MOLYKOTE®

DUPONT™

MOLYKOTE® Anti-Friction Coatings

Smart Lubrication™ solutions for automotive and industrial applications

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Legendary performance for today and tomorrow

In 1948, American scientist Alfred Sonntag introduced the world's first molybdenum disulfide (MoS_2) lubricants – MOLYKOTE® brand – and began a rich history of customer-driven performance and materials innovation.

For well over seven decades – since 1948 – MOLYKOTE® has been a trusted partner, helping engineers and manufacturers meet some of the world's toughest technical design and lubrication challenges. And with the addition of DuPont's technologies and expertise when we joined the company in 2019, we became even better positioned to create solutions for emerging trends.

We continually invest in technology and product innovation to support customers' changing needs. Working side by side with our customers, MOLYKOTE® is forging the future of specialty lubrication with:

- A broad range of trusted, technology-driven specialty lubricant chemistries
- Application expertise and technical support from internationally recognized lubrication experts
- Anti-friction coating (AFC) solutions to meet megatrend needs and provide sustainable and efficient solutions
- Innovative combination of tribology and material science for wet and dry lubrication

High-value, high-performance long-term lubrication

Often described as “lubricating paints,” MOLYKOTE® AFCs contain solid lubricants – rather than coloring pigment – dispersed through carefully selected resin blends and solvents. The choice of raw materials and the concentration of each ingredient are important to the application-based customization of each coating.

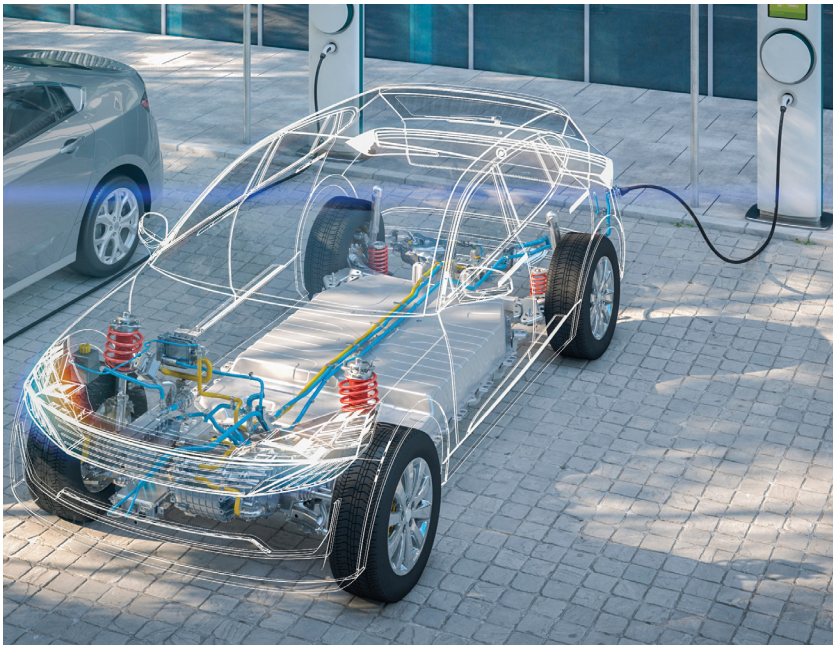
MOLYKOTE® AFCs form a dry film and optimize friction of metal and plastic parts – even under intense loads and harsh operating and environmental conditions.

The coatings are easy to apply by spraying, brushing, dip-spinning, roll-coating or screen printing. After curing, the bonded, dry lubricating film provides durable wear protection with a certain level of corrosion protection and resists dust and contamination.

This makes MOLYKOTE® Anti-Friction Coatings ideal for use in dirty, dusty and humid environments and on inaccessible parts that require long-term lubrication. Economical to apply, long-lasting and valued in uses where other lubricants fail, MOLYKOTE® AFCs provide:

- Dry, clean lubrication unaffected by dust, dirt and moisture
- Lifetime lubrication without aging, evaporation or oxidation
- Rust prevention further enhanced with surface treatments (e.g., Zn-phosphating, galvanizing)
- Nonflammable, nonstaining protection on metals, plastics and elastomers
- Controlled film thickness for exact load-bearing capabilities
- Fully effective lubrication, even after prolonged shutdown

MOLYKOTE® Anti-Friction Coatings help customers improve safety, reliability and performance by controlling friction and wear, preventing component failures, extending lubrication intervals, and reducing production and operating costs.



Delivering results in tough conditions

Operating principles and conditions

MOLYKOTE® Anti-Friction Coatings are particularly effective in boundary friction and mixed friction states, as illustrated in the Stribeck curve (Figure 1). In these states, direct metal-to-metal contact and wear take place because fluid hydrodynamic lubrication cannot be realized.

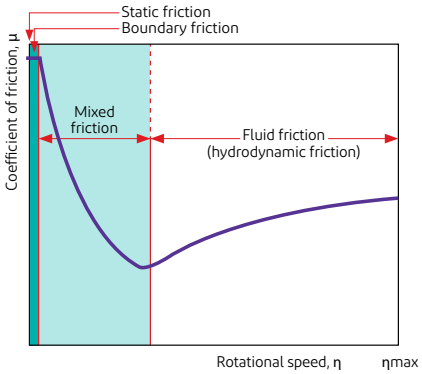


Figure 1. The Stribeck curve: Friction between surfaces as a function of viscosity, speed and load.

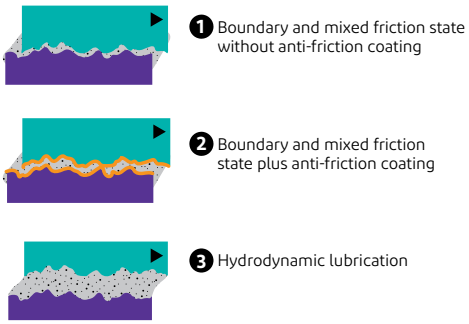


Figure 2. Different lubricants are used to meet the requirements of different regimes. AFCs are particularly effective in boundary and mixed friction states.

In MOLYKOTE® AFCs, the solid lubricants are kept on the substrate surface by the bonding force of the resin package so the surfaces are always separated by an effective dry film – whether under very low speeds, oscillating movements or high loads. MOLYKOTE® Anti-Friction Coatings also can support hydrodynamic lubrication as an agent to improve running-in. In addition, AFCs provide lubricity in case of hydrodynamic film breakdown.

Typical running-in effect and friction value

Anti-friction coatings generally are applied at 10-20 µm dry film thickness. Under load, the structure of the film is compacted, producing an extremely smooth surface covering the asperities of the carrier material (Figure 3). Coefficient of friction values of MoS_2-based anti-friction coatings are compared to PTFE-based coatings in Figure 4. The coefficient of friction value of Mos_2-based coatings drops after a short running-in phase.

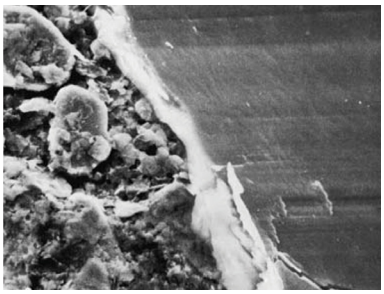


Figure 3. SEM photograph with 1,000x magnification: MoS_2 anti-friction coating before (left) and after (right) load application.

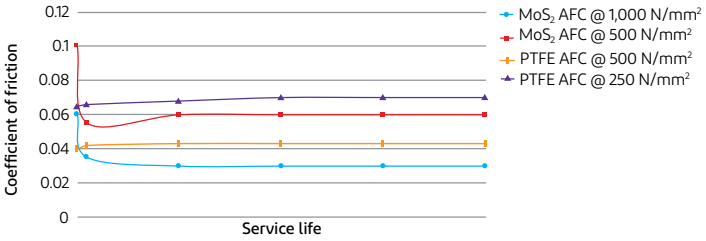


Figure 4. Typical friction values of MoS_2- and PTFE-based anti-friction coatings under different loads, measured with the LFW1 test machine – ASTM D2714 method.

Innovating through collaborative application engineering

MOLYKOTE® Anti-Friction Coatings offer fine-tuned solutions enabled by a customer-oriented development process – made possible by our network of global collaboration and technical development centers equipped with the latest tribological and analytical technology. When customers work together with us, they have the full benefit of our:

- Tribology testing capabilities, from standard data sheet test methods to custom-designed test rigs to match specific customer applications
- Equipment to replicate part movement across a wide range of loads, environmental conditions, temperatures and speeds (LETS) to assist with all stages of development – from prototype to production and maintenance
- In-house coating research and development
- Deep knowledge in resin and solid lubricant technology
- Regional experts who translate customer application challenges into measurable lubricant solutions
- Development guided by safer-by-design principles to deliver robust product performance and a reduced footprint

In addition, we provide support for coating-line designs, process improvements and coating-shop recommendations. Combining DuPont™ resins with MOLYKOTE® lubricant expertise and advanced formulations will help us to develop better solutions for emerging trends and challenges.

Solutions for a wide range of applications

As fail-safe lubricants, MOLYKOTE® Anti-Friction Coatings are valued by the world's leading engineers and manufacturers and are trusted for uses where maximum wear endurance is needed in a wide variety of applications – from increasingly electrified, autonomous and energy-efficient vehicles to industrial challenges where functionality, connectivity, safety and sustainability are critical.

Together, we can create lubrication solutions for your specific automotive and industrial applications. The next few pages highlight common application examples of MOLYKOTE® Anti-Friction Coatings.

Washers for xEV axles

MOLYKOTE® D-6600 Anti-Friction Coating

Coated washers mitigate noise and vibration caused by potential displacement and contact between CVJ shoulder and wheel bearing flange

Starter motor anchors

MOLYKOTE® D-6600 Anti-Friction Coating

Low friction for lifetime durability of metal/metal pairings; suitable for start-stop systems

Exhaust manifold gaskets

MOLYKOTE® D-7620 Anti-Friction Coating

Improves sealing properties and avoids microseizing at high temperatures; enables easier disassembly; designed for coil and roller coating

Lock mechanisms, lock-catching plates and locking levers, safety hooks

MOLYKOTE® 3400A LF Anti-Friction Coating
MOLYKOTE® D-708 Anti-Friction Coating
MOLYKOTE® D-7708 Anti-Friction Coating

Long-term lubrication and corrosion protection; not affected by dust

Door panels, armrests, consoles, interior trim

MOLYKOTE® D-96 Anti-Friction Coating
MOLYKOTE® D-9630 Anti-Friction Coating

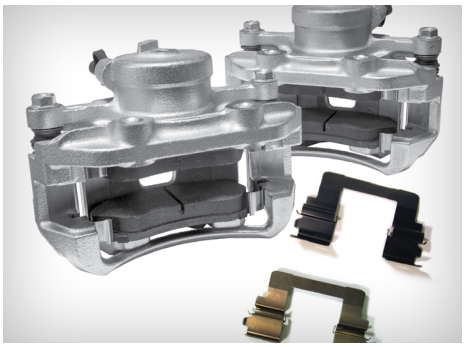
Lifetime anti-noise performance in cases where unfavorable material pairings are combined; when used as a replacement for nonwoven tape, it eliminates squeaks and rattles and represents an economical solution

Seat belt components

MOLYKOTE® D-6600 Anti-Friction Coating
MOLYKOTE® D-708 Anti-Friction Coating
MOLYKOTE® D-7708 Anti-Friction Coating
MOLYKOTE® D-3484 Anti-Friction Coating

Low-friction dry lubrication for lifetime durability of metal/metal pairings; nonstaining

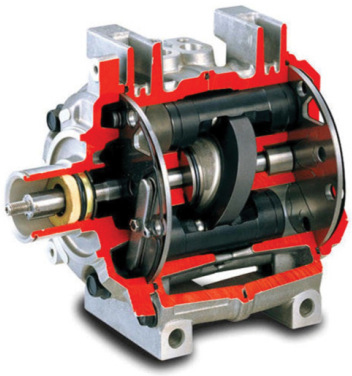
= Automotive application = Industrial application



Caliper springs and brake clips

MOLYKOTE® D-708 Anti-Friction Coating
MOLYKOTE® D-7708 Anti-Friction Coating

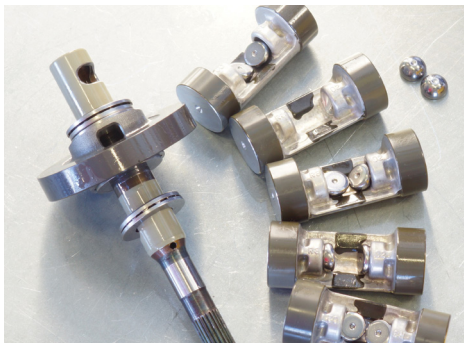
Dry lubrication of steel springs in caliper brake pad sliding guides; works alongside a dry lubricant as an insulating anti-corrosion coating



Air conditioner swash plates

MOLYKOTE® D-6818 Anti-Friction Coating
MOLYKOTE® D-7409 Anti-Friction Coating

Excellent lubrication performance; high wear resistance; efficient processability; excellent chemical resistance



Air conditioner pistons

MOLYKOTE® D-6927 Anti-Friction Coating

Excellent lubrication performance; excellent chemical resistance to refrigerant and compressor oil; high wear resistance at mild conditions; efficient processability

Piston skirt coating

MOLYKOTE® D-10-GBL Anti-Friction Coating
MOLYKOTE® D-6024 Anti-Friction Coating
MOLYKOTE® PA 744 Anti-Friction Coating

For enhanced durability and emergency lubrication on pistons and piston rings; reduces noise and scuffing while increasing efficiency and fuel economy; screen-printable

Gears

MOLYKOTE® D-7409 Anti-Friction Coating
MOLYKOTE® 7400 Anti-Friction Coating
MOLYKOTE® D-321 R Anti-Friction Coating

High load-carrying capacity for running-in protection of heavily loaded gear sets

Threaded connections

MOLYKOTE® D-708 Anti-Friction Coating
MOLYKOTE® D-3484 Anti-Friction Coating
MOLYKOTE® D-7708 Anti-Friction Coating

Defined, constant friction levels and corrosion protection for bolts, studs, nuts and fasteners

Chains

MOLYKOTE® D-7409 Anti-Friction Coating
MOLYKOTE® D-3484 Anti-Friction Coating
MOLYKOTE® D-321 R Anti-Friction Coating

Long-life friction reduction for pins (MOLYKOTE® D-7409 Anti-Friction Coating, MOLYKOTE® D-3484 Anti-Friction Coating); reliable lubrication for complete chains (MOLYKOTE® D-321 R Anti-Friction Coating)

Springs

MOLYKOTE® D-321 R Anti-Friction Coating
MOLYKOTE® D-3484 Anti-Friction Coating
MOLYKOTE® D-7409 Anti-Friction Coating

Friction reduction to eliminate stick-slip and increase efficiency

Valves

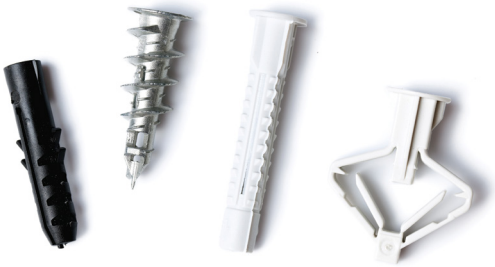
MOLYKOTE® D-7409 Anti-Friction Coating

Operating efficiency; eliminates stick-slip; high chemical and fluid resistance

General assembly

MOLYKOTE® D-321 R Anti-Friction Coating
MOLYKOTE® 3402-C LF Anti-Friction Coating

Powerful dry-film lubricants for easy assembly of sliding parts; MOLYKOTE® 3402-C LF Anti-Friction Coating additionally offers good corrosion protection; MOLYKOTE® D-321 R Anti-Friction Coating also is available in spray cans



Plastics lubrication

MOLYKOTE® D-96 Anti-Friction Coating
MOLYKOTE® D-96 UV Anti-Friction Coating
MOLYKOTE® D-6600 Anti-Friction Coating
MOLYKOTE® D-708 Anti-Friction Coating
MOLYKOTE® D-7708 Anti-Friction Coating

Excellent anti-squeak performance with low coefficient of friction for plastic/plastic and plastic/metal interfaces under low to medium loads and slower movements or vibration; water-based and solvent-based, with the latter particularly suited to metal substrates in plastic/metal pairings

Product selection

MOLYKOTE® Anti-Friction Coating	Substrate			Pairings[1]	Load-carrying capacity, MPa	Solid lubricant	Service temperature range, °C	Environment	
	Metal	Plastic	Elastomer					Wet/dry[2]	Oil/fuel resistance
D-7409	✓			M/M	High	MoS_2	-70 to 300	Dry	+
D-7620	✓			M/M	High	MoS_2	-70 to 300	Dry	+
3400A LF	✓			M/M	High	MoS_2	-200 to 430	Dry	+
106	✓			M/M	High	MoS_2	-70 to 250	Dry	o
D-3484	✓			M/M	High	MoS_2	-70 to 250	Dry	o
D-321 R	✓	✓	✓	M/M	High	MoS_2	-180 to 450	Dry	–
7400	✓			M/M	High	MoS_2	-70 to 200	Dry	–
3402-C LF	✓			M/M	High	MoS_2	-200 to 315	Dry	o
D-10-GBL	✓			M/M	Medium	Graphite	-40 to 340	Wet	+
D-6024	✓			M/M	Medium	MoS_2	-40 to 310	Wet	+
PA 744	✓			M/M	Medium	MoS_2	-75 to 300	Wet	+
D-6818	✓			M/M	Medium	MoS_2	-60 to 240	Wet/dry	+
D-6927	✓			M/M	Medium	PTFE	-60 to 240	Wet/dry	+
D-6600	✓			M/M, M/P, M/E	Medium	PTFE	-40 to 260	Dry	+
D-708	✓			M/M, M/P, M/E	Medium	PTFE	-180 to 240	Dry	+
D-7708	✓			M/M, M/P, M/E	Medium	PTFE	-180 to 240	Dry	+
D-96		✓		P/P, P/M, P/E	Low	PTFE	-40 to 150	Dry	o
D-96 UV		✓		P/P, P/M, P/E	Low	PTFE	-40 to 150	Dry	o
D-9630		✓		P/P, P/M, P/E	Low	PTFE	-40 to 120	Dry	o

Specification writers: These values are not intended for use in preparing specifications. Please contact your local MOLYKOTE® sales representative prior to writing specifications on these products.
[1]M = metal; P = plastic; E = elastomer. The first letter listed in each pairing indicates the substrate that is coated with the anti-friction coating.
[2]Preferred working conditions.

Selected coatings for corrosion protection

Type of coated surface	Plane steel plate		Edged part	
Pretreatment	Zn-phosphating			
Application method	Spraying		Dip-spinning	
MOLYKOTE® Anti-Friction Coating	AFC film thickness, µm	Time to red rust, hr	AFC film thickness, µm	Time to red rust, hr
D-7409	15	250	—	—
3400A LF	12-15	600	10-12	240
3402-C LF	10-12	72	—	—
D-6600	10-12	600	10	360
D-708	12	600	10-12	240

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Testing procedure: ISO 9227 salt spray test.
Because corrosion protection performance depends on the geometry of the parts (plane or edged), pretreatment, application process, and film thickness, MOLYKOTE® recommends running tests on original parts and industrial application processes before setting specifications.

Friction values and specific properties

MOLYKOTE® Anti-Friction Coating	Friction value					Specific properties
	Conditions[1]	Coefficient of friction[2]	Material pairing[3]	Tribological contact	@ pressure, MPa	
D-7409	Dry	0.070	M/M	Linear	550	High load-carrying capacity, low friction, oil/fuel resistance
D-7620	Dry	0.080	M/M	Linear	550	High load-carrying capacity, low friction, oil/fuel resistance
3400A LF	Dry	0.060	M/M	Linear	550	High load-carrying capacity, low friction, corrosion protection
106	Dry	0.060	M/M	Linear	550	High load-carrying capacity, low friction
D-3484	Dry	0.065	M/M	Linear	550	High load-carrying capacity, low friction, quick curing schedule
D-321 R	Dry	0.060	M/M	Linear	550	High load-carrying capacity, low friction, electrical conductivity
7400	Dry	0.060	M/M	Linear	550	High load-carrying capacity, low friction, water-based, air-curing
3402-C LF	Dry	0.050	M/M	Linear	550	High load-carrying capacity, low friction, air-curing, corrosion protection
D-10-GBL	Wet	0.100	M/M	Linear	200	Oil-/fuel-resistant, emergency and wet lifetime lubrication
PA 744	Wet	0.045	M/M	Point	550	Oil-/fuel-resistant, emergency and wet lifetime lubrication
D-6024	Wet	0.047	M/M	Linear	180	Oil-/fuel-resistant, emergency and wet lifetime lubrication
D-6818	Dry	0.060	M/M	Area	2.5	Oil-/fuel-resistant, high durability under harsh conditions
D-6927	Dry	0.090	M/M	Linear	250	Oil-/fuel-resistant, anti-wear performance at low pressures
D-6600	Dry	0.065	M/M	Linear	250	Low friction at low/medium pressures, corrosion protection
		0.060	M/P	Point	60	
D-708	Dry	0.090	M/M	Linear	250	Low friction at low/medium pressures, corrosion protection, black finish
		0.100	M/P	Point	60	
D-7708	Dry	0.090	M/M	Linear	250	Low friction at low/medium pressures, corrosion protection, black finish, China-compliant solvent package for easy handling
		0.100	M/P	Point	60	
D-96	Dry	0.200	P/P	Area	NA	Lifetime anti-noise, low friction at low/medium pressures
D-96 UV	Dry	0.200	P/P	Area	NA	Lifetime anti-noise, low friction at low/medium pressures, UV tracing
D-9630	Dry	0.100	P/P	Linear	4	Lifetime anti-noise, low friction at low/medium pressures, high plastic compatibility

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[1]Wet = mixed friction conditions in presence of engine oil; Dry = dry conditions.
[2]Because the coefficient of friction is influenced by material pairing, tribological contact, load, speed and temperature, MOLYKOTE® recommends running trials on original parts and components before setting specifications.
[3]M = metal; P = plastic; NBR = nitrile butadiene rubber; EPDM = ethylene propylene diene monomer rubber. The first letter listed in each pairing indicates the substrate that is coated with the anti-friction coating.

Application process

MOLYKOTE® Anti-Friction Coating	Application process	Flash point, °C	Curing conditions[1]	Color (dry film)	Surface coverage @ film thickness, m^2/kg	Diluent (MOLYKOTE® Thinner unless otherwise noted)
D-7409	Spraying	35	30 min @ 220°C	Dark gray	16 @ 10 µm	7415
D-7620	Coil-coating	40	30 min @ 200°C	Dark gray	17 @ 12 µm	7415
3400A LF	Spraying, dip-spinning	10	30 min @ 200°C	Dark gray	16 @ 10 µm	L-13
106	Spraying, dip-spinning	30	60 min @ 150°C	Dark gray	19 @ 10 µm	L-13
D-3484	Spraying, dip-spinning	26	10 min @ 170°C	Dark gray	20 @ 10 µm	L-13
D-321 R	Spraying	23	Room temperature	Dark gray	8 @ 10 µm	L-13
7400	Spraying, dip-spinning	None	Room temperature	Dark gray	15 @ 10 µm	Water
3402 C LF	Spraying	15	Room temperature	Dark gray	12 @ 10 µm	L-13
D-10-GBL	Screen printing	77	20 min @ 200°C	Dark gray	15 @ 20 µm	On request
D-6024	Screen printing	29	20 min @ 200°C	Dark gray	18 @ 15 µm	7415
PA 744	Screen printing	57	60 min @ 230°C	Dark gray	19 @ 15 µm	7415
D-6818	Spraying	44	60 min @ 220°C	Dark gray	17 @ 10 µm	7415
D-6927	Spraying	61	60 min @ 230°C	Dark gray	14 @ 10 µm	7415
D-6600	Spraying, dip-spinning, electrostatic	26	20 min @ 200°C	Light yellow	20 @ 10 µm	L-13
D-708	Spraying, dip-spinning, dipping, electrostatic	0	20 min @ 200°C	Black	20 @ 10 µm	L-13
D-7708	Spraying, dip-spinning, dipping, electrostatic	0	20 min @ 200°C	Black	20 @ 10 µm	L-13
D-96	Spraying	None	Room temperature	Translucent	23 @ 10 µm	Water
D-96 UV	Spraying	None	Room temperature	Translucent	23 @ 10 µm	Water
D-9630	Spraying	None	Room temperature	Translucent	34 @ 10 µm	Water

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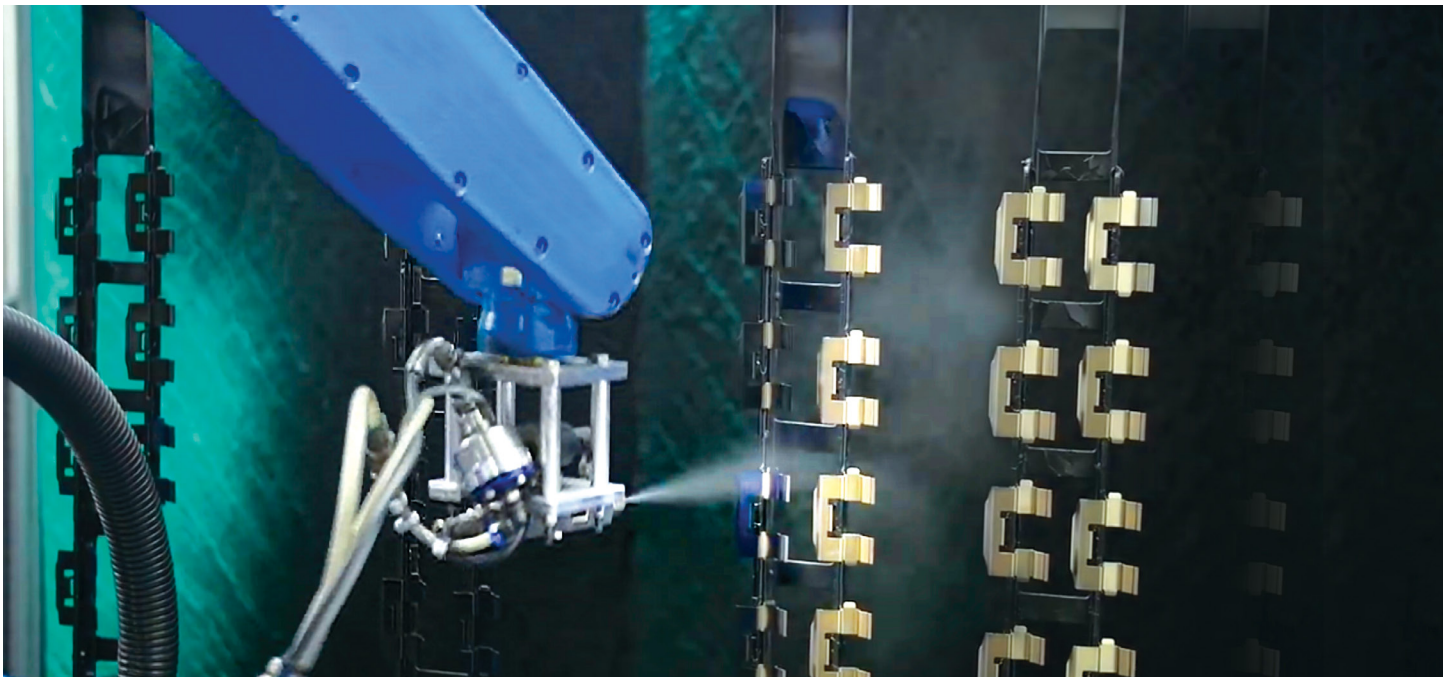
[1]Alternate time and temperature profiles for heat-cure coatings are possible but should be validated to ensure complete cure of film. Contact MOLYKOTE® for assistance with alternate cure conditions.



The coating process

To ensure the effectiveness and full service life of MOLYKOTE® Anti-Friction Coatings, a proper coating process must be followed (Figure 5). Surface pretreatment plays a key role in coating service life and performance. Depending on the material, this can include processes such as solvent sonication, degreasing, media blasting, detergent washing, phosphating, anodizing, acid washing, e-coating, corona/plasma treatment and others (Figure 6).

Once the pretreated parts are dry and clean, different methods – varying by part geometry, weight, quantity and coating liquid viscosity – can be used to apply the anti-friction coating, including dip spinning, tumble spraying, HVLP spraying, screen printing, brushing, rolling and coil-coating.

Once coating is applied to the substrate, a curing process is required. Time to cure (from 2 to 90 minutes) and temperature needed (from ambient temperature up to 250°C) can vary, depending on the cure mechanism (heat, air or UV).

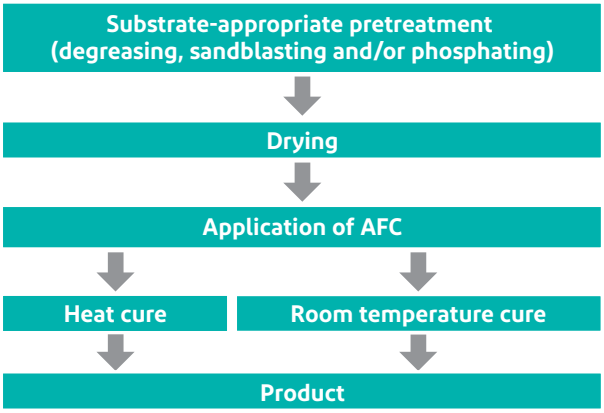
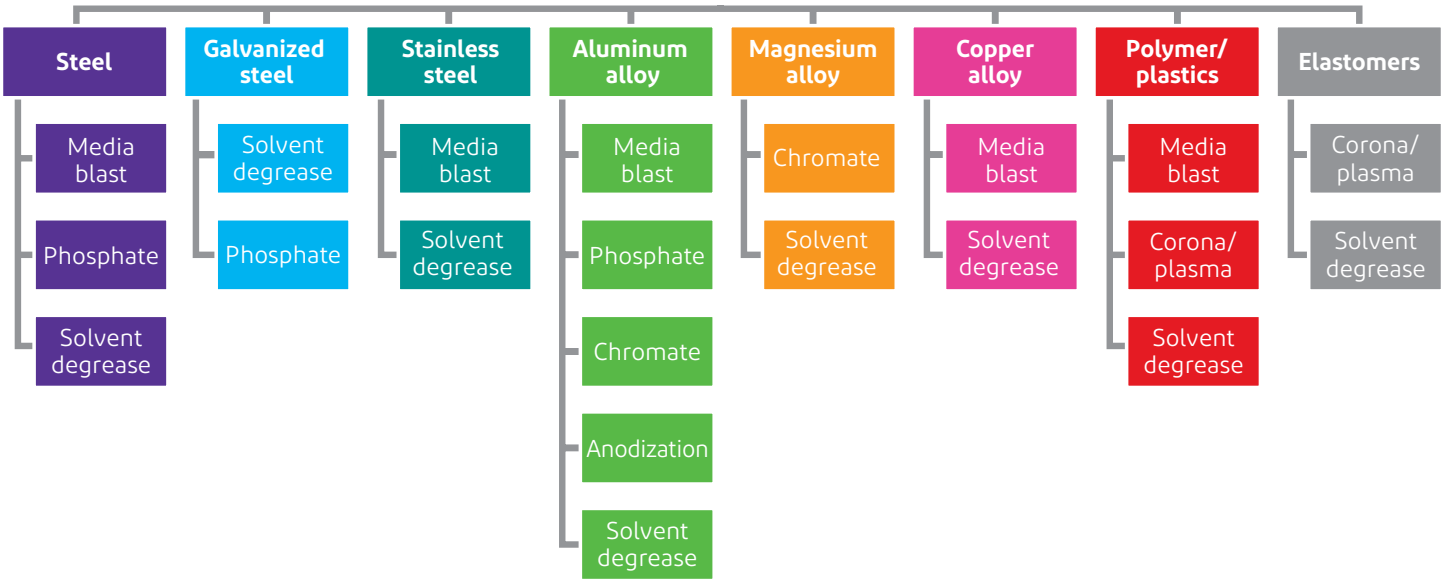


Figure 5. Typical steps for using anti-friction coatings on steel.

Pretreatment methods

Figure 6. Depending on the material, there are many pretreatment methods that can be used to clean the surface and prepare it for coating.



AFCs for automotive application needs

Application	MOLYKOTE® Anti-Friction Coating	Running-in optimization	Emergency lubrication	Corrosion protection	Fuel/oil resistance	Anti-seizing	Stick-slip elimination	Specific benefits
Powertrain								
Pistons	D-10-GBL D-6024 PA 744	✓	✓		✓			
Tappets	D-7409	✓	✓		✓			
O-rings (metal)	3400A LF					✓	✓	
Cylinder head gaskets	D-7620				✓	✓		Separating layer
Starter motor anchors	D-6600		✓	✓				
Exhaust manifold gaskets	D-7620				✓			Oil/fuel resistance
Gears	7400 D-7409	✓			✓			
Bushings	D-7409	✓			✓			
Thrust washers	D-7409	✓			✓			
Chassis								
Ball joints	D-6600 D-708 D-7708			✓	✓		✓	
Bushings				✓				
Rods				✓				
Fasteners				✓		✓		
Spline shafts	7400					✓		
Crash tubes	D-708 D-7708					✓	✓	
Brake systems								
Springs, clips	D-708 D-7708			✓		✓	✓	Insulation properties
Spindles (EPB)	D-708 D-7708 D-6600		✓	✓	✓		✓	
Exterior								
Closures, lock mechanisms	3400A LF D-708 D-7708 D-7409			✓				Suitable as topcoat for zinc-plating
Sunroof rails, guides	D-708 D-7708 D-6600			✓	✓			
Hinges	3400A LF			✓			✓	
Interior								
Door panels, armrests, consoles, interior trim	D-96 D-96 UV D-9630						✓	Air-curing
Seat belt components	D-6600			✓			✓	Nonstaining
Springs	106 D-3484 D-6600						✓	Nonstaining
Spindles	106		✓					
HVAC								
Pistons	D-6927		✓		✓			
Swash plates	D-6818		✓		✓			

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AFCs for industrial application needs

Application	MOLYKOTE® Anti-Friction Coating	Running-in optimization	Emergency lubrication	Corrosion protection	Fuel/oil resistance	Anti-seizing	Stick-slip elimination	Assembly aid
Bearings								
Sliding bearings	D-6600		✓	✓	✓	✓		
Chains								
Pins	D-7409 D-3484		✓				✓	
Chains	D-321 R					✓		
Gears								
Gears	7400 D-7409	✓			✓			
Gear racks	D-7409	✓			✓			
Threaded connections								
Bolts, nuts, studs	D-708 D-7708 D-3484			✓				
Petroleum casing pipes	3402-C LF					✓		
Springs								
Cup, helical	D-321 R D-3484 D-7409					✓	✓	✓
Shaft/hub connections								
Shrink discs	3402-C LF D-321 R					✓	✓	✓
Splined shafts	D-7409 D-3484						✓	
Other applications								
Telescopic booms	D-7409 D-321 R						✓	
Temperature control units of heating systems	D-6600 D-708 D-7708						✓	
Valves, pumps	D-7409				✓		✓	
Plastics lubrication	D-96 D-96 UV						✓	
General assembly, maintenance	D-321 R	✓				✓	✓	✓

Specification writers: These values are not intended for use in preparing specifications. Please contact your local MOLYKOTE® sales representative prior to writing specifications on these products.

About MOLYKOTE® Specialty Lubricants

Since 1948, customers around the world have trusted the MOLYKOTE® brand for performance and expertise to solve or prevent virtually any lubrication problem and to save energy. Available through a global network of more than 3,000 channel partners, MOLYKOTE® brand lubricants – which include well over 500 anti-friction coatings, compounds, dispersions, greases, oils and fluids, and pastes – serve the automotive market and industrial/maintenance, repair and overhaul (MRO) markets. To learn more about our extensive product and service offering, to utilize our interactive product selection tool, or to locate a distributor, visit **molykote.com**.

Contact us

MOLYKOTE® has Contact Centers around the globe. Find the phone number for the center nearest you at **www.dupont.com/molykotecontact**.

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