BAL SEAL® ENGINEERING, INC.

Custom components that drive tomorrow's technologies.

Shaft and housing materials, coatings, and lubricants for optimal cryogenic sealing

Technical Report
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1.0 Introduction

Bal Seal Engineering Inc. is a leading manufacturer of fluid seals used for cryogenic service. Sealing at cryogenic temperatures is difficult, and many factors influence seal performance. This report includes guidelines for selecting coatings, platings, lubricants, and shaft and housing materials that can be used to improve seal performance at cryogenic temperatures. For the purpose of this report, *cryogenic* is defined as usually –100 °F or lower.

2.0 Coatings and Platings

Coatings and platings are used to improve wear resistance and increase the hardness of a shaft or housing material. They are recommended to reduce friction and seal wear. Some coatings and platings used in cryogenic service are described in Table 1.

Table 1: Coatings and Platings for Cryogenic Sealing

Coating or Plating	Hard Anodizing Coating, Type III	Dense Chrome Plating	Electroless Nickel Plating	Titanium Nitride Coating (PVD)
Description	• Aluminum oxide • Thickness = 0.0005–0.0020 in.	• Electrolytic process that deposits a high chromium alloy • Thickness = 0.0002–0.0006 in. (0.00508–0.01524 mm)	• Deposits a phosphorus–nickel alloy in a chemical bath • Thickness = 0.001–0.004 in. (0.0254–0.1016 mm)	• Uses nitrogen as a surface-hardening agent • Thickness = 0.000039–0.000079 in. (0.0009906–0.0020066 mm)
Surface Hardness	60–65 RC	70–72 RC	48–52 RC as plated 58–64 RC after heat treating	86 RC
Shaft and Housing Materials	6061 – T6 Low wear resistance with 2024-T361	15-5 pH, A-286 and 300 series stainless steel	15-5 pH, A-286 and 300 series stainless steel	15-5 pH, A-286 and 300 series stainless steel
Specifications	MIL-A-8625	MIL-DTL-23422	SAE-AMS-2404	None
Advantages and Applications	• Reduces friction • Reduces seal wear • Increases wear resistance • Increases hardness • Improves surface finish • Uses dry film lubricants	• Reduces friction • Reduces seal wear • Increases wear resistance • Improves surface finish • Reduces galling • Improves corrosion resistance • Improves fatigue strength	• Improves corrosion resistance • Reduces friction • Increases wear resistance • Reduces seal wear	• Improves fatigue wear • Reduces seal wear • Increases wear resistance • Provides a hard surface • Improves resistance to fatigue
Notes	• Hone or polish after application • Apply dry lubricants to surface irregularities	• Generally used for interior surfaces with wet lubricants • Bore diameters • Hone or polish after application	• Plating for intricate surfaces • Small or deep bores • Stress-relieving after plating • Light honing or polishing after application	• No dimensional changes
Applicable Bal Seal Engineering Technical Reports	TR-17	TR-14	TR-16	TR-24

3.0 Lubrication

Wet lubricants may be used at temperatures to –77 °F (–60 °C). At lower temperatures, dry lubricant should be used. Dry lubricants are recommended for cryogenic service because they improve seal performance and create a protective film between the seal and sealing surface. This protective film reduces friction and seal wear, minimizes galling, and improves sealing ability. Some lubricants used at low and cryogenic temperatures are described below in Tables 2 and 3.

Table 2: Wet lubricants for low temperatures to –77 °F (–60 °C)

Wet Lubricant	Source	Description	Application
Krytox: greases and oils	Chemours USA Fluoroproducts 1007 Market St. Wilmington, DE (800) 424-7502	Fluorinated oils and greases	• Substantially inert • Non-flammable • Liquid oxygen (LOX) compatible
Halocarbon oils	Halocarbon Products Corp. 887 Kinderkamack Rd. River Edge, NJ (201) 262-8899	Polymers of chlorotrifluoroethylene	• LOX and liquid nitrogen (LN) Pumps • LOX compatible • Non-flammable

Table 3: Dry lubricants for cryogenic service and other applications

Dry Lubricant	Source	Description	Application
Microseal	Metal Improvement Co. 80 Rte. 4 E, Ste. 310 Paramus, NJ 07652 (201) 843-7800	Proprietary impingement process deposits a precise amount of graphite and molydisulfide.	• Reduces possibility of galling • Precisely control thickness • Improves surface finish
Molydisulfide Spray Coating	Anadite, Inc. 10647 Garfield Ave. Southgate, CA 90280 (562) 862-4786	Weak bonding force between sulfur atoms enables layers of lattice molecular structure to slide.	• Vacuum and inert gas service • Improves sealing ability • Reduces friction • Reduces seal wear • Removes excess by polishing
Graphite Spray-On Coating	Crest Coating, Inc. 1361 S. Allec St. Anaheim, CA 92805 (714) 635-7090	Moisture promotes slippage between weakly bonded layers of lattice molecular structure.	• Reduces friction • Improves sealing ability • Provides self-release properties • Reduces seal wear • Removes excess by polishing

4.0 Shaft and Housing Materials

Most structural metals, such as aluminum, nickel, aluminum alloys, nickel alloys, and 300-series stainless steels, provide good service at cryogenic temperatures. Some of the mechanical properties of metals typically used in low temperature equipment are indicated in Table 4.

Table 4: Shaft and housing materials for cryogenic service

Material	Condition	Tensile Strength (psi)	Yield Strength (psi)	Elongation (%)	Rockwell Hardness	Basic composition (% by weight)	Application
Stainless Steel 15-5 pH	Annealed	150,000	110,000	10	34 HRC	C = 0.07 Mn = 2.00 Si = 1.00 Cr = 15.00 Ni = 4.50 Cb = 0.35	• General purpose: dams, housing, etc. • Higher mechanical properties than 17-4 pH
	Heat-treated	200,000	185,000	14	44 HRC		
Stainless Steel A-286	Solution-treated and aged	169,000	115,000	22	30 HRC	C = 0.05 Mn = 1.40 Si = 0.05 Cr = 14.75 Ni = 25.25 Mo = 1.30 Ti = 2.15 Al = 0.15 V = 0.30	• Excellent corrosion resistance • Screws, bolts, etc.
Stainless Steel 303	Annealed	90,000	35,000	50	84 HRB	C = 0.15 Mn = 2.00 Si = 1.00 Cr = 18.00 Ni = 9.00 Mo = 0.60	• General purpose: very low speeds and pressures • Moderate corrosion resistance
	Cold-worked 20%	100,000	60,000	40	20 HRC		
Stainless Steel 304L	Annealed	85,000	35,000	55	85 HRB	C = 0.03 Mn = 2.00 Si = 1.00 Cr = 19.00 Ni = 10.00	• Non-magnetic applications • Low speeds and pressures • Moderate corrosion resistance
	Cold-worked 20%	130,000	118,000	15	28 HRC		
Stainless Steel 316	Annealed	85,000	35,000	55	85 HRB	C = 0.08 Mn = 2.00 Si = 1.00 Cr = 17.00 Ni = 12.00 Mo = 2.50	• Solid-spray environments • Low speeds and pressures • Excellent corrosion resistance
	Cold-worked 20%	130,000	118,000	15	28 HRC		
Stainless Steel 316L	Annealed	85,000	35,000	55	85 HRB	C = 0.03 Mn = 2.00 Si = 1.00 Cr = 17.00 Ni = 12.00 Mo = 2.50	• Applications requiring welding • Low speeds and pressures • Excellent corrosion resistance
	Cold-worked 20%	130,000	118,000	15	28 HRC		
Aluminum Alloy 2024-T361	n/a	72,000	57,000	13	n/a	Fe = 0.50 Mn = 0.60 Si = 0.50 Cr = 0.10 Mg = 1.50 Zn = 0.25 Cu = 4.35 Ti = 0.15	• General purpose: valve bodies, poppets, etc.
Aluminum Alloy 6061-T6	n/a	45,000	40,000	17	60 HRB	Fe = 0.70 Mn = 0.15 Si = 0.60 Cr = 0.20 Mg = 1.00 Zn = 0.25 Cu = 0.15 Ti = 0.15	• When a greater degree of grain structure is required • Salt spray applications
Titanium TI-6 AL-4V	Annealed	135,000	130,000	12	n/a	Al = 6.13 V = 4.00 N = 0.07 C = 0.10 Fe = 0.40 O = 0.30	• Valve bodies, poppets, etc.