Selection of Shaft and Housing Seal Materials in Contact with Bal Seal® Spring-Energized Seals in Dynamic Service

Technical Report
TR-15 Rev. C

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1.0 SUMMARY

BAL™ Seal performance in reciprocating and rotating service is substantially affected by the hardness and surface finish of the shaft or housing.

In general, a hard shaft and housing with a smooth surface finish produce lower friction and result in reduced BAL Seal wear. Proper wet or dry lubrication between the seal and sealing surface also reduces friction and improves seal performance.

2.0 DISCUSSION

Wear of the shaft or housing takes place over the area of contact between the seal and sealing surface. This wear occurs over the length of piston travel in reciprocating service, while wear in rotating service is concentrated over the area of continuous dynamic action.

3.0 SELECTION OF THE SHAFT AND HOUSING MATERIALS

Typical shaft and housing materials used in contact with BAL Seals for dynamic service are indicated in Table 2.

3.1 General purpose, non-corrosive applications

Several types of materials are used in contact with BAL Seals for general-purpose applications. Typical materials are indicated in Table 1.

MATERIALS	GRADE
Stainless Steel	303, 316, 316L
Stainless Steel	440C
Carbon Steels	SAE 1045
High Alloy Steels	4140, 4340
Air Hardening Tool Steels	D-2

Typical Shaft and Housing Materials
Table 1

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3.2 Corrosive applications

Shaft and housing materials for corrosive applications may be divided into three groups: precipitation hardening stainless steels, solution treated and aged stainless steels, and Austenitic stainless steels.

3.2.1 Precipitation hardening stainless steels

There are three general types of precipitation hardening steels available: 17-4 PH, 15-5 PH, and 13-8 PH. The selection will depend on the tensile properties and corrosion resistance required. For light-duty service, precipitation hardening stainless steels should be hardened to obtain a hardness of 41 to 43 Rc. If service under high speed or high-pressure conditions is required, a higher hardness is recommended. Higher hardness may be obtained by chrome plating, electroless nickel plating, or plasma spray coating. See BAL Seal Technical Reports TR-3, TR-14, and TR-16.

3.2.2 Solution treated and aged stainless steel

This material is relatively soft and should be limited to low speeds and low pressures. It has excellent corrosion resistance and greater stability than Austenitic, 300 series, cold worked stainless steel. A typical material is A-286.

3.2.3 300 Series, austenitic stainless steels

There are four types generally used: 303, 304, 316 and 316L. Type 303 is designed primarily for very light duty service where ease of fabrication is the important consideration. Type 304 is for general-purpose applications, while type 316 is designed for those applications where a greater degree of corrosion resistance is needed. The 316L is indicated where maximum corrosion resistance is required. These materials are relatively soft and wear quickly when in contact with BAL Seals. They are available in annealed and cold worked conditions. Cold worked steel have better mechanical properties and are preferable for use in dynamic service.

If the application involves high speeds or high pressures, other materials should be used or the materials should be chrome plated, electroless nickel plated, or plasma spray coated to achieve the higher surface hardness that is necessary for better BAL Seal performance.

Nitronic® 50 and Nitronic® 60[1] are two other types of Austenitic stainless steels available. Both offer twice the yield strength of type 304, while Nitronic® 50 offers greater corrosion resistance, low magnetic permeability at sub-zero temperatures and is used in marine, chemical, nuclear waste and oil and gas production. Nitronic® 60 offers superior galling and wear resistance properties and can be found in bridge expansion joints, hydroelectric power systems, food processing and pharmaceuticals (also oil and gas and chemical). Both materials have excellent high and low temperature properties.

[1] Nitronic® 50 and Nitronic ® 60 are registered trademarks of Armco. Inc.

4.0 SURFACE HARDNESS AND ITS EFFECT ON BAL™ SEAL PERFORMANCE

High surface hardness is necessary to reduce adhesion and abrasion between the seal and the sealing surface to achieve longer seal life. With a higher hardness, better overall seal performance can be expected. Generally, a higher hardness can be obtained by hardening, carburizing, chrome plating, electroless nickel plating, or plasma spray coating. The selection of the process will depend on the specific material to be used, the corrosion resistance needed, the BAL Seal performance required, and cost considerations.

Hardening and carburizing are perhaps the simplest processes that can be used to provide a hardness from 41 to 62 Rc. Chrome plating can achieve a surface hardness from 65 to 68 Rc. Electroless nickel plating can achieve a surface hardness from 50 to 68 Rc, and plasma spray coating can achieve a hardness from 68 to 74 Rc.

5.0 SURFACE FINISH AND ITS EFFECT ON BAL™ SEAL PERFORMANCE

A good surface finish reduces abrasion between the seal and the sealing surface and promotes longer life. See BAL Seal Technical Reports TR-78 and TR-4.

5.1 Selecting the proper surface finish for the application

The type of surface finish will depend on various factors, but it may be divided into a fine surface and an average surface finish. A fine surface finish of 2 to 4 microinches RMS (0.046 to 0.091 microns RMS) is necessary for those applications involving high speeds, high pressures, high temperatures and non-lubricated environments. An average surface finish can be used in applications involving lower speeds, low pressures and good lubrication.

5.2 Obtaining good surface finishes

Good surface finishes may be obtained by turning, polishing, grinding, honing or lapping. Honing or lapping will provide a much better surface finish, which will promote better sealing ability and better overall BAL Seal performance.

6.0 DRY LUBRICANTS

Wet lubricants provide substantially better performance than dry lubricants, but, in those applications where wet lubricants cannot be used or do not remain on the surface of the seal, dry lubricants should be used. There are three basic types of dry lubricants used: molydisulfide, graphite, and PTFE. Such lubricants are only recommended when the surface structure permits locking of the lubricant into the mating part. This can only be achieved successfully with chrome plating, plasma spray and hard anodized coatings, and similar plating and coatings. When a dry lubricant is used, it should be baked-in so that it bonds itself to the metal surface irregularities. Excess dry lubricant should be removed by polishing. See BAL Seal TR-20.

7.0 TYPICAL SHAFT AND HOUSING MATERIALS FOR USE IN CONTACT WITH BAL™ SEALS IN DYNAMIC SERVICE

Some typical shaft and housing materials used in contact with BAL Seals are described in Table 2. The mechanical properties and compositions are included along with recommendations as to which materials to use in contact with the various metals.

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Typical Shaft and Housing Materials for Use in Contact with Bal Seals in Dynamic Service Mechanical Properties Applications, and Recommended Bal Seal Materials

Table 2

MATERIAL	TYPE OF MATERIAL 4,5	CONDITION	TENSILE STRENGTH PSI	YIELD STRENGTH PSI	ELONGATION %	TENSILE		TYPICAL BASIC COMPOSITION						TYPICAL APPLICATION	RECOMMENDED BAL SEAL MATERIAL 4,5
						BRINNEL NUMBER	ROCKWELL C OR EQUIVALENT	C	Mn	Si	Cr	Ni	Mo		
STAINLESS STEEL	17-4 PH	Annealed (N. R.)[1]	150000 PSI	110000 PSI	10	330	35	.05	.10	.10	12.5	8.0	2.5	General purpose with moderate corrosion resistance.	T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
		Heat Treated	200000 PSI	185000 PSI	14	410	44								GFP-10, GFPM,T,TA,G,SP-45,SP-50,UPC-10, UPC-16, UP-40
	15-5 PH	Annealed (N. R.)[1]	150000 PSI	110000 PSI	10	320	34	.07	1.0	1.0	15.0	5.0	---	General purpose with better mechanical properties than 17-4PH.	T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
		Heat Treated	200000 PSI	185000 PSI	14	410	44								GFP-10,GFPM,SP-45,SP-50,UPC-16,UP-40
	13-8 PH	Annealed (N. R.)[1]	160000 PSI	145000 PSI	15	330	35	.07	1.0	1.0	16.5	4.0	---	General purpose with better mechanical properties than 17-4PH and 15-5PH.	T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
		Heat Treated	214000 PSI	185000 PSI	16	435	46								GFP-10,GFPM,SP-45,SP-50,UPC-16,UP-40
	A-286	Solution Treated[1] and Aged	169000 PSI	115000 PSI	22	290	30[2]	.08	2.0	1.0	15.4	25.1	1.5	Excellent corrosion resistance for use in steam, water, chemicals, low speeds and pressures.	T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
	303	Annealed (N. R.)[1]	90000 PSI	35000 PSI	50	160[2]	---	.15	2.0	1.0	18.0	9.0	.6	Free machining, very soft for very low speeds and pressures, with moderate corrosion resistance.	T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
		Cold Worked 20%[1]	100000 PSI	60000 PSI	40	228[2]	20[2]								T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
	304	Annealed (N. R.)[1]	85000 PSI	35000 PSI	55	150[2]	---	.08	2.0	1.0	19.0	9.5	---	Soft material with moderate corrosion resistance for use at low speeds and pressures.	T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
		Cold Worked 30%[1]	130000 PSI	118000 PSI	15	270[2]	28[2]								T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
	316	Annealed (N. R.)[1]	85000 PSI	35000 PSI	55	150[2]	---	.08	2.0	1.0	17.0	12.0	2.5	Soft material with good corrosion resistance for use at low speeds and pressures.	T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
		Cold Worked 30%[1]	130000 PSI	118000 PSI	15	270[2]	28[2]								T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
	316L	Annealed (N. R.)[1]	85000 PSI	35000 PSI	55	150[2]	---	.03	2.0	1.0	18.0	14.0	.30	Excellent corrosion resistance for use at low speeds and pressures.	T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
		Cold Worked 30%	130000 PSI	118000 PSI	15	270[2]	28[2]								T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
	Nitronic®[3] 50	Annealed 30%[1]	116000 PSI	57,000	47%	192	11.5	0.06	5.0	1.0	22.0	12.5	2.5	Good mechanical properties at elevated and sub-zero tempertures. Outstanding corrosion resistance compond to 304 and 316, while having appoximately	T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
		Cold Worked 40%[1]	194000 PSI	174,000	15%	320	34								T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
	Nitronic®[3] 60	Annealed[1]	103000 PSI	60000 PSI	64	212	16	.10	8.0	4.0	17.0	8.5	---	Galling and wear resistant austenitic stainless steel with comparable corrosion resistance to 304 and 316, while having approximately twice the	T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
		Cold Worked 40%[1]	195000 PSI	153000 PSI	20	357	38								GFP-10, GFPM,T,TA,G,SP-45,SP-50,UPC-10, UPC-16, UP-40
	440C	Annealed (N. R.)[1]	110000 PSI	70000 PSI	13	235[2]	27.7[2]	1.1	1.0	1.0	17.0	.50	.75	Heat treated material is hardest of all stainless steels, for higher speeds and pressures, but moderate to low corrosion resistance.	T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
		Hardened	285000 PSI	275000 PSI	2	600	57								GFP-10, GFPM,T,TA,G,SP-45,SP-50,UPC-10, UPC-16, UP-40
CARBON STEEL	SAE 1045	Cold Drawn (N.R.)[1]	110000 PSI	85000 PSI	19	223	18.8	.47	.75	---	---	---	---	Good machinability with higher strength than other low carbon steels. Non-corrosive media.	T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
		Hardened	300000 PSI	280000 PSI	10	620	58								GFP-10, GFPM,T,TA,G,SP-45,SP-50,UPC-10, UPC-16, UP-40
HIGH ALLOY STEEL	4140	Annealed (N. R.)[1]	95000 PSI	60000 PSI	26	187	10	.4	.85	.25	.95	---	.2	General service applications in non-corrosive media.	T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
		Hardened	250000 PSI	230000 PSI	12	485	50								GFP-10, GFPM,T,TA,G,SP-45,SP-50,UPC-10, UPC-16, UP-40
	4340	Annealed (N. R.)[1]	110000 PSI	60000 PSI	23	197	12.7	.4	.75	.3	.8	1.8	.25	General service applications with better mechanical properties than 4140. Deeper harding in large sections.	T,TA,G,GC,SP-45,SP-50,UPC- 10,UPC-16,UP-40
		Hardened	250000 PSI	230000 PSI	10	485	50								GFP-10, GFPM,T,TA,G,SP-45,SP-50,UPC-10, UPC-16, UP-40
TOOL STEEL	D-2	Hardened	Approx. 324,000 PSI	Approx. 298,000 PSI	1	712	62	1.5	.4	.4	12.0	.4	1.0	High hardness and wear resistance but limited corrosion resistance for high speeds at moderate pressures.	GFP-10, GFPM,T,TA,G,SP-45,SP-50,UPC-10, UPC-16, UP-40

1. Not recommended. These materials in the softer conditions are not recommended for rotary service in contact with Bal Seals due to insufficient hardness resulting in rapid wear of the shaft.
2. Higher hardness may be obtained by chrome plating or plasma spray coating of these shaft materials. Refer to ;TR-1,TR-3,TR-14, AND TR-16 for surface coating information.
3. Nitronic® is a trademark of Armco. Inc.
4. Soft shaft materials (under RC-38) Require the use of non abrasive ring material to minimize shaft wear.(eg.,T,TA,G,SP-45,SP-50,UPC-10,UPC-16, and UP-40).
5. Hard shaft materials (over RC 38) can use ALL Bal Seal materials as well as abrasive type such as GFP-10 and GFPM.