TECHNI/TIPS

A Publication of the Lubrication Engineers technical Department
LEADERS IN LUBRICANTS NUMBER 99

SEALS

Fluid seals are divided into two main classes-static seals and dynamic seals. Static seals are gaskets, o-ring joints, packed joints, welded joints, and similar devices used to seal static connections or openings with little or no relative motion between mating parts. A dynamic seal is any device used to restrict flow of fluid through an aperture closed by relatively moving surfaces. Some dynamic seals include static sealing elements in their design.

Seals are also frequently classified as contact seals or clearance seals. Some seal elements may operate as clearance seals under certain conditions and as contact seals under others. The term seal may refer to a system rather than a single device. A sealing system may require a mechanical seal, a viscoseal and a labyrinth seal in order to produce the desired end result.

Table 1 shows the dynamic seal elements which make up the bulk of industrial, commercial, utility and transportation sealing applications.

Table 1

CATEGORIES OF DYNAMIC SEALS

Operational principle for dynamic seal element	Normal motion	Extent of use	Energyloss	Leakage	Life
Positive contact					
Face	Ro Os	H	L	L	M-H
Rings	Ro Os Re	H	H	L	L-M
Lip	Ro Os Re	H	L	L	L-M
Packings	Ro Os Re	H	L-H	L-H	L
Diaphragms	Os Re	L	L	L	H
Controlled clearance					
Hydrodynamic	Ro	L	L	L-M	M-H
Hydrostatic	Ro Os	L	L	L-M	M-H
Floating bushing	Ro Os Re	M		M-H	H
Fixed-geometry clearance					
Labyrinth	Ro Os Re	H	H	H	H
Bushing	Ro Os Re	M	H	H	M-H
Special control of fluid					
Freeze	Ro Os	L	L	M	L-M
Magnetic fluid	Ro Os Re	L	L	L	M
Centrifugal	Ro	L	M	L	H
Screw	Ro	L	M	L	H
Magnetic	Ro Os	L	L	M	M

Note: Ro = rotary, Os = oscillatory, Re = reciprocating, H = high, M = moderate, and L = low.

MATERIALS

Seal components and gland ring parts for noncorrosive fluids such as gasoline, hydrocarbons and oils are usually made from ferritic stainless steel. For moderate corrosion resistance in environments such as water, sea water, dilute acids, fatty acids and alkalis, austenitic stainless steels are widely used. For highly corrosive environments such as strong mineral acids and strong alkalis, nickel-copper base materials such as Monel or nickel-molybdenum alloys such as Hastelloy B or Hastelloy C are frequently employed. Temperature range for these materials is -100°C. to 400°C. (-150°F. to 750°F.). Table 2 presents seal face material combinations for various environments. Tables 3 and 4 show recommended temperature limits for seal faces and secondary seal materials.

Table 2
FACE SEAL MATERIAL COMBINATIONS[4,8]

Common end face seal and material combinations used in a variety of fluids (Seal nose material vs. Seal seat material)	Hard faced stainless vs. Carbon graphite	Stellite vs. Carbon graphite	Chromium boride vs. Carbon graphite	Ceramic vs. Carbon graphite	Hastelloy A.B.C. vs. Carbon graphite	Carbon-filled Teflon® vs. Carbon graphite	Glass-filled Teflon® vs. Carbon graphite	Cast iron vs. Carbon graphite	Ni-Resist vs. Carbon graphite	Nitralloy vs. Carbon graphite	Stellite-faced stainless vs. Carbon graphite	400 Series stainless steel vs. Carbon graphite	Bronze vs. Carbon graphite	Tungsten carbide vs. Carbon graphite	Sintered iron or bronze vs. Carbon graphite	Tool steel, hardened vs. Carbon graphite	Monel vs. Carbon graphite	Nickel cast iron vs. Carbon graphite
Environment																		
Acids	A	A	A	A	A	1												
Caustics	2					A					3							
Gasoline				A		A	A	A	A	A	A	A						
Gas (O_2,N_2,H_2,He,CO_2)				A								A		A		A		
Heat transfer		A		5					A					5				
Oil				A		A	A	A	A	A	A	A	A	A	A	A		
Oxidizing fluids																		
Salt solution				A								A					A	
Salt water		A																
Slurry																		
Water				A		A	A		A		A	3	A	A				4

Common end face seal and material combinations used in a variety of fluids (Seal nose material vs. Seal seat material)	Chrome plate vs. Carbon graphite	Ceramic faced stainless vs. Carbon graphite	Chrome carbide vs. Carbon graphite	Ceramic vs. Carbon	Tungsten carbide vs. Carbon	Laminated plastic vs. Bronze	Tungsten carbide vs. Bronze	Tungsten vs. Tungsten	Tungsten carbide vs. Tungsten carbide	Stellite vs. Ceramic	Glass-filled PFTE vs. Ceramic	PFTE vs. Ceramic	Ceramic vs. Ceramic	Ceramic faced stainless vs. Ceramic	Phosphor bronze vs. Carbon babbitt	Aluminum bronze vs. Carbon babbitt	Aluminum bronze vs. Stellite on stainless	Boron carbide vs. Boron carbide
Environment																		
Acids										7	6	A						
Caustics																		
Gasoline																		
Gas (O_2,N_2,H_2,He,CO_2)	A		A															
Heat transfer			A						5									
Oil																		
Oxidizing fluids																		A
Salt solution													A	A	A			
Salt water						A		A							A	A		
Slurry				A	A		A	A										
Water	A	A							A									

Note: 1. For nonoxidizing acids. 2. Nonmetallic carbon graphite. 3. Metallic carbon graphite. 4. For constant operation only. 5. For high temperature (approx. 700 °F). 6. For oxidizing acids. 7. Attacked by many mineral acids. A = Acceptable.

Table 3

RECOMMENDED TEMPERATURE LIMITS FOR FACE SEAL MATERIALS[a]

Material	Maximum temperature °F	°C
Tungsten carbide	750	400
Stainless steel	600	316
Carbon-graphite	525	275
Stellite	450	232
Nickel-cast iron	350	177
Leaded bronze	350	177
Alumina[b]	350	177
Glass-filled TFE	350	177

[a] Product temperature; maximum working temperature is higher.
[b] Subject to thermal shock fracture.

From *Guide to Modern Mechanical Sealing*, Durametallic Corporation, Kalamazoo, Mich., 1971. With permission.

Table 4

RECOMMENDED TEMPERATURE LIMITS FOR SECONDARY SEAL MATERIALS[a]

Material	Minimum temperature °F	°C	Maximum temperature °F	°C
Nitrile-low	−40	−40	176	80
Nitrile-medium	−22	−30	194	90
Nitrile-high	−4	−20	212	100
Neoprene	−58	−50	212	100
Butyl	−40	−40	194	90
Silicone, fluorosilicone	−76	−60	392	200
Fluorocarbon	−58	−50	437	225
TFE	−100	−73	350	177
Glass-filled TFE	−175	−115	450	232
Graphite	−450	−268	750	400

[a] Product temperature.

From *Guide to Modern Mechanical Sealing*, Durametallic Corporation, Kalamazoo, Mich., 1971. With permission.

TEMPERATURE

Excessive lip temperature is a prime cause of seal failure. Typical sump temperatures for many applications range from 70°C. to 130°C. (158°F. to 266°F.). Conventional lip seals, operating about 50% submerged, experience underlip temperature rises on the order for 10°C. to 36°C. (18°F. to 65°F.). Some newer hydrodynamic seals have underlip temperature rises about 15% to 30% less than conventional seals. High lip temperatures may degrade the elastomer, increase chemical reaction between the elastomer and sealed fluid, and thermally degrade the sealed fluid (sludge deposits and carbonized abrasive particles). At low temperatures, -30°C. (-22°F.) or below, some elastomers become hard, brittle, and unable to follow shaft excursions. Leakage results. The higher modulus of elasticity also increases lip loading which causes wear. Extreme temperature problems can generally be solved by heating or cooling the sump, selecting suitable lubricants and giving special attention to elastomer selection-see Tables 5 and 6.

Table 5
CHEMICAL RESISTANCE OF LIP SEAL ELEMENTS

Fluid medium	Nitrile (BF,BG,BK,CH)*	Polyacrylate (DF,DH)	Silicone (FC,FE,GE)	Fluoroelastomer: Fluorosilicone (FK)	Fluoroelastomer: Fluorocarbon (HK)	Fluoroplastic PTFE
Engine oil	Good	Good	Good	Good	Good	Good
ATF-A	Fair	Good	Good	Good	Good	Good
Grease	Good	Fair	Fair	Fair	Good	Good
EP Lube	Fair-poor	Good	Poor	Fair	Good	Poor
SAE90 (nonadditive)	Good	Good	Good	Good	Good	Good
MIL-L-7808	Fair	Poor	Good	Good	Good	Good
MIL-L-23699	Fair	Poor	Good	Good	Good	Good
MIL-L-6082-A	Good	Good	Good	Good	Good	Good
MIL-L-5606	Good	Good	Poor	Good	Good	Good
MIL-L-2105	Fair	Good	Poor	Fair	Fair	Good
MIL-G-10924	Good	Good	Poor	Good	Good	Good
Fresh or salt water	Good	Poor	Good	Good	Good	Good
Acetic acid	Poor	Poor	Poor	Poor	Fair	Good
Ammonium gas	Good	Poor	Fair	Poor	Poor	Good
Brake fluid	Good	Good	Fair	Good	Good	Good
Butane	Good	Good	Fair	Fair	Good	Good
Freon 12	Good	Poor	Poor	Poor	Fair	Good
Fuel oil	Good	Fair	Poor	Poor	Fair	Good
Kerosene	Good	Fair	Poor	Poor	Fair	Good
Gasoline	Good	Fair	Poor	Poor	Fair	Good
Ketones (MEK)	Poor	Poor	Poor	Poor	Poor	Good
Methyl chloride	Poor	Poor	Poor	Poor	Good	Good
Molybdenum disulfide	Good	Good	Good	Good	Good	Good
Oxygen	Good	Good	Fair	Fair	Good	Good
Perchlorethylene	Fair	Poor	Poor	Poor	Good	Good
Petroleum base hydraulic oil	Good	Good	Good	Good	Good	Good
Phosphate ester	Poor	Poor	Good	Good	Good	Good
Trichlorethylene	Poor	Poor	Poor	Poor	Good	Good

* ASTM D2000/SAE J200 type and class designations.

From Dreger, D. R., Ed., *Mach. Design*, 52(8), 1980. With permission.

Table 6
SEAL ELEMENT SELECTION GUIDE[21,22]

Material	Cost factor	Sump temp range °C (°F)	Advantages	Disadvantages
Nitrile (BF, BG, BK, CH)*	1	−46 to 107°C (−50 to 225°F)	Low cost; low swell; easily processed; good oil resistance; good low-temperature properties; good abrasion resistance	Poor resistance to EP additives; poor high-temperature resistance
Polyacrylate (DF, DH)	1.2	−40 to 135°C (−40 to 275°F)	Good oil resistance including EP lubricants; low swell; good high-temperature resistance; High-oxidation resistance	Poor water resistance; fair wear resistance; Poor low-temperature characteristics; poor compression set; poor abrasion resistance
Silicone (FC, FE, GE)	1.3	−62 to 149°C (−80 to 300°F)	Wide temperature range; very flexible; easily molded; high-lubricant absorbency; good water resistance	Easily torn or cut; high swell; poor resistance to oxidized oil; poor abrasion resistance; poor dry running properties
Fluorosilicone (FK)	2.0	−62 to 149°C (−80 to 300°F)	Good oil and chemical resistance; good low-temperature properties; wide temperature range; low-compression set	Poor abrasion resistance; poor dry running; poor tear strength; expensive; difficult to process; poor wear resistance
Fluorocarbon (elastomer) (HK)	2.0	−40 to 177°C (−40 to 350°F)	Very good oil and chemical resistance; excellent heat resistance; wide temperature range low swell; good wear properties	Difficult to process; expensive; becomes stiff at low temperatures; poor followability at low temperatures
Fluorocarbon thermoplastic PTFE	3	−96 to 204°C (−140 to 400°F)	Excellent temperature range; excellent oil and chemical resistance; low friction; no swell; good dry running	Difficult to process; limited design options; high cost; easily damaged; nonelastic; becomes stiff at low temperatures; poor followability at low temperatures

* ASTM D2000/SAE J 200 Type and Class Designations

SQUEEZE PACKING

Squeeze packings are made in several shapes, in a large number of standard sizes and from over a dozen elastomers with hardness ranging from 10 to 100 Shore A. These seals, Figure A, are low in cost, require minimum space, are easy to install, require no adjustment, seal in both directions, have low friction, can be used as piston or gland seals, can be selected from compatibility with a wide range of fluids, and are readily available for industrial, aerospace and military applications. Squeeze rings, though simple *in* form, are made with closely held diametral and cross section tolerances. To ensure long life and effective sealing, recommended groove dimensions, surface finishes and diametral clearances must be carefully followed. Table 7 gives some characteristics of the most widely used squeeze seal materials.

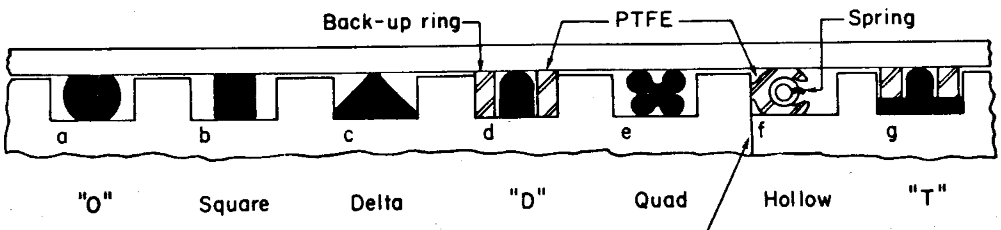

FIGURE A Typical squeeze-type packing rings.

Table 7

CHARACTERISTICS OF COMMON SQUEEZE SEAL MATERIALS

Elastomer	Tensile strength (MPa)	Compression set resistance	Abrasion resistance	Oxidation resistance	Resiliency — hot	Resiliency — cold	Fuels and lubricants petroleum based	Acid resistance	Alkali resistance	Water and steam resistance	
Nitrile	GE 20.7	GE	G	FG	G	FG	FE	FG	FG	FE	
Ethylene propylene	GE 20.7	FE	G	E	G	FG	P	GE	GE	E	Phosphate ester base fluids
Fluorocarbon	G 17.2	FE	FG	E	G	F	E	G	GE	FG	
Neoprene	GE 20.7	FG	G	GE	GE	G	PF	G	GE	G	High aniline oils
Silicone	P 10.3	GE	P	E	G	G	PF	FG	FG	FG	
Polyurethane	E 31.0	FG	E	G	F	F	FG	PF	PF	PF	
Buna S	GE 20.7	FG	G	FG	G	G	P	FG	G	FG	Brake fluids
Polyacrylate	F 13.8	G	FG	GE	G	P	GE	P	P	P	
Fluorosilicone	P 8.3	G	P	E	G	FG	G	P	P	G	

Note: E, G, F, and P = excellent, good, fair, and poor.

Above material provided by *Handbook of Lubrication, Theory and Practice of Tribology, Volume II, Theory & Design,* sponsored by The Society of Tribologists and Lubrication Engineers.

LUBRICATION ENGINEERS,® Inc.
300 Bailey Ave, Fort Worth, TX 76107 | 817-834-6321 | 800-537-7683
fax 817-834-2341 | http://www.le-inc.com

L099*TT
Rev. 10-92