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North American and Corporate Headquarters
Dow Corning Corporation
P.O. Box 994
Midland, Michigan 48686-0994, U.S.A.
Phone: +1 989 496 4000

Brazil Region
Dow Corning do Brasil Ltda.
Rua Francisco Tramontano, 100 - 8 andar
CEP 05686-902 - São Paulo - SP- Brasil
Phone: +55 11 3759 4300

Mexico Region
Dow Corning de Mexico S.A. de C.V.
Campos Eliseos 345-5 Piso
Col. Polanco
Delegacion Miguel Hidalgo
C.P. 11550 Mexico, D.F.
Phone: +525 327 1300

European Area
Dow Corning GmbH
Rheingaustraße 34
D-65201 Wiesbaden
Germany
Phone: +49 611 23 70

Asian Area
Dow Corning Asia Limited
4th Fl, AIG Building
1-1-3 Marunouchi, Chiyoda-ku
Tokyo 100-0005, Japan
Phone: +81 3 3287 1151

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MOLYKOTE®

Anti-Friction Coatings Selection Guide

DOW CORNING

Welcome to the
MOLYKOTE®
Anti-Friction Coatings
Selection Guide
from Dow Corning.
In the following pages,
you will find a complete
overview of the Molykote
Anti-Friction Coatings
product range.
It includes a variety of
technical information
that you will find helpful
when selecting the
right product for your
specific application.
If you cannot find
the specific information
you need, please
contact your Molykote
representative.

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MOLYKOTE® Anti-Friction Coatings

Anti-Friction Coatings (formerly known as bonded coatings) are paint-like products. They contain, instead of a colouring pigment, submicron-sized particles of solid lubricants dispersed through carefully selected resin blends and solvents. Important for the lubricating and corrosion protection properties are the choice of the raw materials and the volume concentration of the lubricant content. MOLYKOTE® Anti-Friction Coatings form a slippery film, which covers all surface roughness and thus optimises metal-to-metal, metal-to-plastic or plastic-to-plastic friction even under extreme loads and working conditions. These coatings can be applied by conventional painting techniques: spraying, dipping or brushing.

Other common application methods are spraying drums, centrifuges, electro-static or automatic spraying, printing or roller coating followed by well-known methods of industrial drying and curing. The time required for these drying and curing methods is between 3 minutes air drying and 60 minutes oven curing.

The Anti-Friction Coatings Product Line

The current product line can be differentiated by the various solid lubricants, binders and solvent bases contained in the formulations.

MOLYKOTE® Product line

Product	Lubricant	Binder	Thinner-compatible solvent
D 321R	MoS_2	Titanate	L 13
3402-C	MoS_2	Special	L 13
D 3484	MoS_2	Phenolic	L 13
3400A Leadfree	MoS_2	Epoxy	L 13
106	MoS_2	Epoxy	L 13
7409/7620	MoS_2	Polyamide-imide	7414
D 106	MoS_2	Epoxy	Water
7400	MoS_2	Acrylic	Water
PTFE-N UV	PTFE	Acrylic	L 13
D 708	PTFE	Epoxy	L 13
D 96	PTFE	PU	Water
7405	Synth.	Polyamide-imide	7414
D 10	Graphite	Polyamide-imide	7414
D 88	Special pigments	Polyamide-imide	7414

Footnote:
L13 is a mixture of organic solvents
7414 is an organic solvent with flash-point >90°C

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Strengths/Potential weaknesses of Anti-Friction Coatings Technologies

1. Lubricating Substances

Type	Strengths	Potential weaknesses
MoS_2 Molybdenum Disulfide	+ High load carrying capacity + Wide temperature range + Paintable + Excellent adhesion + Low coefficient of friction at high loads + Protects against fretting corrosion + Increases lifetime (Synergism with graphite) + Electrical insulator	- High friction at low loads - Running-in at high loads - High coefficient of friction under humidity - Dark grey colour only
Graphite	+ High temperature stability + Separating effect (metal-forming) + Good lubricant under humidity	- Lower service life at room temperature (when compared to MoS_2) - Electrically conductive - Black colour only
PTFE	+ Colourless + Separation effect + Low coefficient of friction at low load + Electrical insulator + Good chemical resistance	- Decomposition (+315°C)= toxic vapour - Low load carrying capacity - Not paintable
Synthetics	+ Colourless / colourable + Extreme low coefficient of friction at low loads (curing temperature) + Good chemical resistance + Good fretting corrosion protection + Low curing temperature	- Low load carrying capacity - Limited temperature range

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Strengths/Potential weaknesses of Anti-Friction Coatings Technologies (continued)

2. Binders

Type	Chemical Resistance	Temp. Resistance	Air Curing	Corrosion Resistance	Remarks
Epoxy	+++	+++	-	+++	High hardness, water-based feasible
Polyamide	+++	+++	-	++	Self lubricating/ difficult application
Phenolic	++	+++	-	+	Water-based feasible
Acrylic	++	++	+++	-	Water-based feasible
Titanate	-	++++	+++	-	Limited film forming

3. Solvents

Type	Flash Point	Evaporation Curing Ranking	Remarks
Water	-	8	Non toxic/ corrosion
7414	+ 93 °C	7	Skin irritant
L13	+ 27 °C	4	Smell

General differences to other types of lubricants

(in view of possibly replacing them)

Anti-Friction Coatings usually provide the following advantages compared to greases and pastes:

- Dry and clean lubrication, not affected by dust, dirt and humidity
- Lifetime lubrication in most cases
- Localized lubrication
- No aging, evaporation, oxidation
- Non flammable, dry film
- Can be applied in a film of controlled thickness
- Can often replace burnishing, hard chrome, lead plating, cadmium and galvanizing
- Fully effective even after prolonged shut down
- Vacuum and radiation resistant

Potential limitations:

- Not recommended for high speed applications
- Under hydrodynamic conditions should only be used in combination with grease, oil, paste (they provide running-in aid and emergency lubrication)
- Comprehensive application process

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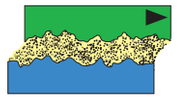
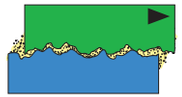
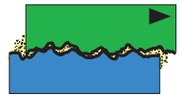
Operating principles and conditions of Anti-Friction Coatings



1. Hydrodynamic lubrication



2. Boundary and mixed friction states



3. Mixed friction state plus Anti-Friction Coatings

Anti-Friction Coatings are particularly effective in frictional states of boundary friction and mixed friction as illustrated in the Stribeck diagram (see below). In these two conditions a fluid hydrodynamic lubrication can not be realized and direct metal-to-metal contact and wear take place; the solid lubricants are kept on the surface by the bonding force of the resin package; in this way the surfaces are always separated by an effective dry film, also in conditions of very low speeds, oscillating movements and high loads.

Anti-Friction Coatings can also effectively support hydrodynamic lubrication during running-in conditions and assuring emergency-running properties in case of break down of the hydrodynamic film.

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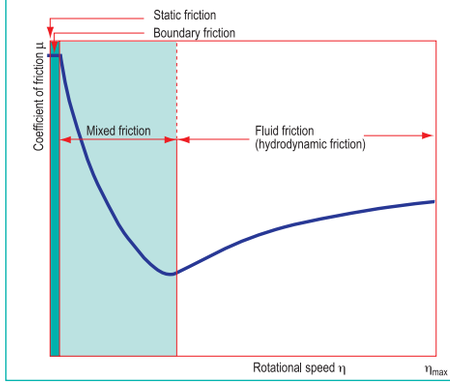
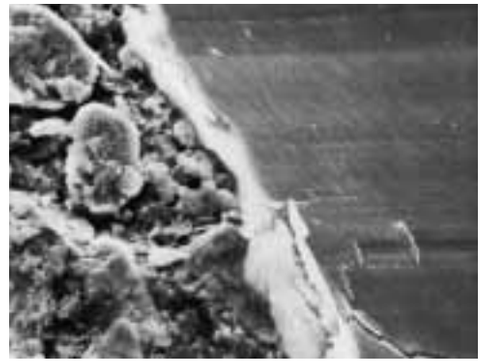
Stribeck diagram



Model of lubrication regimes of a hydrodynamic bearing



SEM photograph with 1000x magnification: MoS_2 Anti-Friction Coatings before (left) and after (right) load application

Applied Anti-Friction Coatings contain up to 70% solid lubricants. Solid lubricants with a lamellar structure like MoS_2 exhibit a floating effect in a wet film, whereby, as the film dries, they orient themselves horizontally and are deposited as individual layers. Under load, the structure of the film is further compacted producing an extremely smooth film surface covering the asperities of the carrier material.

Typical friction values of Anti-Friction Coatings

Typical friction values of MoS_2 and PTFE based Anti-Friction Coatings under different loads. (Values measured with the LFW1 test machine - ASTM-D-2714 method) "In the diagram the typical running-in effect of MoS_2 based, Anti-Friction Coatings can be noticed"

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Strengths/Potential weaknesses compared to other lubricant types

Lubricant	MoS_2 AFC	PTFE AFC	Graphite AFC	Synth. AFC
Mineral-Oil grease	Sealing	Sealing	Sealing	Sealing
	Noise reduction	Noise reduction	Noise reduction	Noise reduction
	Load carrying	Temp. range	Load carrying	Load carrying
	Temp. range	Adhesion	Temp. range	Temp. range
	Adhesion	Fretting corrosion	Adhesion	Adhesion
	Fretting corrosion	Solid state friction	Fretting corrosion	Fretting corrosion
	Solid state friction	Chem. resistance	Solid state friction	Solid state friction
	Chem. resistance	Separating effect	Chem. resistance	Chem. resistance
	Corrosion protection	Colourless	Oil resistance	Separating effect
		Corrosion protection	Solvent resistance	Colour
Synthetic grease	Sealing	Sealing	Sealing	Sealing
	Noise reduction	Noise reduction	Noise reduction	Noise reduction
	Plastics compatibility		Plastics compatibility	
	Load carrying	(Temp. range)	Load carrying	Load carrying
	Temp. range	Adhesion	Temp. range	(Temp. range)
	Adhesion	Fretting corrosion	Adhesion	Adhesion
	Fretting corrosion	Solid state friction	Fretting corrosion	Fretting corrosion
	Solid state friction	(Chem. resistance)	Solid state friction	Solid state friction
	(Chem. resistance)	Separating effect	(Chem. resistance)	(Chem. resistance)
	Corrosion protection	Colourless	(Oil resistance)	Separating effect
		Corrosion protection	(Solvent resistance)	Colour
Silicone grease	Sealing	Sealing	Sealing	Sealing
	Noise reduction	Noise reduction	Noise reduction	Noise reduction
	Plastics compatibility		Plastics compatibility	Plastics compatibility
	Load carrying	Load carrying	Load carrying	Load carrying
	Temp. range	(Temp. range)	Temp. range	Adhesion
	Adhesion	Adhesion	Adhesion	Fretting corrosion
	Fretting corrosion	Fretting corrosion	Fretting corrosion	Solid state friction
	Solid state friction	Solid state friction	Solid state friction	Lower friction coeff.
	Lower friction coeff.	Lower friction coeff.	Lower friction coeff.	Corrosion protection
		(Colourless)	(Oil resistance)	Colour
		Corrosion protection	(Solvent resistance)	
MoS_2 paste	Corrosion protection	Corrosion protection	Corrosion protection	Corrosion protection
	Adhesion	Adhesion	Adhesion	Adhesion
		Separating effect		Separating effect
		Colour		Colour
Grease paste	Sealing	Sealing	Sealing	Sealing
	Noise reduction	Noise reduction	Noise reduction	Noise reduction
	Load carrying	Corrosion protection	Load carrying	Load carrying
	Corrosion protection	Adhesion	Corrosion protection	Corrosion protection
	Adhesion	Separating effect	Adhesion	Adhesion
		Colourless	Separating effect	Separating effect
			Oil resistance	Colour
			Solvent resistance	
Thread paste	Sealing	Sealing	Sealing	Sealing
	Easy application	Easy application	Easy application	Easy application
	Adhesion	Adhesion	Adhesion	Adhesion
	Corrosion protection	Corrosion protection	Corrosion protection	Corrosion protection
		Separating effect	Separating effect	Colourless
		Colourless	Oil resistance	Very low coeff. of friction
			Solvent resistance	

= Strengths of Anti-Friction Coatings ☐ = Strengths of other lubricants

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Strengths/Potential weaknesses compared to other lubricant types

Strengths comparison among PTFE and Synthetics- based Anti-Friction Coatings

	PTFE-N UV	D 708	D 96	7405
PTFE-N UV		Colourless	Temperature resistance	Colourless
		Air drying	Adhesion	Air drying
		Aerosol	Aerosol	Aerosol
		Load carrying capacity	Water-based	Load carrying capacity
		Chemical resistance	Low friction	Low friction
		Corrosion protection		Chemical resistance
		Adhesion		Corrosion protection
D 708	Load carrying capacity		Temperature resistance	Chemical resistance
	Chemical resistance		Load carrying capacity	Corrosion protection
	Corrosion protection		Chemical resistance	
	Adhesion		Corrosion protection	
			Adhesion	
	Colourless		Colourless	Low friction
	Air drying		Air drying	Higher flash point
	Aerosol		Water-based	
D 96	Water-based	Colourless		Colourless
	Low friction	Air drying		Air drying
		Water-based		Water-based
	Temperature resistance	Temperature resistance		Temperature resistance
	Adhesion	Load carrying capacity		Load carrying capacity
	Aerosol	Chemical resistance		Chemical resistance
		Corrosion protection		Corrosion protection
		Adhesion		Adhesion
7405	Load carrying capacity	Low friction	Temperature resistance	
	Low friction	Higher flash point	Load carrying capacity	
	Chemical resistance		Chemical resistance	
	Corrosion protection		Corrosion protection	
			Adhesion	
	Colourless	Chemical resistance	Colourless	
	Air drying	Corrosion protection	Air drying	
	Aerosol		Water-based	

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■ = strengths of the Anti-Friction Coatings in the row compared to the Anti-Friction Coatings in the column

□ = strengths of the Anti-Friction Coatings in the column compared to the Anti-Friction Coatings in the row

Strengths comparison among PTFE and Synthetics based Anti-Friction Coatings

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Strengths comparison among MoS_2 based Anti-Friction Coatings

	D 321R	D 3484	3400A Leadfree	3402-C	106	7409/7620	D 106	7400
D 321R		Temp. resistance Extreme load Aerosol Air curing	Low friction Air drying Aerosol Higher flash point	Temp. resistance Low friction Aerosol Higher flash point Non toxic	Temp. resistance Good adhesion Air drying Aerosol	Air drying Aerosol	Temp. resistance Air drying Aerosol	Temp. resistance Good adhesion Aerosol
		No chalking Chem. resistance Corr. protection	No chalking Corr. protection Chem. resistance	Corr. protection No chalking MIL- spec.	Chem. resistance No chalking	Chem. resistance Corr. protection No chalking	Corr. protection No chalking Water-based	Water-based No flash point
D 3484	No chalking Chem. resist. Corr. protection Temp. resistance Extreme load Aerosol Air curing		Low friction Fast curing Higher flash point Temp. resistance Corr. protection	Low friction Higher flash point Non toxic Temp. resistance Air drying MIL-spec.	Low friction Corr. protection Fast curing MIL-spec.	Fast curing Temp. resistance Chem. resistance Corr. protection	Low friction Fast curing Water-based	Temp. resistance Corr. protection Air drying Water-based No flash point
3400A Leadfree	Corr. protection Chem. resistance No chalking Low friction Air drying Aerosol Higher flash point	Temp. resistance Corr. protection Low friction Fast curing Higher flash point		Temp. resistance Corr. protection Air drying	Temp. resistance Corr. protection Low friction Lower curing temp. Higher flash point	Temp. resistance Corr. protection Low friction Chem. resistance Higher flash point	Temp. resistance Chem. resistance Corr. protection Low friction Water-based	Temp. resistance Chem. resistance Corr. protection Low friction Air drying Water-based No flash point
3402-C	No chalking Corr. protection MIL-spec. Temp. resistance Low friction Aerosol Higher flash point Non toxic	Temp. resistance Air drying MIL-spec. Low friction Higher flash point Non toxic	Air drying Temp. resistance Corr. protection		Temp. resistance Corr. protection Air drying MIL-spec. Low friction Higher flash point Non toxic	Air drying MIL-spec. Temp. resistance Low friction Chem. resistance Corr. protection Higher flash point Non toxic	Temp. resistance Air drying MIL-spec. Low friction Water-based Non toxic	Temp. resistance Chem. resistance Corr. protection MIL-spec. Low friction Water-based No flash point Non toxic
106	Chem. resistance No chalking Temp. resistance Good adhesion Air drying Aerosol	MIL-spec. Low friction Corr. protection Fast curing	Low friction Lower curing temp. Higher flash point Temp. resistance Corr. protection	Low friction Higher flash point Non toxic Temp. resistance Corr. protection Air drying MIL-spec.		Lower curing temp. MIL-spec. Temp. resistance Chem. resistance Corr. protection	Storage stability Lower curing temp. MIL-spec. Corr. protection Water-based	Temp. resistance Chem. resistance MIL-spec. Air drying Water-based No flash point
7409 / 7620	Chem. resistance Corr. protection No chalking Air drying Aerosol	Temp. resistance Chem. resistance Corr. protection Fast curing	Low friction Chem. resistance Higher flash point Temp. resistance Corr. protection	Temp. resistance Low friction Chem. resistance Corr. protection Higher flash point Non toxic Air drying MIL-spec.	Temp. resistance Chem. resistance Corr. protection Lower curing temp. MIL-spec.		Temp. resistance Chem. resistance Corr. protection Storage stability Water-based	Temp. resistance Chem. resistance Corr. protection Air drying Water-based No flash point
D 106	Corr. protection No chalking Water-based Temp. resistance Air drying Aerosol	Water-based Low friction Fast curing	Low friction Water-based Temp. resistance Chem. resistance Corr. protection	Low friction Water-based Non toxic Temp. resistance Air drying MIL-spec.	Corr. protection Water-based Storage stability Lower curing temp. MIL-spec.	Water-based Temp. resistance Chem. resistance Corr. protection Storage stability		Temp. resistance Corr. protection Chem. resistance Air drying No flash point
7400	Water-based No flash point Temp. resistance Good adhesion Aerosol	Air drying Water-based No flash point Temp. resistance Corr. protection	Low friction Air drying Water-based No flash point Temp. resistance Chem. resistance Corr. protection	Low friction Water-based No flash point Non toxic Temp. resistance Chem. resistance Corr. protection MIL-spec.	Air drying Water-based No flash point Temp. resistance Chem. resistance MIL-spec.	Air drying Water-based No flash point Temp. resistance Chem. resistance Corr. protection	Air drying No flash point Temp. resistance Corr. protection Chem. resistance	

= strengths of the Anti-Friction Coatings in the row compared to Anti-Friction Coatings in the column

□ = strengths of the Anti-Friction Coatings in the column compared to Anti-Friction Coatings in the row

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Typical properties of MOLYKOTE® Anti-Friction Coatings

MOLYKOTE® Product	Solid lubricant	Thinner - compatible solvent	Colour	Service temperature range [°C]	Load carrying capacity (Falex test, ASTM-D-2625) [N]	Endurance life (LFW- 1 test, ASTM- D- 2714)		Fretting corrosion resistance (Deyber test) [oscillations]	Typical corrosion protection values (*) (ISO R 1456) [h]	Curing schedule [min/°C]	Flash point [°C]	Surface coverage m²/kg
						[Revolutions in thousands]	[Oscillations in thousands]					
D 321R	MoS_2	L 13	grey	-180/+450	15.000	s=480	s=210	$14x10^6$	_	5/20	+23	7
3402-C	MoS_2	L 13	grey	-200/+315	15.500	s=150	s=15	$5x10^6$	p+sp=120	120/20	+12	15
D 3484	MoS_2	L 13	grey	-70/+250	15.500	p=300	p=350	$28x10^6$	p+sp=24	10/170	+23	10
3400A Leadfree	MoS_2	L 13	grey	-200/+430	20.000	p=100	p= > 50	$7x10^6$	p+sp=500 p+dp=240	30/200	< +21	15
106	MoS_2	L 13	grey	-70/+250	15.500	p=380	p=280	$24x10^6$	_	60/150	+24	15
7409	MoS_2	7414	grey	-70/+380	15.800	p=350	p=100	> $36x10^6$	p+sp=300 p+dp=96	30/220	+28	12
7620	MoS_2	7414	grey	-70/+380	15.800	p=400	p=100	> $36x10^6$	p+sp=300	20/220	+28	14
7400	MoS_2	water	grey	-70/+200	13.000	p=200	p=100	$9x10^5$	_	40/20	None	16
D 106	MoS_2	water	grey	-70/+250	13.500	p=300	p=180	$24x10^6$	p+sp=24	60/200	+84	15
PTFE-N UV	PTFE	L 13	transparent	-180/+240	4.000	p=15	p=36	$20x10^6$	p+sp=24	120/20	-19	18
D 708	PTFE	L 13	black	-180/+240	1.220	p=9	p=13	$1x10^6$	p+sp=500 p+dp=360	20/200	0	18
D 96	PTFE	water	transparent	-40/80	-	-	-	-	-	120/20	> +100	-
7405	Synt.	7414	yellowish transparent	-70/+200	15.000	p=150	p=100	> $36x10^6$	p+sp=200 p+dp=96	60/120	+41	16
D 10	Graphite	7414	black	-70/+380	13.600	p=6	p=1	> $36x10^6$	-	30/180	+63	8
D 88	Special	7414	silver-grey	-70/380	-	-	-	-	p+sp=300 p+dp=120	20/210	+63	-

dp= application by dip-spinning – sp= application by spraying
p= phosphated surface – s= sandblasted surface

(*): as the performance in corrosion resistance is affected by the geometry of the parts coated, by the pre-treatment of the surface, by the application method and by the thickness of the applied dry film, these values should be considered typical.

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MOLYKOTE® Anti-Friction Coatings solutions for machine com ponents

Solutions for	Running-in damages	Scuffing, scoring, seizure	High wear, pitting	Short service life because of high loads	Fretting corrosion	Stick-slip	Unsteady coefficient of friction	Short lubrication intervals	Contamination, chalking	Unsatisfactory surface quality	Short service life because of extreme temperatures	Lubrication failure because of chemical attack	Environmental application problems	Corrosion
Machine components														
Hinges, springs, locks, switches, bolts, safety belts, ski-bindings	D 321R	3400A Leadfree D 3484 7409 3402-C D 106	3400A Leadfree 7409 106	D 3484 3400A Leadfree D 106	106 7409	3400A Leadfree D 3484 7409 D 106	7405 PTFE-N UV	D 3484 3400A Leadfree	7405 7409 D 708	D 321R D 3484 3400A Leadfree	D 321R 7409 3400A Leadfree	7409 3400A Leadfree D 708 D 10	7400 D 106	3400A Leadfree 7409 D 708
Brake parts, clutches, solenoids	D 321R 7400	D 106 7409 3400A Leadfree	D 106 7409	3400A Leadfree D 106 7409	106	D 106 7405 7409	7405	106	7405 7409 D 708	D 321R 106	3400A Leadfree D 321R 7409		7400 D 106	7409 3400A Leadfree D 708
Sleeve bearings, chain elements, self-aligning bearings, sintered metal bushings, bearings	D 321R	106 3400A Leadfree	106 7409	3400A Leadfree D 106 7409	106	D 321R 7409	7405	106	7405 7409	D 321R 106	3400A Leadfree D 321R 7409	3400A Leadfree 7409	7400 D 106	7409 3400A Leadfree D 708
Slides, spindles, bed ways, adjusting wedges, gear racks	D 321R	D 321R 106 D 106	3400A Leadfree 106 7409 D 106	D 321R 106 D 106	106	D 321R 106 D 106	D 321R 106 7405	3400A Leadfree 106 D 3484	7409	D 321R D 106	D 321R 7409 3400A Leadfree	7409 3400A Leadfree	7400 D 106	7409 3400A Leadfree D 708
Reactor parts lubrication	D 321R	D 321R	D 321R 7409	D 321R	7409	D 321R	7409	D 321R	7409	D 321R	D 321R	D 321R 7409		7409
Weapons, ammunition	3402-C	3402-C 7409 3400A Leadfree	3402-C 3400A Leadfree	3402-C 3400A Leadfree	3400A Leadfree 3402-C 7409	3402-C 3400A Leadfree D 708	7409 D 708	7409 3400A Leadfree	7409	3402-C	7409 3400A Leadfree	7409 D 708		3400A Leadfree 7409 D 708
Valves, carburettors, pumps	7409	7409	7409	7409	7409	7409	7409	7409	7409	3400A Leadfree	7409	7409	7409	7409
Nuts and bolts		D 708 7405		3402-C	3402-C	D 708 7405	7405 D 708		7405 D 708	7405	D 321R	7405 D 708	7400 7405	7405 D 708
Elastomer seals/profiles, plastic parts	D 96			D 96		D 96	PTFE-N UV D 96	D 96		D 96			D 96	
Aircrafts, rockets, helicopters, space stations	D 321R	7409 3402-C	7409 3400A Leadfree 3402-C	3400A Leadfree 3402-C 7409	106 7409	3400A Leadfree 3402-C D 321 R	3402-C 7409	3402-C 3400A Leadfree	7409	D 321R 3402-C	D 321R 3400A Leadfree 7409	7409 3400A Leadfree	D 321R	7409 3400A Leadfree
Pistons, hydraulic parts, cam shafts, gears	D 10 D 88 7409 7400	D 10 7409 D 88	7409 D 10 D 88	7409	7409	7409	7409	7409 D 10 D 88		3400A Leadfree	7409	7409 D 10 D 88	7400 7409 D 10	D 10 7409 D 88

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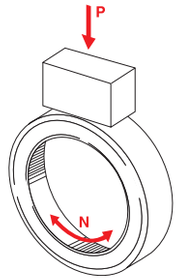
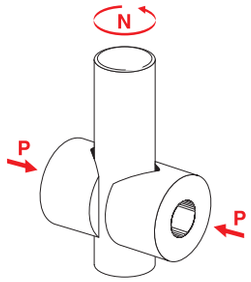
Typical testing methods for Anti-Friction Coatings

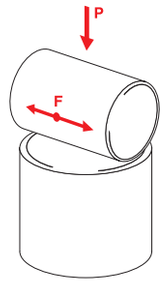
The performance characteristics of Anti-Friction Coatings can be evaluated on standard test machines which can simulate the different tribological contacts; by changing the different testing parameters the performance of the lubricant on several machine elements can be simulated. Sketches and description of the operating principles of the machines are reported here.



Falex LFW1 (Block on Ring Test Machine)
- ASTM D 2714
- A stationary block is loaded against a rotating or oscillating ring
- Type of contact: line or area
- Type of friction: sliding friction
- Test criteria: friction force, sliding distance, number of oscillations/revolutions
- Measured properties: endurance life, friction value, load carrying capacity



Falex Pin and Vee Test Machine
- ASTM D 2625
- Two stationary vee blocks are loaded against a rotating pin specimen
- Type of contact: 4 lines
- Type of friction: sliding friction
- Test criteria: weld load, friction torque
- Measured properties: extreme pressure, load carrying capacity, endurance life



SRV Test Machine
- DIN 51834
- A translatory oscillating ball or cylinder is loaded against a fixed flat disc specimen
- Type of contact: point (ball) or line (cylinder)
- Type of friction: sliding friction
- Test criteria: weld load, friction force, number of oscillations
- Measured properties: load carrying capacity, endurance life, friction value

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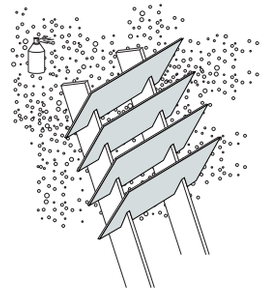
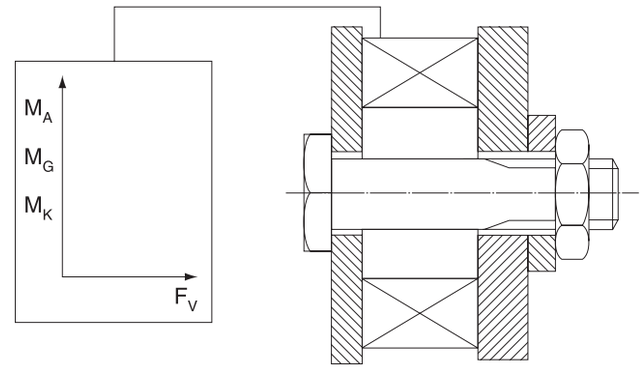


Salt spray test
- DIN 50021 – ASTM B 117
- Coated specimen or original parts are put in a chamber with salt water spray
- Test criteria: rust formation
- Measured properties: corrosion resistance



Erichsen Test Machine
- Test equipment to measure the coefficient of friction on bolted connections at room temperature
- Type of contact: area (thread and underhead)
- Type of friction: sliding friction
- Test criteria: pretensioning force, tightening torque
- Measured properties: coefficient of friction on thread and underhead

All these test equipments are currently in operation at our technical centres. Furthermore our test fields are equipped with special test machines based on original automotive or industrial machine elements to evaluate the tribological behaviours under different environmental conditions.

Based also on these capabilities we are confident to be able to offer to our customers the best solution to solve their dry lubrication problems.

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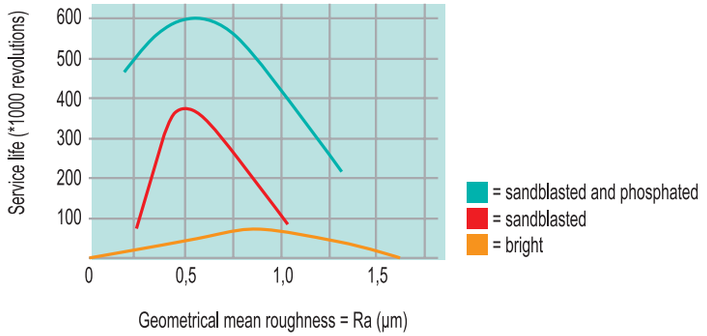
Surface pre-treatment of Anti-Friction Coatings

Pre-treatment of metal surfaces

The adhesion and service life of Anti-Friction Coatings are greatly affected by the surface pre-treatment of components.

Life of Anti-Friction Coatings



Effect of pre-treatment and surface roughness on the service life of Anti-Friction Coatings

Degreasing

In order to achieve a uniform surface pre-treatment and satisfactory application of Anti-Friction Coatings, the components must first be degreased carefully. Even when corrosion is removed with acid, a thorough degreasing is necessary to achieve an even wetting in the bath.

Degreasing is particularly successful using organic solvents or ultrasonic cleaners and wash plant with alkaline aqueous agents. Because of toxicological and safety concerns, however, consider to using organic solvents with very low-aromatic content.

If steam degreasing equipment is not available, remove oil and grease residues by washing in a suitable solvent. The solvent should leave no residue after evaporation, e.g. acetone or white spirit. Repeat the washing operation several times using fresh solvent each time.

Pre-treatment of corroded surfaces

Pretreat corroded surfaces by mechanical or chemical methods. As a mechanical method, sandblasting with aluminium oxide or with cast-steel (grain size 55 µm) is recommended. This produces an additional roughening of the component surface and provides better adhesion of the Anti-Friction Coatings. The acid and alkali treatments customary in electroplating are generally adequate. Baths should remove corrosion products but not unnecessarily attack the basic metal. Remove all traces of chemicals or solutions used in cleaning. Do not handle parts with bare hands.

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Phosphating

Phosphating is suitable for pretreating iron and steel, not stainless steel, and for galvanised iron parts. Manganese phosphating increases the load carrying capacity of the coating. Zinc phosphating increases its corrosion protection. Only use phosphating baths which produce very fine crystalline layers. The process should produce a maximum dimensional deposition between 3 and 8 µm at the surface. This is equivalent to an increase in weight between 5 to 15 g/m^2.

The phosphate layer should have an even, uniform structure and its colour should range between grey and black. The components should not be speckled and, in particular, should exhibit neither specks of dried-on phosphating solution nor traces of corrosion. After treatment, parts should not be touched with bare hands.

Parts exhibiting a slightly irregular colour may be used. The Anti-Friction Coatings must be applied to the phosphated metal parts within 24 hours, otherwise corrosion may occur.

Oxalic acid treatment of stainless steel

Special oxalic acid baths are required because of the corrosion resistance of stainless steels. The operating instructions of the manufacturer concerned should be observed.

Sandblasting (after degreasing)

Sandblasting is recommended for parts made of steel, titanium, aluminium, copper, magnesium and their alloys. Aluminium oxide or cast-steel (grain size 55 µm) are most suitable for this purpose. It will produce an average surface roughness Ra between 0.5 and 1.0 µm. In most applications the dimensional change produced by sandblasting is of little significance, being less than 1.3 µm.

Remove adhering sand particles with dry, oil-free compressed air. To avoid corrosion, treated surfaces must not be touched with the bare hand and coated as soon as possible.

Anodic oxidation (anodizing) of aluminium and aluminium alloys

Aluminium and aluminium alloys should be pretreated by electrolytic oxidation. Alloys with a copper content of 0.5% or more or with a total content of alloying additions in excess of 7.5% must be treated in a sulphuric acid bath.

All other aluminium alloys and aluminium can be treated in a chromic acid bath. A chromic acid bath produces a thin surface film that ensures good corrosion protection. For a good surface film to develop, use water of high purity (low chloride and sulphate content) for all baths.

	Minimum weight of surface film	Thickness of coating
Chromic acid process	2,15 g/m^2	2,5 µm
Sulphuric acid process	6,50 g/m^2	5,0 µm

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Surface pre-treatment of Anti-Friction Coatings (continued)

Washing, drying and impregnation of surface film

a) Chromic acid process: rinse thoroughly in hot water (65°C); allow to air dry.
b) Sulphuric acid process: wash parts thoroughly in water and seal coating in a 5% sodium dichromate or potassium dichromate solution by dipping. Rinse and allow to dry. The temperature during drying should not exceed 102°C. The component must not be touched with the bare hand thereafter.

Acid dip for copper and copper alloys instead of sandblasting

Copper and copper alloys are treated with a mixture of two or more of the following acids: sulphuric, phosphoric, chromic, nitric and hydrochloric acids. The mixing ratios and concentrations will vary greatly, depending on the alloy and surface conditions. Dipping times range from 5 seconds to 5 minutes. When pickling, take care that the basic metal is not attacked unnecessarily. When using nitric acid, toxic nitric oxide fumes must be removed by good ventilation. A quick-acting pickling bath can be used for flat components. For a large number of components or parts with complicated shapes, use a slow-acting bath. Follow any pickling with a thorough rinsing to remove any acid residue.

Pre-Treatment methods

Pre-treatment	Steel	Galvanised parts	Aluminium alloy	Copper alloy	Magnesium alloy	Titanium alloy	High-grade steel
Degreasing	×	×	×	×	×	×	×
Removal of oxides:							
- by pickling				×			×
- by sandblasting with aluminium oxide or cast-steel 55 µm	×		×	×		×	
Anodising to							
MIL-A-8625 C			×				
AMS 2488 (Tioxide Typ II)						×	
Bichromate treatment to MIL-M-3171 C					×		
Phosphating to DOD-P-16 232	×	×					
Oxalic acid treatment							×

Recommended pre-treatment methods for metal surfaces

Pre-treatment of plastic surfaces

With plastics too, surface pre-treatment increases the adhesion and service life of Anti-Friction Coatings. This is done primarily by degreasing and cleaning.
Use only solvents that will not damage the substrate. Review relevant information supplied by the manufacturer of the plastic or plastic part. Adhesion can also be improved by roughening (e.g. fine sandblasting) or by activating the plastic surfaces in a low-pressure plasma. Before production starts, test the effectiveness of the chosen pre-treatment.

Page width 140mm

Application of Anti-Friction Coatings

Depending on the nature of the parts being treated and the surface finish required, Anti-Friction Coatings are applied by spraying, dipping, or by using paint/spraying drums and centrifuges. The components should be appropriately pre-treated. In the case of partial coating of the components, it is advisable to use masking stencils or removable protective film. These must be removed before curing. Anti-Friction Coatings are supplied ready for use according to the recommended application processes (see technical data sheet of the considered product). Before application they need to be stirred thoroughly in order to obtain a uniform fluid. Only in cases where the film thickness has to be below 5 µm, it is necessary to dilute, stirring thoroughly. When handling non-water-based Anti-Friction Coatings use only electric mixers with explosion-proof motors. When applying such coatings, always comply with local safety regulations for handling paints and varnishes.

Application to metal surfaces
Spraying

Apply sprays in spray booths. If it is done elsewhere, good ventilation should be provided. The volatile solvents can be dangerous: no naked flame must be in the room. A round-jet spray gun with a 0.8 mm nozzle is recommended for small areas. The spraying pressure should be of the order of 2 to 5 bar. The distance between component and spray gun should be such that the product is still moist when it strikes the surface. Tears or droplets should not occur. If the spray gun is held too far away from the component, the product will dry before reaching the surface. This will prevent the formation of a uniform Anti-Friction Coatings and the film will appear rough.

It is far more important to work with extreme care when applying Anti-Friction Coatings than when painting or varnishing, since an extremely thin but uniform film has to be produced.
In order to produce a thicker film, several coats of Anti-Friction Coatings can be sprayed on. Each successive coat should, however, be applied to the previous coat when this is almost dry.

When spraying, use only compressed air that is free of water and oil. To apply the resin and the solid lubricant uniformly, the product must be stirred, especially after long breaks. In addition to spraying with compressed air, an electrostatic process may also be used. Before the coating hardens, sprayed parts must be handled with great care to prevent damages. Anti-Friction Coatings should dry in air for at least 10 minutes before being touched.

Dipping and centrifuging

If the shape and size of the parts permit, a dipping process can be used. Dip-spinning with a centrifuge is economical for applying Anti-Friction Coatings to large numbers of bulk goods like screws, nuts and small parts. Always dip-spin twice.
1. Dipping; centrifuging; spreading on wire grids; drying
2. Repetition of 1 to cover defects (contact points).

The required film thickness can be reached regulating the rotational speed of the centrifuge by the given viscosity of the Anti-Friction Coatings.

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Application of Anti-Friction Coatings (continued)

Dipping individual components

Big bolts, bushings, rods, sections, tubes, etc. and in general flat parts which cannot be treated in a dip-centrifuge can be coated in a dipping bath, and then allowed to drip-dry. Use a controlled dipping action to prevent air from being dragged in. Adjust withdrawal speed to prevent tears and droplet formation and to regulate the desired film thickness. Circulate the contents of the dipping bath with a suitable pump and an overflow lip. When using Anti-Friction Coatings containing organic solvents, arrange an edge extractor directly above the maximum level. During a stoppage, cover dipping containers to minimize evaporation and prevent contamination.

Brush application

Anti-Friction Coatings can also be brushed on. Even with fine-bristled brushes, the resulting film is often irregular. Consequently, consider alternative methods.

Roll coating and printing

Anti-Friction Coatings can be applied with standard coil-coating machines, but simpler transfer roll coating methods can also be used. Silk-screen and pad printing techniques are used for partial application.

Suitability for coating methods

AFC-Product	Centrifuging	Paint/ spraying drum	Automatic dipping	Automatic spraying	Brushing	Printing	Coil-coating
D 321R	×	●	✓	✓	✓	●	–
3402-C	×	×	✓	✓	✓	×	✓
D 3484	×	✓	×	✓	×	●	✓
3400A Leadfree	✓	✓	×	✓	✓	×	✓
106	×	×	×	✓	×	●	✓
7409	×	✓	✓	✓	×	×	✓
7620	×	●	✓	●	×	✓	✓
7400	×	●	×	✓	✓	●	●
D 106	×	×	×	✓	×	●	✓
PTFE-N UV	●	●	●	✓	×	●	●
D 708	✓	×	✓	✓	×	×	✓
D 96	×	●	×	✓	×	✓	●
7405	×	×	✓	×	✓	✓	✓
D 10	×	×	●	●	●	✓	✓
D 88	×	×	●	●	●	✓	✓

✓ = excellent × = good ● = limited

Curing

Heat cured coatings exhibit better resistance values. The corresponding curing times and temperatures are given in the data sheets. These are guidelines, which need to be verified under production conditions. The curing time must be extended for large parts, depending on weight and cross-section. Paint drying circulation ovens are recommended. It is also possible to use infra-red heat for curing. A wipe test using MOLYKOTE® 7414 thinner is recommended as a check of complete curing. If the coating is removed, the film is not fully cured.

Coating thickness

The film thickness has a considerable influence on the service life, coefficient of friction and anti-corrosion properties of Anti-Friction Coatings. It should be greater than the surface roughness of the mating surfaces and is generally between 5 and 20 µm. It is better to apply as thin a coat as possible to both surfaces, rather than a relatively thick coat on only one surface, since thicker layers cannot stand as heavy mechanical loads.

The following methods can be used to measure the layer thickness:
1. Magnetic method in accordance with DIN 50 981/ISO 2178 on ferromagnetic basic substances.
2. Eddy current method in accordance with DIN 50 984/ISO 2360 on non-ferrous metals.
3. Beta back-scatter method in accordance with DIN 50 983/ISO 3543 on plastics.
4. In exceptional cases (when the above methods are not available), micrometer and optical methods.

Removal of Anti-Friction Coatings (stripping)

In most cases, Anti-Friction Coatings can be removed from metal surfaces by placing the parts in MOLYKOTE® 7414 thinner overnight. Should this fail to produce the desired result, commercial paint removers for epoxy resins can also be used. Another efficient method (if permitted) is sand-blasting the coated surfaces.

Application to plastic surfaces

Selection

When choosing the Anti-Friction Coating, bear in mind that coatings containing MoS_2 are suitable for reinforced plastics, and MoS_2-free coatings for non-reinforced plastics. If a thermosetting Anti-Friction Coating is preferred to an air-drying Anti-Friction Coating, conduct a test beforehand to determine whether the plastic has sufficient thermal stability.

Application methods

Anti-Friction Coatings can be applied by spraying, dipping, brushing, roll coating and printing. The chosen method will depend on the shape, size, weight and quantity of the components. Consideration must also be given to the film requirements, as well as to the proportion and location of the sliding surfaces being coated.

Drying/curing

This depends on the coating used and can be obtained from the data sheets. Trial coating and testing for stress crack formation are required.

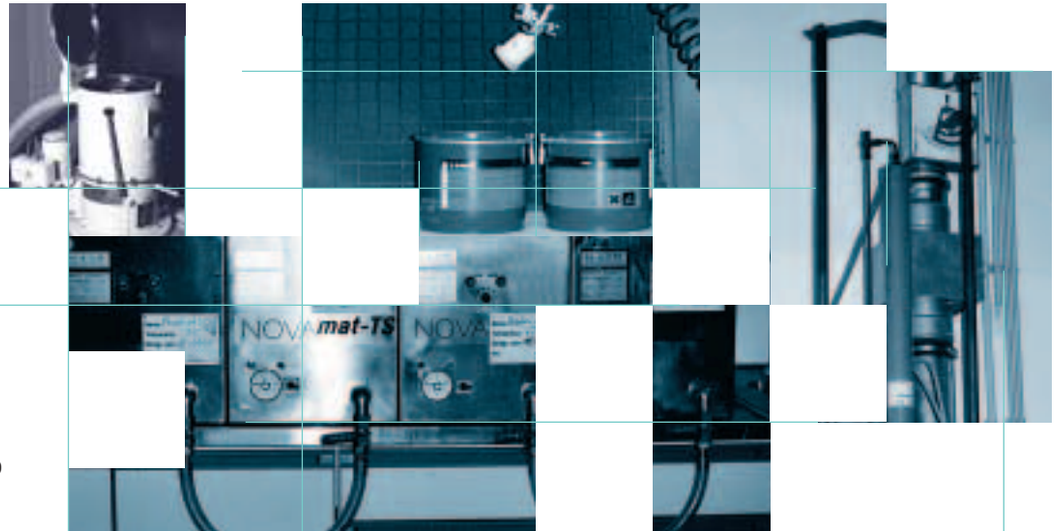
Resistance of cured film layer

Anti-Friction Coating product	Fuels	Brake fluid	Acids	Alkalines	Aromatics	Alcohols	Deionized Water	Ketone	Cutting fluids	Mineral oils	Synth. Oils	Dewatering fluids	Detergents	Radiation	Dielectric strength	Paintability
D 321R	●	●	●	×	●	×	✓	●	●	●	●	●	×	✓	●	×
3402-C	✓	×	×	×	✓	●	✓	●	✓	×	×	✓	×	×	×	×
D 3484	✓	✓	×	●	✓	✓	✓	✓	✓	✓	✓	✓	×	–	●	×
3400A Leadfree	✓	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓
106	✓	×	×	●	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	●	✓
7409	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓
7620	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓
7400	×	×	●	●	●	×	×	●	×	●	×	×	×	–	–	×
D 106	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	×	–	–	✓
PTFE-N UV	×	×	×	×	●	✓	✓	●	×	✓	×	×	✓	–	×	●
D 708	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	–	✓	●
D 96	×	●	●	●	●	×	×	●	–	×	×	–	–	–	×	●
7405	×	●	×	●	×	✓	✓	✓	✓	✓	✓	×	✓	–	✓	●
D 10	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	–	✓	×
D 88	✓	✓	✓	×	✓	✓	×	✓	✓	✓	✓	✓	✓	–	–	×

✓ = excellent × = good ● = limited – = n.a.

Application engineering

Our application facility is another strong asset of our technology leadership. In this dedicated laboratory area the most common application machines for Anti-Friction Coatings are in operation to produce prototype samples for customers, or for optimising the application parameters for new projects.



Application examples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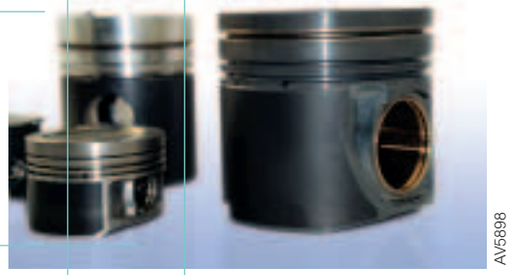
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