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KAMATICSRWG
Engineered Performance

QTP-2396

Qualification Test Plan
Specification: EN 4854
Kamatics P/N: KSC640700FS

ASD-CERT
Certification of Aerospace Standard Products
OEM Auditor Stamp
No 0052
Volker Müncheberg
Signature : ..... Date : 28.08.19

Prepared by:

Basili Tyropolis | Engineering Supervisor

Date:
August 9th, 2019

REVISIONS

Revision Level	Details	Date	Initials
Initial		8/28/19	BJT

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1.0 INTRODUCTION

This report describes the EN 4854-3 spherical qualification test procedures for the EN4854-1(narrow series) and EN4854-2 (wide series) part numbers. This report describes the testing program that will be employed by Kamatics during the qualification of the bearing. This qualification test plan (QTP) procedure contains all of the information necessary for qualifying the parts mentioned to the EN 4854 specification.

2.0 TEST OVERVIEW AND INSPECTIONS

2.1 PART NUMBERS TO BE QUALIFIED

The following part numbers are to be qualified. These parts shall be produced and the inspections described in section 2.2 along with testing defined in section 3.0 shall be repeated for each part number in table 1.

Kamatics P/N	EN Reference
KSC640700FS-04W	EN4854-2S04*
KSC640700FS-04N	EN4854-1S04*
KSC640700FS-05N	EN4854-1S05*
KSC640700FS-06W	EN4854-2S06*

**P/N does not designate a finish code, plating on the outer race has been omitted. Outer race plating will have no impact on qualification*

Table 1, Part Number to be Qualified

2.2 QUALIFICATION INSPECTIONS

Table 2 states requirements for inspections of qualification product while subsections with section 2.2 state the requirements for each individual inspection.

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Type of inspections and tests[a]		Defined in subclause	Serial number of samples													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
Materials		2.2.1	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dimensions and tolerances		2.2.2	X	X	X	X	X									
Masses		2.2.3	X	X	X	X	X									
Marking		2.2.4	X	X	X	X	X									
Surface appearance		2.2.5	X	X	X	X	X									
Hardness		2.2.6	X	X												
Surface roughness[b]		2.2.7	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Surface treatment		2.2.8	X	X	X	X	X									
Behavior in rotation and tilt		2.2.9	X	X	X	X	X									
Internal clearances (radial and axial)		2.2.9	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Starting torque without load	at ambient temperature	2.2.10.1				X	X	X	X	X	X	X	X	X		
	at low temperature[c]	2.2.10.2				X	X	X	X	X	X	X	X	X		
	after limit temperatures[c]	2.2.10.3				X	X	X	X	X	X	X	X	X		

a The order is left to the initiative of the qualification authority. The tests apply to bearings with or without swaging grooves.

b For samples 6 to 14 only surface roughness of SØK

c This test shall apply to size bearing EN4854-2S04 only

Table 2, Non-Destructive Inspections and Tests to be Carried Out for Qualification

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2.2.1 MATERIALS

Materials shall conform to the product standards or design documentation. Materials shall be verified by using chemical analysis or certificate issued by semi-finished product manufacturer

2.2.2 DIMENSIONS AND TOLERANCES

Dimensions and tolerances shall conform to the product standards or design documentation. Dimensions not shown shall be at manufacturer's option. Suitable calibrated measuring instruments shall be used to verify dimensions and tolerances.

Measurement of bore and outer diameter:

— Rings with a width of < 10 mm: in the center plane;
— Rings with a width of > 10 mm: in two planes parallel to the outer faces and at a distance from these faces of twice the maximum value of the ring chamfer. The minimum and maximum diameters shall be determined in each measuring plane.

Measurement of ring width:

— The width of each ring (distance between the two faces) shall be verified at a minimum of four points.

2.2.3 MASSES

Shall conform to the product standards or design documentation. Verification shall use suitable methods. The approximate mass for each part to be qualified shall be:

Kamatics P/N	Approximate Mass (g)
KSC640700FS-04W	14
KSC640700FS -04N	10
KSC640700FS -05N	14
KSC640700FS - 06W	27

Table 3, Part Masses

A mass greater than 10% of the given value shall be cause for rejection.

2.2.4 MARKING

Shall conform to the product standards or design documentation. It shall be legible and shall not adversely affect the material or the functioning of the bearing. The marking shall be verified via visual examination.

2.2.5 SURFACE APPEARANCE

The bearings shall be free of surface discontinuities liable to have an adverse effect on their characteristics and endurance;

- The liner shall not contain contaminant products and shall not show broken or voided areas;
- Lubrication shall not be permitted.

The ring shall be magnetic particle inspected or fluorescent penetrant inspected prior to assembly. When assembled the assembly shall be visually examined.

2.2.6 HARDNESS

Hardness of the ball and outer race shall be verified using suitable instruments. The hardness shall conform to the product definition.

2.2.7 SURFACE ROUGHNESS

Surface roughness shall be verified by using suitable measuring instruments or visual-tactile samples. Surface roughness shall conform to the product standards or design documentation.

2.2.8 SURFACE TREATMENT

Surface treatment shall conform to the product standards or design documentation. Verification shall be through visual inspection and as per the surface treatment standard.

2.2.9 MOVABILITY AND CLEARANCES

Bearings shall be able to move freely within the angular limits specified in the product standards or design documentation. The internal radial and axial clearances shall conform to the product standards. Clearances shall be verified with a test load of ±13.3 N (±3 lbs).

2.2.10 STARTING TORQUE WITHOUT LOAD

The measurement of the starting torque without load shall be preceded by some rotations and a few turning movements by hand. The torque, applied gradually to the inner ring, shall be measured in both directions with the outer ring held stationary.

2.2.10.1 STARTING TORQUE WITHOUT LOAD AT AMBIENT TEMPERATURE

The starting torque shall be within the limits stated in the table below at ambient temperature when measured at (+25) to (+13) °C.

Code	Nominal diameter *OD (mm)*	EN4854-1	EN4854-2
04	6.350	0.03 max. Nm	0.03 max. Nm
05	7.937		
06	9.525		
a Defined starting torques uninstalled condition or for installation via clearance fit, respectively			

Table 4, Starting Torques

2.2.10.2 STARTING TORQUE WITHOUT LOAD AT LOW TEMPERATURE

This test will only be done to part number EN4854-1S04 (Kamatics P/N KSC640700FS-04N). The part shall be subjected to four hours of temperature in the range -65 °C to -50 °C. Either in situ or immediately after the parts are removed from the environmental chamber, they shall be checked for no load breakaway torque. The torque shall not be greater two times that listed in table 4.

2.2.10.3 STARTING TORQUE WITHOUT LOAD AT AFTER LIMIT TEMPERATURES

This test will only be done to part number EN4854-1S04 (Kamatics P/N KSC640700FS-04N). The part shall be subjected to one hour at the temperature range of -65 °C to -50 °C followed by one hour at the range of +95 °C to 80 °C. The temperature limits shall be repeated 10 times. Within four hours of having the limit temperatures applied the no load breakaway torque shall be measured at ambient temperature. The torque shall comply with that listed in table 4.

3.0 DESTRUCTIVE TESTING

Table 5 defines all the destructive tests and inspections to be carried out along with the quantity to be tested.

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Type of inspections and tests[a]			Defined in subclause	Serial number of samples													
				1	2	3	4	5	6	7	8	9	10	11	12	13	14
Conformity of ball and race	Normal conformity		3.1.1													X	
	Circumferential conformity		3.1.2														X
Under static load	Radial	Permissible *(C$_r$)*	3.2.1	X	X												
		Ultimate	3.2.1	X	X												
	Axial	Permissible (C_a)	3.2.2			X											
		Ultimate	3.2.2			X											
Dynamic radial loads at various environmental conditions		100 % C_{dyn}	3.3				X										
		50 % C_{dyn}						X									
		5 MPa							X	X							
		3 MPa									X	X					
		1 MPa											X	X			
Friction coefficient			3.3				X	X	X	X	X	X	X	X			
Peel strength[b]			NA														
Bond integrity			3.3				X		X		X		X		X		

a The order is left to the initiative of the qualification authority. The tests apply to bearings with or without swaging grooves.

b The liner to be qualified is not peelable and therefore only bond integrity testing applies

Table 5, Destructive Inspections and Tests to be Carried Out For Qualification

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3.1 CONFORMITY OF BALL AND RACE

3.1.1 NORMAL CONFORMITY

Encapsulate the bearing in plastic material as used in metallurgical mounts, to prevent motion of the ball with respect to the race. Section the bearing following a diameter plane normal to the race side and polish the surfaces (see Figure 1).

By use of an optical comparator or another accurate technique, measure dimension "t" radially from the ball to the race on both opposite surfaces at a minimum of five uniformly spaced positions across the bearing (see Figure 1). The selected points shall include the center position of the race as well as both the C/10 positions. Difference between the values measured radially from the center of the bore shall not exceed 0.08mm.

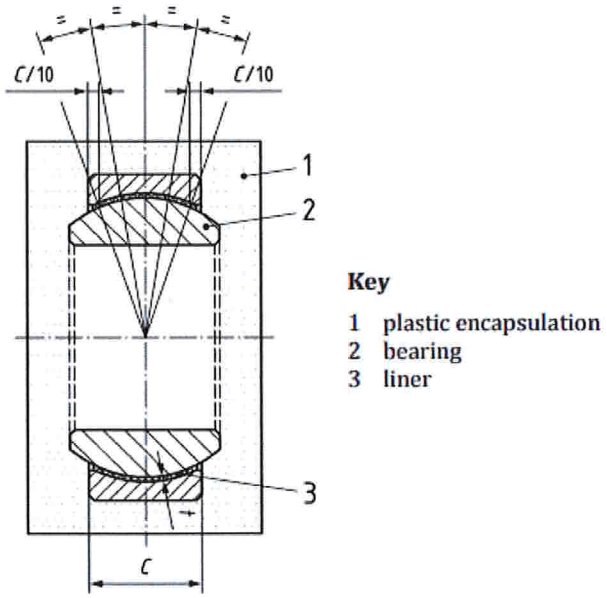


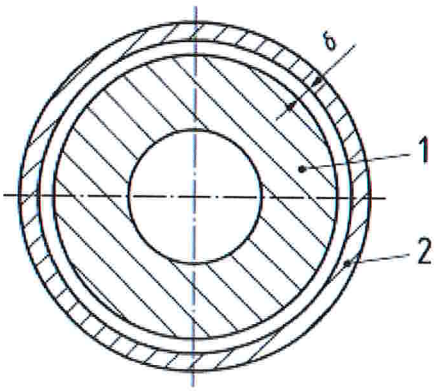
Figure 1, Normal Conformity

3.1.2 CIRCUMFERENTIAL CONFORMITY

Bearings with injected/moulded liners shall be encapsulated in plastic material as used in metallurgical mounts, to prevent motion of the ball with respect to

the race. Section the bearing along the diameter described by the centerline of the race width and polish the surfaces (Figure 2)

By use of an optical comparator or another accurate technique, measure dimension "8' radially from the center of the bore at a minimum of eight uniformly spaced positions. Difference between the values measured radially from the center of the bore shall not exceed 0.08 mm.



Key

1 ball
2 outer ring (race)

Figure 2, Circumferential Conformity

3.2 STATIC TESTING

3.2.1 STATIC RADIAL TESTING

The Cs static radial load and 1.5* C_s radial ultimate load for each test bearing is as follows:

Kamatics P/N	C_s Load (kN)	1.5 * C_s Load (kN)
KSC640700FS-04W	24.52	36.78
KSC640700FS -04N	22.15	33.23
KSC640700FS -05N	29.13	43.70
KSC640700FS -06W	55.03	82.55

Table 6, Radial Static Loads

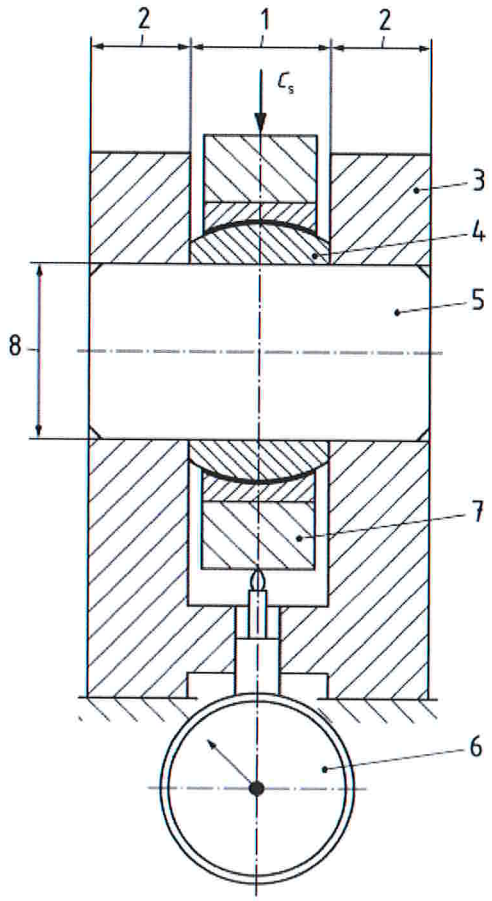
The procedure shall be as follows:

1. Mount the bearing similar to that shown in Figure 3;
2. Apply a radial pre-load equal to 5 % of C_s for 3 min;
3. Set the dial gauge to zero;

4. Continuously increase this pre-load (1 % per s) until Cs is obtained;
5. Maintain load C_s for 3 min;
6. Record the value of the total deformation indicated by the dial gauge;
7. Reduce the load continuously (1 % per s) to the pre-load value;
8. Record the value of the permanent deformation indicated by the dial gauge;
9. Remove the pre-load. Check the bearing considering the passing criteria below.
10. Apply a radial load of 1,5 C_s by increasing the load at a rate of 1 % per s.
11. Maintain the load 1,5 C_s for 1 min.
12. Remove the load continuously at a rate of 1 % per s. Check the bearing considering the passing criteria below.

The test shall have been considered passed if the following criteria are met:

- Permissible radial static load C_s:
  - The maximum deflection under the Cs load shall be 0.203 mm maximum
  - The maximum permanent deformation after load shall be 0.051mm maximum
- Ultimate radial static load (1.5 x C_s): After the removal of the loads, there shall be no cracks, no push out of the inner ring or deterioration of the bearing.



Key

1 width of bearing inner ring +0,10
2 H min. = Ø spherical part −Ød
3 frame 40 HRC min.
4 bearing with self-lubricating liner
5 pin in steel 50 HRC min.
6 dial gauge or similar device
7 test ring 50 HRC min., outer dia. ≥ 2 x bearing outer dia.
8 clearance range $^{+0,025}_{0}$

Figure 3, Radial Static Test Setup Principle Used for Qualification

3.2.2 STATIC AXIAL TESTING

The Ca static axial load and 1.5* C_a axial ultimate load for each test bearing is as follows:

Kamatics P/N	C_a Load (kN)	1.5*C_a Load (kN)
KSC640700FS-04W	5.15	7.73
KSC640700FS-04N	2.55	3.83
KSC640700FS-05N	3.49	5.24
KSC640700FS-06W	8.33	12.50

Table 7, Axial Static Loads

The procedure shall be as follows:

1. Mount the bearing similar to that shown in Figure 4 ;

2. Apply an axial pre-load equal to 5 % of C_a for 3 min;
3. Set the dial gauge to zero;
4. Continuously increase this pre-load (1 % per s) until C_a is obtained;
5. Maintain load C_a for 3 min;
6. Reduce the load continuously (1 % per s) to the pre-load value;
7. Record the value of the permanent deformation indicated by the dial gauge;
8. Remove the pre-load;
9. Repeat steps 2 through 9 after rotating one ring 180° (in plane) in relation to the other. Check the bearing according to the passing criteria below.
10. Apply an axial load of 1,5 C_a by increasing the load at a rate of 1 % per s.
11. Maintain the load 1,5 C_a for 1 min.
12. Remove the load continuously at a rate of 1 % per s. Check the bearing according to the passing criteria below.

The test shall have been considered passed if the following criteria are met:

- Permissible axial load C_a: The maximum permanent deformation after load shall be 0.102mm maximum
- Ultimate axial static load (1.5 x C_a): After the removal of the loads, there shall be no cracks, no push out of the inner ring or deterioration of the bearing.

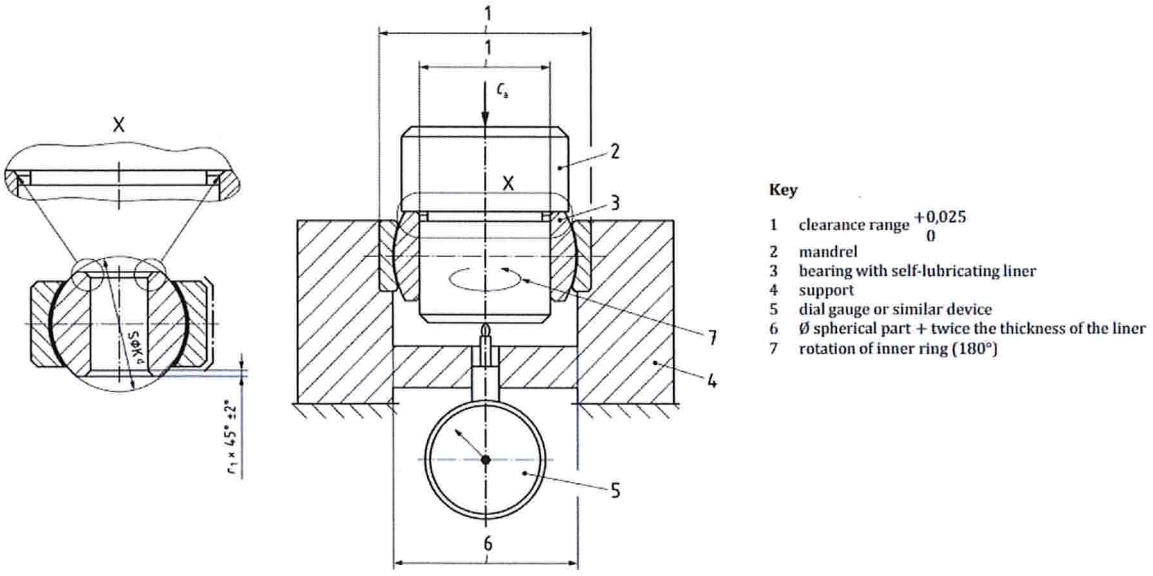


Figure 4, Axial Static Test Setup Principle Used for Qualification

3.3 DYNAMIC RADIAL LOADS

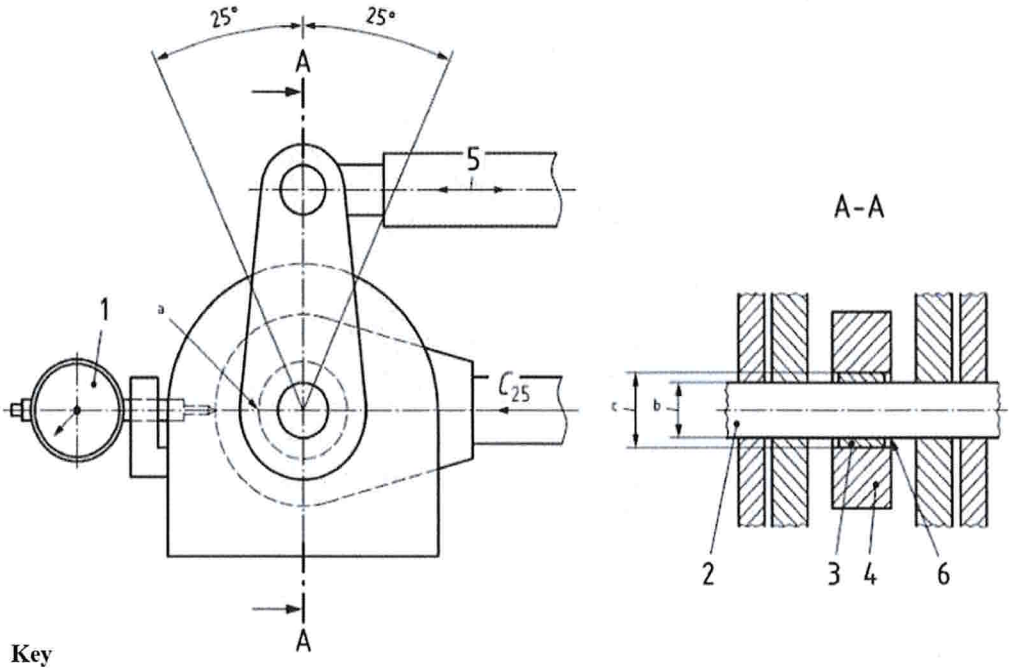
This section is subdivided into four sections including test setup, test procedure, friction, bond integrity and pass/fail criteria.

3.3.1 TEST SETUP

The test setup shall be similar to that shown below. The bearing shall be rotated +/-25° for each cycle. The dynamic load of C_{dyn} shall be applied as a constant load in the radial direction. The load for each part number is as follows:

Bearing Pressure (MPa)	KSC640700FS-04W Load (kN)	KSC640700FS-04N Load (kN)	KSC640700FS-05N Load (kN)	KSC640700FS-06W Load (kN)
1	0.09	0.06	0.08	0.15
3	0.27	0.18	0.24	0.45
5	0.45	0.30	0.39	0.74
60	5.35	3.55	4.66	8.81
120	10.70	7.09	9.32	17.61

Table 8, Dynamic Loads



Key

1 dial gauge or similar device
2 pin in steel 50 HRC min.
3 bearing with self-lubricating liner installed into the bearing support considering clearance fit or in case of a stake bearing a transition fit.
4 bearing support
5 power unit
6 The contamination shall be sprayed on the face of the bearing at the liner gap.

a location of the temperature gauge

b pin diameter = d nominal diameter $^{+0.010}_{-0.025}$

c support diameter = D nominal diameter considering clearance fit or transition fit (refers to key note 3)

Figure 5a, Dynamic Test Setup Principle Used for Qualification

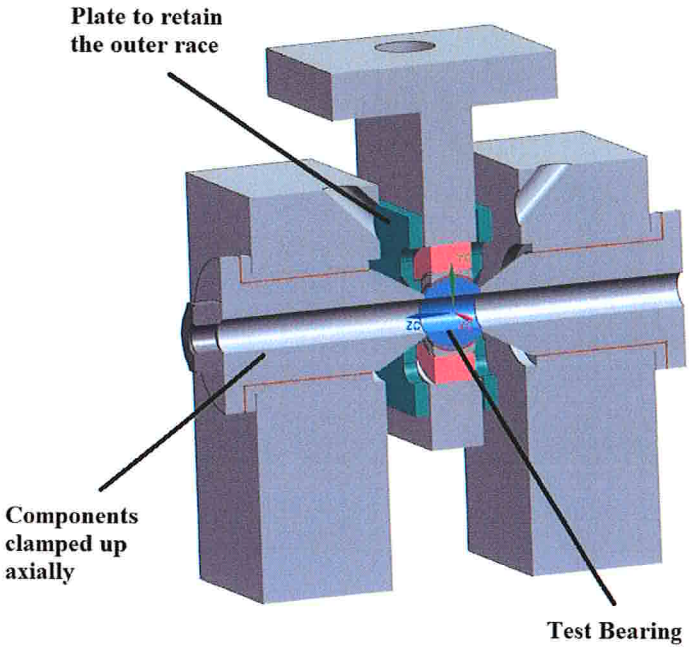


Figure 5b, Dynamic Test Setup Retention

3.3.2 TEST PROCEDURE

Prior to and after testing the coefficient of friction shall be measured according to section 3.3.3. The surface finish of the ball shall be measured for reference prior to and after the test. Following the initial measurements the bearing shall be installed in a fixture similar to that shown in Figure 5. The test parameters are as follows:

Number of cycles: 200 000
Rate: (12 ± 2) cycles/min
Test loads: 100 %, 50% of load Cdyn, 5 MPa, 3MPa, 1MPa

The 200 000 cycles shall be broken up into 4X 50000 cycle test blocks. Each of the 4 test blocks shall undergo the sequences included in the table below:

Step	Environmental condition	Operating cycle		Test method
		Start	End	
1	**Ambient temperature**	0	5.000	• Permissible temperature range: $23° {}^{+2}_{-10}$ °C • Number of cycles to be performed: 5.000
2	**Salt laden atmosphere**			Increase and maintain the temperature to +35° ± 3°C;
a)				The bearing shall be contaminated with the salt solution (20ml) using a suitable manual sprayer with a fine nozzle (see figure 5a). Exposure time: 10 minutes
b)				Followed by this the bearing shall be dried using no air flow, usage of heating elements are acceptable in static air only.
c)				Repeat step a and b for one time
3	**High operating temperature (+ 70°C)** [a]	-	-	-
a)				Increase and maintain the temperature to $+ 70° {}^{+10}_{-5}$ °C
b)		5.001	9.500	Number of cycles to be performed: 4.500
c)				Decrease the temperature back to an ambient temperature range of $23° {}^{+2}_{-10}$ °C
4	**Phosphate ester based hydraulic fluid**			The bearing shall be contaminated with the phosphate ester based hydraulic fluid (10ml) using a suitable manual sprayer with a with fine nozzle (see figure 5a). Exposure time: 10 minutes
5	**Ambient temperature**	9.501	12.500	• Permissible temperature range: $23° {}^{+2}_{-10}$ °C • Number of cycles to be performed: 3.000
6	**Fuel for turbine engines**			The bearing shall be contaminated with fuel for turbine engines (10ml) using a suitable manual sprayer with a with fine nozzle (see figure 5a). Exposure time: 10 minutes
7	**Ambient temperature**	12.501	15.500	• Permissible temperature range: $23° {}^{+2}_{-10}$ °C • Number of cycles to be performed: 3.000
8	**Silicon Fluid Wacker AK 10**			The bearing shall be contaminated with Silicon Fluid Wacker AK 10 (10ml) using a suitable manual sprayer with a with fine nozzle (see figure 5a). Exposure time: 10 minutes
9	**Ambient temperature**	15.501	18.500	• Permissible temperature range: $23° {}^{+2}_{-10}$ °C • Number of cycles to be performed: 3.000
10	**Cleaning agent**			The bearing shall be contaminated with 96 % denatured isopropyl alcohol (10ml) using a suitable manual sprayer with a with fine nozzle (see figure 5a). Exposure time: 10 minutes

Table 9, Duty Cycle Environment: Started

Step	Environmental condition	Operating cycle		
		Start	End	
11	**Low operating temperature (-55°C)** [b]	-	-	-
a)				Decrease and maintain the temperature to $-55^{\circ}{}^{+5}_{-10}$ °C
b)		18.501	18.750	Number of cycles to be performed: 250
c)				Increase and maintain the temperature to $-20^{\circ}{}^{+2}_{-5}$ °C
12	**De-icing / Anti-icing fluid**			The bearing shall be contaminated with de-icing / anti-icing fluid ISO (SAE) Type II (10ml) using a suitable manual sprayer with a with fine nozzle (see figure 5a). Exposure time: 10 minutes
13	**Low operating temperature (-20°C)** [b]	-	-	-
a)		18.751	22.500	Number of cycles to be performed: 3.750
b)				Increase the temperature back to an ambient temperature range of $+23^{\circ}{}^{+2}_{-10}$ °C
14	**Ambient temperature**	22.501	27.500	Repeat step 1
15	**Salt laden atmosphere**			Repeat step 2
16	**High operating temperature** [a]	27.501	32.000	Repeat step 3
17	**Mineral fluid for hydraulic transmission**			The bearing shall be contaminated with mineral fluid for hydraulic transmission (10ml) using a suitable manual sprayer with a with fine nozzle (see figure 5a). Exposure time: 10 minutes
18	**Ambient temperature**	32.001	35.000	Repeat step 5
19	**Fuel for turbine engines**			Repeat step 6
20	**Ambient temperature**	35.001	38.000	Repeat step 7
21	**Silicon Fluid Wacker AK 10**			Repeat step 8
22	**Ambient temperature**	38.001	41.000	Repeat step 9
23	**Cleaning agent**			Repeat step 10
24	**Low operating temperature (-55°C)** [b]	41.001	41.250	Repeat step 11
25	**De-icing / Anti-icing fluid**			Repeat step 12
26	**Low operating temperature (-20°C)** [b]	41.251	45.000	Repeat step 13
27	**Ambient temperature**	45.001	50.000	Repeat step 1

[a] Heating due to friction could be balanced by adjusting the heating source

[b] The temperature of the specimen may change during the test sequence. In case of a temperatures out of the stated tolerances, the test shall be stopped and the operating temperature readjusted.

Table 9, Duty Cycle Environment: Concluded

The definitions of the fluids used during testing are as follows:

1. Fluid for De-icing circuit / Cleaning agent

Nature:	96 % denatured isopropyl alcohol
Density at 15°C, max.:	0,0806 g/cm^3
Distillation:	90 % distilled between 80°C and 90°C
Final distillation point, max.:	123°C

2. De-icing and anti-icing fluids

ISO (SAE) Type II (glycol base) according to ISO 11708 (AMS1428)

3. Mineral fluid for hydraulic transmission

Mineral fluid according to MIL-PRF-87257B

4. Phosphate ester hydraulic fluid

Low density LD Type IV according to NSA 307110

5. Fuel for turbine engine

Jet Fuel A-1 according to ASTM D1655

6. Silicon fluid Wacker AK 10

Density at 25°C, max.:	approx. 0,93 g/cm^3
Flash point:	180°C
Ignition temperature (liquids):	365°C
Kinematic viscosity, at 25°C.:	approx. 10 mm^2/s

7. Salt laden atmosphere

The salt shall be sodium chloride containing on the dry basis not more than 0,1 percent sodium iodide and not more than 0,5 percent of total impurities. A five ± 1 percent solution shall be prepared by dissolving five parts by weight of salt in 95 parts by weight of distilled or demineralised water. The solution shall be adjusted to and maintained at a relative density between the limits shown in the Figure 4 below by utilizing the measured temperature and density of the salt solution.

The pH of the salt solution shall be maintained so that the solution at 35 degrees will be in the pH range of 6.5 to 7.2. Only diluted chemically pure hydrochloric acid or chemically pure sodium hydroxide shall be

used to adjust the pH. The pH shall be measured before each contamination phase and if necessary new adjusted.

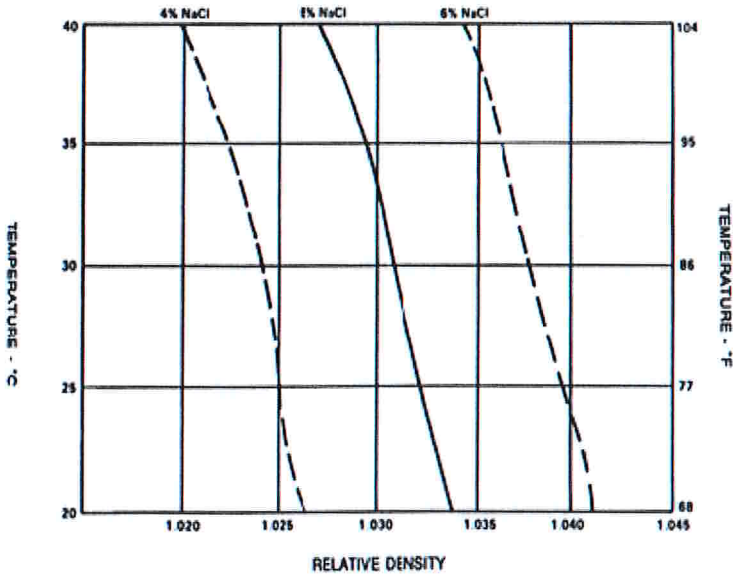


Figure 6, Salt Solution Relative Density

3.3.3 FRICTION MEASUREMENT

The friction measurement shall be done in the housing used during dynamic testing. The remaining fixtures may be substituted to better isolate bearing friction. As needed a tare measurement may be taken to adjust the friction measurement.

For each temperature and each surface pressure level three single torque measurements must be taken before and after the completion of the duty cycles. The friction coefficient shall be taken at the following temperatures intervals:

Temperature Interval	Temp °C	
	Low	High
1	+ 65	+ 80
2	+ 13	+ 25
3	- 15	- 10
4	- 35	- 27
5	- 65	- 50

Table 10, Required Temperature Intervals

For each temperature interval the CoF shall be measured at the following bearing pressures with the associated loads:

Bearing Pressure (MPa)	KSC640700FS-04W Load (kN)	KSC640700FS-04N Load (kN)	KSC640700FS-05N Load (kN)	KSC640700FS-06W Load (kN)
1	0.09	0.06	0.08	0.15
3	0.27	0.18	0.24	0.45
5	0.45	0.30	0.39	0.74
60	5.35	3.55	4.66	8.81
120	10.70	7.09	9.32	17.61

Table 11, CoF Loading

3.3.4 BOND INTEGRITY

Following testing test pieces as specified in table 5. For non-peelable liners, a sectioned bearing shall be examined for bond integrity. The liner shall adhere tightly to the outer ring over at least 90 % of the contact area.

No void shall be allowed which cannot be circumscribed within a circle of diameter equal to:

-25 % of outer ring width;
-6 mm;
whichever is smaller.

3.3.5 PASS/FAIL CRITERIA

The pass fail criteria for dynamic testing shall be as follows:

-No metal-to-metal contact between inner and outer ring;

-The liner wear shall not exceed 0.15mm;

-Bond integrity shall be as stated in section 3.3.4.

-The inner race shall show no signs of damage and the surface finish should not have deteriorated. Inner ring surface finish should be measured before and after dynamic testing;

-The friction coefficient measured shall meet the limits stated in the table below:

Temperature (°C)	Max. Friction Coefficient at Test Start (μ)	Max. Friction coefficient after Duty Cycles (μ)
ambient	0,08	0,14
+ 70	0,10	0,18
- 55 to -10	0,18	0,18

Table 12, CoF Limits

4.0 TEST REPORT

Upon the completion of testing, a test report shall be generated to disclose the results of the testing.

PLEASE NOTE: THE TEST PLAN CAN'T BE EXECUTED WITHOUT APPROVAL FROM THE QUALIFICATION AUTHORITY