Appendix 3

Abbreviations and mathematical variables

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Individual appendices of the Kalsi Seals Handbook are periodically updated. To determine if a newer revision of this appendix exists, please visit www.kalsi.com/seal-handbook.htm.

1. Abbreviations

The following abbreviations used in this seal handbook:

AA	arithmetic average
ACN	acrylonitrile
ASTM	American Society for Testing and Materials
BOP	blowout preventer
°C	degree Celsius
CDA	Copper Development Association
cm	centimeter
cSt	centistokes
cu in	cubic inches
DOE	Department of Energy
EPDM	ethylene-propylene rubber
°F	degree Fahrenheit
FEPM	Tetrafluoroethylene and propylene copolymer
FIM	full indicator movement
FKM	fluorocarbon rubber
ft	foot
ft/minute	feet per minute (surface velocity)
gpm	US gallons per minute
hr	hour
HNBR	hydrogenated nitrile rubber
HSN	highly saturated nitrile
ID	inside diameter
in	inch
in-lb	inch-pound
ISO	International Organization for Standardization
kPa	kilopascal
lb	pound
lbf	pounds force
lb/gallon	pounds per US gallon

LMC	least material condition
m	meter
max	maximum
min	minimum
ml	milliliter
mm	millimeter
m/s	meters per second (surface velocity)
MMC	maximum material condition
MOV	motor operated valve
MPa	megapascal
NBR	nitrile rubber
N	Newton
N·m	Newton meter
OD	outside diameter
Pa	Pascal
psi	pounds per square inch
RCD	rotating control device
rpm	revolutions per minute
SBIR	Small Business Innovation Research
SHC	synthetic hydrocarbon
TIR	total indicator runout
μin	micro-inch
μm	micro-meter
VG	viscosity grade
XNBR	carboxylated nitrile

2. Mathematical Variables

The following mathematical variables are used in this seal handbook. Many are modified by the subscript avg, nom, min, or max to represent the average, nominal, minimum, or maximum condition.

B	=	Seal carrier static sealing interface diameter.
C	=	Seal radial compression dimension.
CL	=	Lateral offset of the shaft installation chamfer relative to the seal groove that is possible during shaft insertion, taking all factors into account, such as chamfer machining eccentricity, mechanic's manual alignment accuracy, and/or the mechanical alignment accuracy provided by an alignment tool or by the fit of the seal carrier to the shaft. (Used to design chamfer size.).
CD	=	Installation chamfer diameter of the shaft.
$CS_{percent}$	=	Percent compression set.
D	=	Seal radial cross-sectional depth.
D_{WELL}	=	Depth of the fluid column within a well.
E	=	Accumulative eccentricity tolerances that can affect the position of the seal groove relative to the shaft during operation, expressed in diameter format.
Ec	=	Eccentricity tolerance that can affect the position of the sliding seal groove relative to the piston OD, expressed in diameter format.
Ep	=	Equivalent pressure, due to axial spring force acting on the seal.
F_{BO}	=	Breakout load from torque test data
F_{WEIGHT}	=	Fluid specific weight
G	=	Groove diameter.
G_t	=	Groove diameter tolerance.
H	=	Compensating piston housing bore diameter.
ID_{SEAL}	=	Seal inside diameter.
J	=	Compensating piston outer diameter.
K	=	Compensating piston sliding seal groove diameter.
K_m	=	Secant Bulk Modulus.
L	=	Maximum angulation-related lateral shaft deflection at the sealing lip due to shaft articulation within clearances and due to side load-induced shaft bending.

L_C	=	Lubricant side shaft to housing radial clearance.
M	=	Accumulative diametric mounting clearance of the seal groove relative to the shaft, including bearing mounting clearance, bearing internal clearance, seal carrier to bearing housing mounting clearance (if any), etc.
P	=	Pressure.
P_B	=	Pilot bore diameter.
P_D	=	Pilot outer diameter.
P_{DEPTH}	=	Well pressure at a given depth.
PI	=	3.1415927
P_L	=	Pilot length.
$P_{SURFACE}$	=	Well pressure at the surface.
PV	=	Differential pressure times shaft surface velocity.
Q	=	Hydrodynamic rotary leak rate.
Q_{total}	=	Total system hydrodynamic leak rate.
R	=	Radial Gland Depth.
S	=	Shaft diameter.
S_1	=	High pressure seal ID
S_2	=	Compensation Piston Seal ID
Sf	=	Spring force, in pounds.
$Stroke_{min}$	=	Total minimum design piston stroke length.
S_T	=	Shaft diameter of a test rotary seal.
$Stroke_{SL}$	=	Minimum piston stroke length for tool service life.
$Stroke_{TE}$	=	Piston stroke length required for thermal expansion of system lubricant volume.
ΔP	=	change in pressure.
Δt	=	change in temperature.
α	=	linear coefficient of thermal expansion.
β	=	volumetric coefficient of thermal expansion.
°C	=	Temperature, degree Celsius.
°F	=	Temperature, degree Fahrenheit.

$T_{initial}$	=	Initial specimen thickness.
T_{final}	=	Final specimen thickness.
$T_{compressed}$	=	Compressed specimen thickness.
T_S	=	Predicted torque for any given diameter shaft, as determined from the torque of a test rotary seal of a different diameter.
T_T	=	Torque of a test rotary seal.
V	=	Rotational Velocity of shaft surface.
Vol_{lub}	=	Total required lubricant volume for tool service life
V_N	=	The component of the rotational velocity of the shaft surface that is normal to the wavy edge of the dynamic sealing interface.
V_{rpm}	=	Shaft rotational velocity in revolutions per minute.
V_T	=	The component of the rotational velocity of the shaft surface that is tangent to the wavy edge of the dynamic sealing interface.
W	=	Radial gland dimension of the compensation piston sliding seal.
Y	=	Viscosity constant.