


Fig. 10.2 Lubrication in vacuums

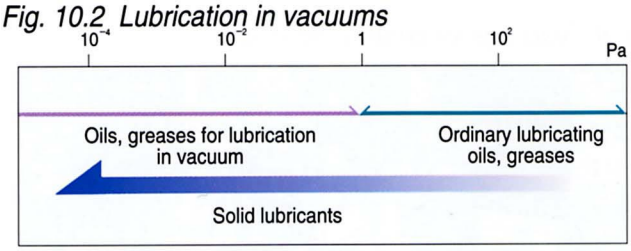


Fig. 10.3 Lubrication in corrosive environments

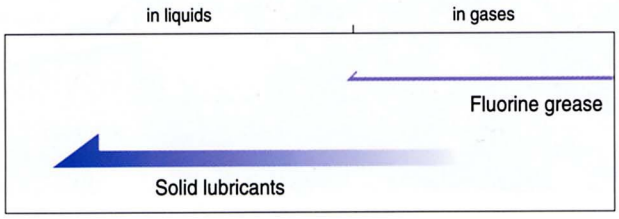


Fig. 10.4 Lubrication at high temperatures

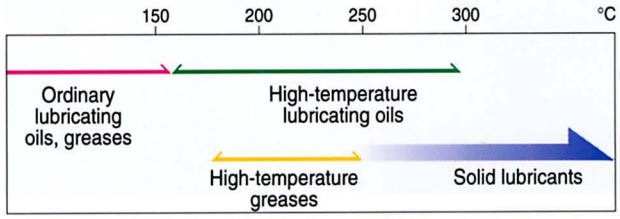


Fig. 10.5 Lubrication at low temperatures

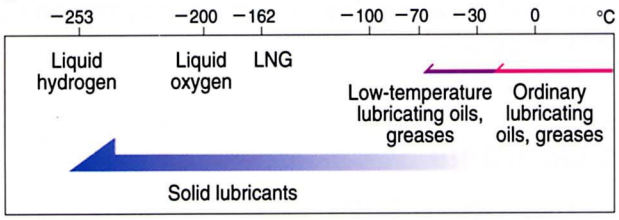


Fig. 10.6 Lubrication in radioactive environments

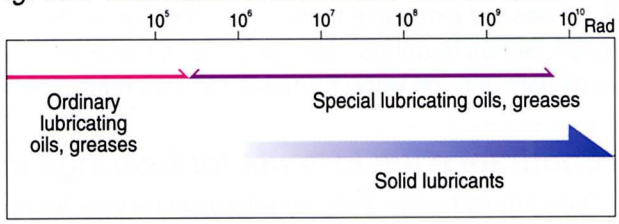


Fig. 10.7 Lubrication at high speeds

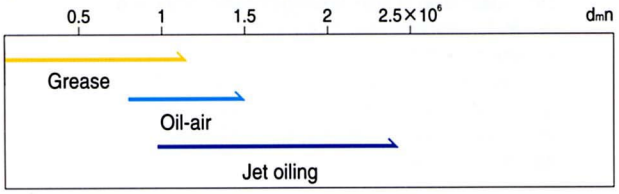
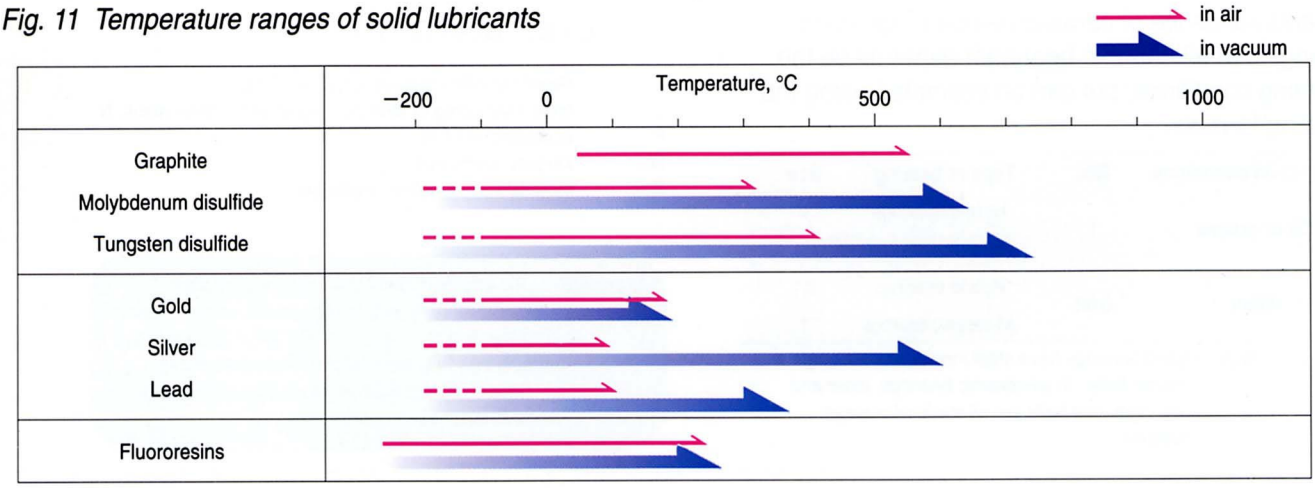


Fig. 11 Temperature ranges of solid lubricants



Ceramic materials

Ceramic materials offer superior corrosion resistance, heat resistance and dimensional stability compared to steel. Therefore, ceramic materials are ideally suited to corrosive, high-temperature and high-speed conditions. As Silicon nitride has excellent material characteristics at high temperatures silicon nitride bearings can be used where all-metal bearings would fail. The figures below show the performance of ceramic bearings under high temperature conditions.

Fig. 12 Temperature/hardness of silicon nitride and bearing steel

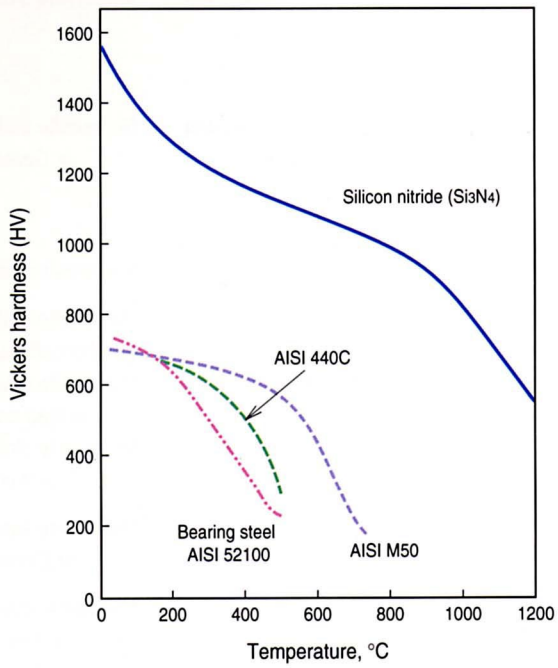
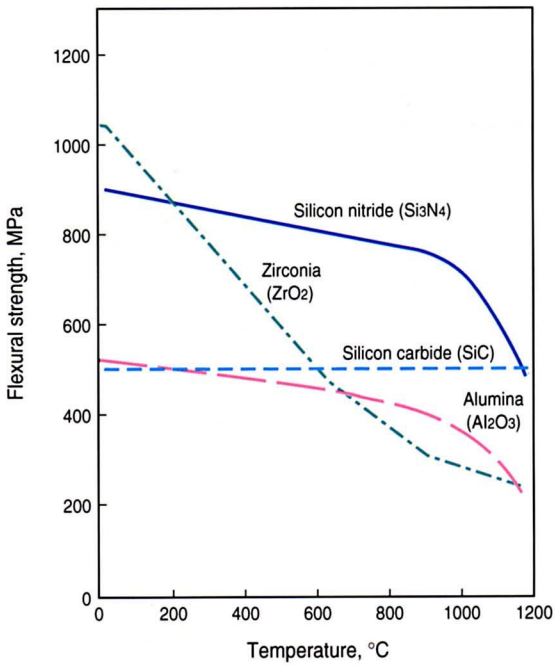


Fig. 13 Temperature/flexural strength of ceramic materials



Metallic materials

SPACEA Series bearings for use in vacuum conditions, at high temperatures or at high speeds are made chiefly of ferrous metals. NSK's non-magnetic bearings are made of non-magnetic stainless steel and beryllium copper.

Table 4 Properties of metallic materials in SPACEA Series bearings

Application	Metal	Ratio of linear expansion, x 10^{-6}/°C	Young's modulus of elasticity, GPa	Brinell hardness (HB)
High speeds **Radioactive environments**	Bearing steel AISI 52100	12.5	208	650-740
Clean environments	Martensite stainless steel AISI 440C	10.1	200	580
Vacuum conditions **Corrosive environments**	Austenite stainless steel AISI 304	16.3	193	150
Low temperatures **High temperatures**	Precipitation hardened stainless steel AISI S17400	10.8	200	277-363
High temperatures	High resistant steel T5	9.4	210	≧800
Non-magnetic environments	Non-magnetic stainless steel	17.0	195	420
	Beryllium copper alloys	16.3	135	300-380

Note: Hardness is normally expressed using the Rockwell C scale, but for ease of comparison this table uses the Brinell scale.