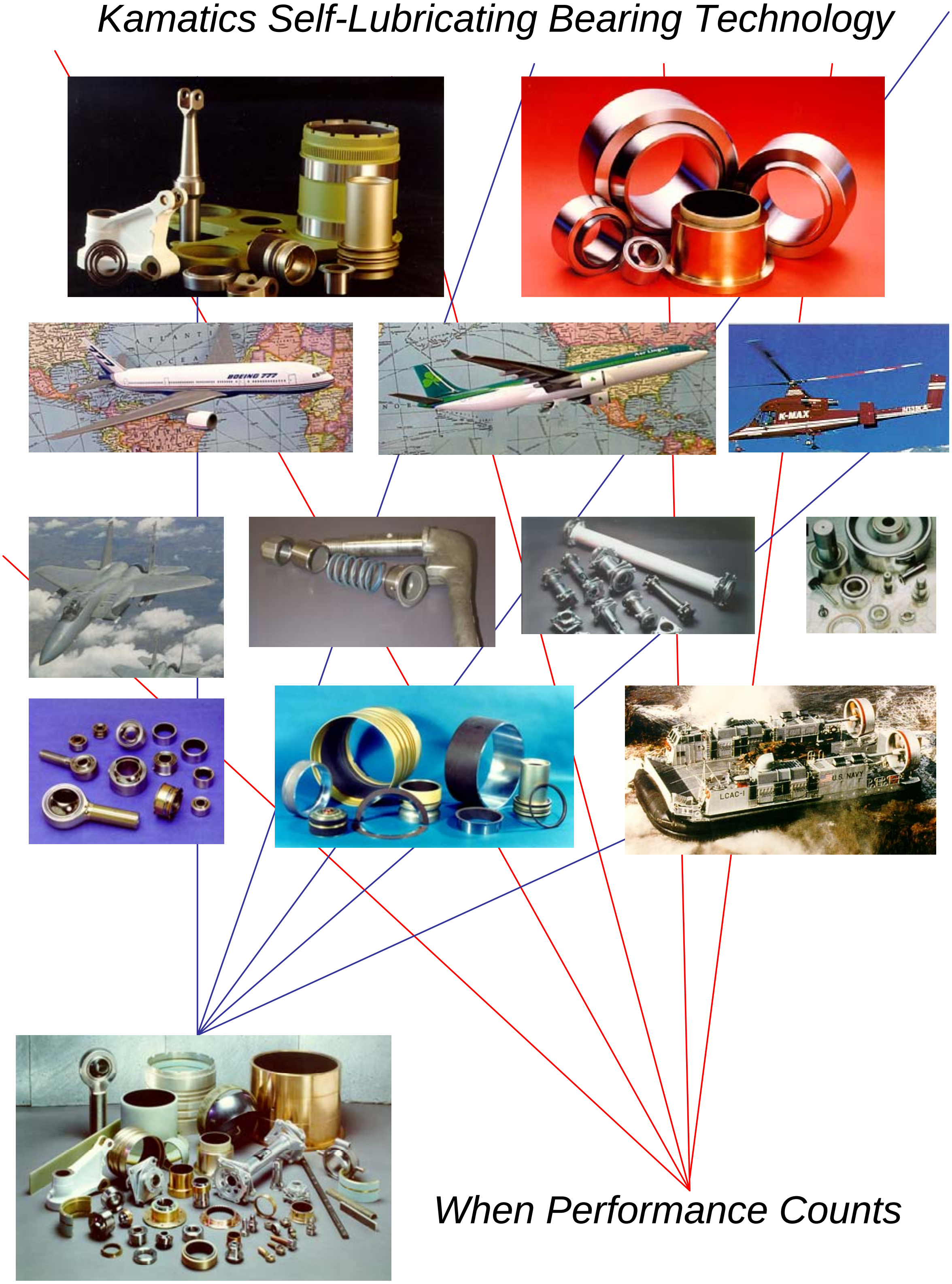
Kamatics Self-Lubricating Bearing Technology



When Performance Counts

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Kamatics Self-Lubricating Bearing Technology
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An Overview of Kamatics Products including KAron, KAtherm, KAflex & Composite Systems

Kamatics Corporation manufactures self-lubricating bearing systems that can be used at temperatures ranging from cryogenic to 1200 F (635 C). KAron is used for temperatures to 400 F (204 C). KAtherm is used for temperatures to 600 F (315 C), and KAcarb for temperatures to 1200 F (635 C). Kamatics also produces various Composite Materials for use as wear pads, anti-fretting barriers, and other applications requiring low friction and long life.

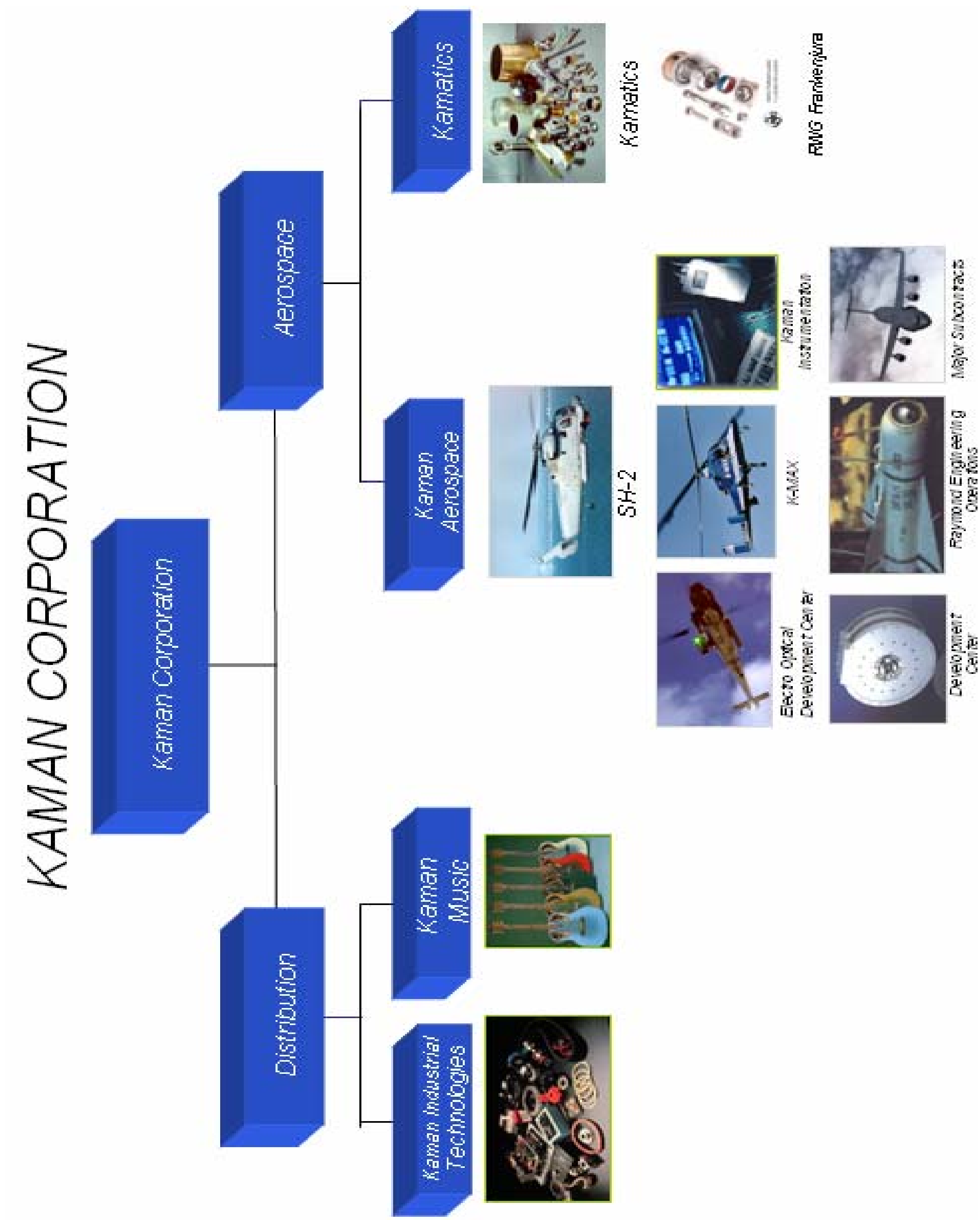
KAron is a combination of thermosetting resin and filler materials in particle or fiber form. This differs significantly from other self-lubricating materials in that there are no continuous interconnecting fibers or weave that can provide a moisture path to the bonding substrate. A moisture path may either promote corrosion under the liner or significant liner swelling when used in a moisture-laden or other liquid environment.

KAron liner systems are homogenous in nature, a mixture of resin, polytetrafluoroethylene (PTFE), and other special fillers. Because of this, consistent friction and extremely low, linear, rates of wear can be expected throughout the life of the liner. Other "self-lube" materials are generally made up of a fabric blanket with various strata of PTFE, fiberglass, nylon, resin, etc. and therefore constant performance cannot be anticipated throughout its thickness.

Characteristics considered in the formulation of KAron liners include load carrying capability, operating temperature, coefficient of friction, sliding/rubbing velocities or any combination of these.

See the KAflex section for a full description of the unique design that is providing high torque and misalignment for thousands of drive shafts in aerospace and commercial applications.

See "Kamatics KAron Design Guide" for a more complete description of KAron, its application and uses.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Kamatics KAron Design Guide Cover Sheet

Refer to the "Kamatics KAron Design Guide" for additional information pertaining to the design, use and installation of KAron lined bearing components.

KAMATICS KARON® Design Guide

KAMATICS Corporation,
1330 Blue Hills Avenue
Bloomfield, Connecticut 06002
Phone 860 243-9704, Fax 860 243-7993

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Rev E, 03/04/05

Kamatics KAron Bearing Catalog Cover Sheet for Spherical, Rod End and Journal Sleeve Bearings

Refer to the "Kamatics KAron Bearing Catalog - Spherical, Rod End and Journal Sleeve Bearings" for additional information pertaining to the types and sizes of readily available spherical and journal bearings, along with load ratings.

KAMATICS KARON BEARING CATALOG
SPHERICAL, ROD END AND JOURNAL SLEEVE BEARINGS

KAMATICS CORPORATION
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Bloomfield, CT USA 06002
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Rev D 11/06/03

Kamatics "KRP" Catalog Cover Sheet for Track Rollers, Cam Followers and Airframe Pivot Bearings

Refer to the Kamatics "KRP' Catalog for Track Rollers, Cam Followers and Airframe Pivot Bearings" for additional information pertaining to the types and sizes of readily available track rollers, cam followers and airframe pivot bearings along with load ratings.

KAMATICS "KRP" CATALOG
TRACK ROLLERS, CAM FOLLOWERS, AIRFRAME PIVOT BEARINGS

KAMATICS CORPORATION
P. O. Box 3 (1330 Blue Hills Avenue)
Bloomfield, CT USA 06002
860-243-9704, fax 860 243-7993

Rev D May 5, 2004
Affected Pages: 13,14,28,29

KAron Systems

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3	KAron and KAtherm Liner Designations
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8	KAron M Material Data Sheet
9	KAron V Material Data Sheet
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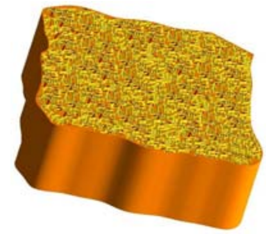


General Characteristics of KAron

KAron liner systems are homogenous mixtures of a resin, polytetrafluoroethylene (PTFE) and other special fillers. Because of this, consistent friction and extremely low, linear, rates of wear can be expected throughout the life of the liner.

Characteristics considered in the formulation of KAron include load carrying capability, operating temperature, coefficient of friction, sliding/rubbing velocities or any combination of these. The operating conditions and parameters vary widely. For example:

•Temperature ranges from cryogenic to over 400° F (205° C).
•Static contact pressures in excess of 100,000 psi (690 mPa).
•Short term operating velocities of 100 feet/minute (30 meters/min) or higher.
•Liner thickness up to 0.060 in. (1.5 mm).
•Operation with contaminates such as oil, grease, sand, grit, deicer, hydraulic fluid and cleaning fluids, and others.
•Requirement to adhere to various materials including stainless and carbon steels, titanium, copper, nickel and aluminum alloys, fiberglass, carbon fiber and others.
The need to operate against various materials, hardness, and surface finishes.

KAron has definite thickness associated with it. It is not a thin "film lubricant" that can be applied after final machining without affecting dimensions. Therefore, space must be provided for the liner when designing components that will include KAron. Liner thicknesses normally range between 0.010 to 0.015 inches (0.25 to 0.38mm). Liner thickness is also a function of the amount of wear or clearance a system can tolerate and continue to operate as intended. For applications where clearance is not an issue, the liner thickness can be increased.

See the "Kamatics KAron Design Guide" for additional information.

KAron and KAtherm Liner Designations

Liner	Approximate Physical Properties	Characteristics	Typical Applications
KAron B High Load	Density – 1.51 gm/cc Hardness Rockwell M 95 Thickness Range .005 - .060” (.127 – 1.5 mm)	Dynamic Operating Pressures to 50,000 psi (345 MPa). Velocities to 3 fpm (1 M/min.) Temp Range –100° to 400° F (-73° to >205°C) SAE AS81820 & SAE AS81934 Qualified	Aircraft controls, landing gears etc. Highly loaded linkages. Jet engine controls. Other high loaded demanding, maintenance free applications.
KAron V High Load / Low Friction	Density – 1.36 gm/cc Hardness Rockwell M 85 Thickness Range .005 - .060” (.127 – 1.5 mm)	Dynamic Operating Pressures to 40,000 psi (276 MPa). Velocities to 10 fpm (3 M/min.) Temp Range –100° to 300° F (-73° to 150°C) Mil-B-8943 Qualified	Track rollers. Cam followers. Marine/naval applications. Aircraft shock struts. Other high loaded, low friction applications.
KAron F Low Friction	Density – 1.36 gm/cc Hardness Rockwell M 85 Thickness Range .003” – min. (.076 mm min.)	Rubbing surface is a predominately PTFE enriched outer surface, providing low coefficient of friction at low loads and at low temperatures. The general operating parameters are the same as KAron V. A minimum thickness liner of .003” (.076 mm) can be obtained.	Spherical bearings Track rollers. Cam followers Other moderately high loaded, low friction applications
KAron VS Low Friction	Density – 1.56 gm/cc Hardness Rockwell 15X 88 Thickness Range .005 - .060” (.127 – 1.5 mm)	Dynamic Operating Pressures up to 15,000 psi (103MPa), excellent low temperature friction capabilities. Temp Range –100° to 300° F (-73° to 150°C)	Spherical bearings Track rollers. Cam followers Other moderate loaded, low friction applications
KAron SP Ductile	Density – 1.44 gm/cc Hardness Rockwell 15X 77 Thickness Range .005 - .060” (.127 – 1.5 mm)	Dynamic Operating Pressures up to 25,000 psi (145MPa), excellent low temperature friction capabilities. Temp Range –100° to 250° F (-73° to 121°C) Designed for Mil-B-8943	Landing gear shock struts. Other applications requiring low friction and low rates of wear along with a degree of ductility to accommodate system deflections.
KAtherm T87S High Speed / Low Friction **500°F (260°C)**	Density – 1.39 gm/cc Hardness Rockwell M 80/90 Thickness Range .005 - .030” (.127 – .75 mm)	Dynamic Operating Pressures to 15,000 psi (103 MPa). Velocities 50 fpm (15 M/min.) Temp Range –100° to 500° F (-73° to 260°C) Designed for SAE AS81819	Formulated for helicopter pitch link, pitch change, lead lag, scissors bearings requiring long life/low wear with very low friction. Also used for commercial/industrial oscillatory and continuous direction applications.
KAtherm T87 High Speed / High Temperature **500°F (260°C)**	Density – 1.37 gm/cc Hardness Rockwell M 80/90 Thickness Range .005 - .030” (.127 – .75 mm)	Dynamic Operating Pressures to 20,000 psi (140 MPa). Velocities to 30 fpm (9 M/min.) Temp Range –100° to 500° F (-73° to 260°C) Designed for SAE AS81819	Formulated for high temperature applications to 500°F (260°C) such as variable guide vane bushings, engine linkages, thrust reverser bearings, engine controls, high temperature cam followers, high speed track rollers, helicopter rotor control bearings, and industrial pulleys.
KAtherm T88 High Speed / High Temperature **600°F (316°C)**	Density – 1.30 gm/cc Hardness Rockwell M 80/90 Thickness Range .005 - .030” (.127 – .75 mm)	Dynamic Operating Pressures to 10,000 psi (70 MPa). Velocities to 30 fpm (9 M/min.) Temp Range –100° to 600° F (-73° to 316°C)	Formulated for high temperature applications to 600°F (316°C) such as VG bushings, engine linkages, thrust reverser, cam followers, track rollers and helicopter rotor control bearing
KAtherm T10 High Load / High Temperature **600°F (316°C)**	Thickness .010” (.254 mm)	Dynamic Operating Pressures to 20,000 psi (140 MPa) Velocities to 30 ft/min (9 M/min) Temp Range –100° to 600° F (-73° to 316°C)	High temperature/high load fabric for applications to 600°F (316°C) such as high temperature cam followers and spherical bearings used in aircraft gas turbine engines, high

KAron Military Qualification Specifications

Type	Specification	Title	QPL Approval
B	MIL-B-81820D*	Bearing, Plain Self-Aligning Self-Lubricating, Low Speed, Oscillation	2 Nov 1979
B	MIL-B-81934** Amendment 2	Bearings, Journal, Plain and Flanged, Self-Lubricating	9 Mar 1978
RP	MIL-B-8943A Amendment 2	Bearings, Journal, Plain and Flanged, TFE Lined	28 Oct 1980
V	MIL-B-8943A Amendment 2	Bearings, Journal, Plain and Flanged, TFE Lined	21 Nov 1980
M	MIL-B-8943 Amendment 3	Bearings, Journal, Plain and Flanged, TFE Lined	20 May 1987
RM	MIL-B-8943 Amendment 3	Bearings, Journal, Plain and Flanged, TFE Lined	18 Nov 1987

** Now AS-81820*

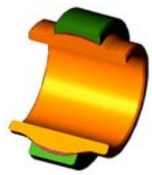
*** Now AS-81934*

Typical Kamatics Bearings

M/M & Lined
Sphericals

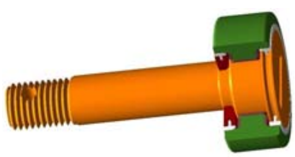
M/M, Lined & Ball
Bearing Rod Ends

M/M & Lined
Straight Journals



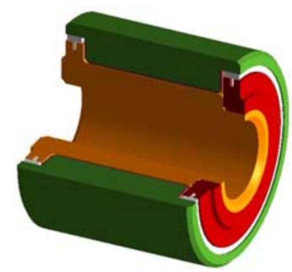
M/M & Lined
Wide Sphericals

M/M & Lined
Flanged Journals



Ball, Needle & Lined
Cam Followers

Ball, Needle & Lined
Narrow Rollers



Ball, Needle & Lined
Wide Rollers

Ball & Lined
Thin Airframe Brgs

Ball & Lined
Self-aligning
Torque Tube Brgs

"Specials"

KAron B Material Data Sheet

Characteristics

A. Nominal liner thickness: .010/.015 in. (.25/.38mm), max: .060 (1.5mm).

B. Operating temperature range: -100°F to +450°F (-73°C to +232°C).

C. Coefficient of friction range: .03 to .10 depending on temperature, pressure, and velocity.

D. Compatible backing substrates: stainless steel, carbon steel, titanium, bronze (all), aluminum, nickel alloys, composites, fiberglass and more.

E. Suggested maximum surface speeds: 3 feet per minute.

Physical Properties

A. Specific gravity: 1.508

B. Density: 1.505 gm/cc

C. Hardness: Rockwell M 90-100

D. Approximate compression modulus: 7x10^{5} psi

Load Carrying Capabilities

A.	*Static ultimate* :*	*120,000 psi (828 mPa)*
B.	*Static limit**:*	*80,000 psi (551 mPa)*
C.	*Dynamic (maximum):*	*50,000 psi (345 mPa)*
D.	*Dynamic (continuous)***:*	*35,000 psi (241 mPa)*

** Equivalent to 1.5 times static limit load. Local liner distress may occur.*

*** Maximum load which will result in a permanent set in the liner no greater than .003 in (.08 mm) after the load is applied for 3 minutes.*

**** .0045 in. (.11 mm) wear after 25,000 cycles of oscillation at +-25 degrees and at 10 cpm.*

Applicable Specifications

MIL-B-81820 - Bearings, plain, self-aligning, self-lubricating, low speed oscillation. Kamatics KR-CNB, KR-CNGB, KR-CWB & KR-CWGB.

MIL-B-81934 – Bearings, sleeve, plain & flanged, self-lubricating. Kamatics KRJ-B & KRJ-UDB

Typical Applications

Airframe controls, flaps, slats, ailerons, etc., industrial applications requiring high load carrying capability and self-lubricating features.

(Reference Kamatics Data Sheet 175)

KAron V Material Data Sheet

Characteristics

A. Nominal liner thickness: .010/.015 in. (.25/.38mm), max: .060 (1.5mm).

B. Operating temperature range: -100 F to +300 F (73° C to +149° C).

C. Coefficient of friction range: .03 to +.08 depending on temperature, pressure, and velocity.

D. Compatible backing substrates: stainless steel, carbon steel, titanium, bronze (all), aluminum, nickel alloys, composites, fiberglass and more.

E. Suggested maximum surface speeds: 3 feet per minute.

Physical Properties

A. Specific gravity: 1.363

B. Density: 1.360 gm/cc

C. Hardness: Rockwell M 85-90

D. Approximate compression modulus: $7x10^{5}$ psi

Load Carrying Capabilities

A.	Static ultimate* :	100,000 psi (690 mPa)
B.	Static limit**:	67,000 psi (462 mPa)
C.	Dynamic (maximum):	40,000 psi (276 mPa)
D.	Dynamic (continuous)***:	30,000 psi (207 mPa)

* Equivalent to 1.5 times static limit load. Local liner distress may occur.

** Maximum load which will result in a permanent set in the liner no greater than .004 in (.10 mm) after the load is applied for 3 minutes.

*** .006 in. (.15 mm) wear after 5,000 cycles of oscillation at +-25 degrees and at 10 cpm.

Applicable Specifications

MIL-B-8943 – Bearings, sleeve, plain & flanged, self-lubricating, TFE lined (MS21240 & MS21241). Kamatics KRJ-V & KRJ-UDV

Typical Applications

Airframe controls, flaps, slats, ailerons, etc., industrial applications requiring high load carrying capability and self-lubricating features. Marine environment, including rudder, pintle and hub bearings as well as hydrofoil and submarine applications.

(Reference Kamatics Data Sheet 174)

KAron VS Material Data Sheet

Characteristics:

Description: A non-peelable, non-fabric, machinable homogeneous mixture of PTFE fibers and a polyester resin system that enable very low friction levels.

A. Nominal liner thickness: .010 to .015 in.(.25 to .38 mm), Max .060 in.(1.52 mm)

B. Operating temperature range: -100° F to +300°F (-73 to +149°C)

C. Coefficient of friction range: .02 to .09, depending upon temperature, pressure, and velocity.

D. Compatible backing substrate materials: stainless steel, carbon steel, titanium, aluminum, nickel alloys, composites.

E. Surface speeds to 10 fpm (3.0 m/min)

Physical Properties:

A.	Density	1.56 gm/cc
B.	Hardness	Rockwell 15X 88
C.	Compression Modulus	3.1 x 105 psi (2,137 MPa)

Typical Load Carrying Capabilities:

A.	Static Ultimate *	80,000 psi (551 MPa)
B.	Static Limit **	50,000 psi (345 MPa)
C.	Dynamic (max.)	25,000 psi (172 MPa)
D.	Dynamic (continuous) ***	15,000 psi (103 MPa)

Notes:

* Equivalent to 1.5 times the static limit load, local liner distress may occur. Typical liner thickness 0.012 in. (0.3 mm).

** Maximum load which will result in a permanent set in the liner no greater than .004 (0.10mm) inches after the load is applied for 3 minutes. Typical liner thickness 0.012 in. (0.3 mm).

*** .006 inches (0.152 mm) maximum permitted wear after 5,000 cycles of oscillation at ± 25o at 10 cpm (MIL-B-8943 requirement). Typical liner thickness 0.012 in. (0.3 mm).

Fluid Compatibility:

Compatible with aircraft hydraulic fluids, lubricating oils, jet fuels, de-icing fluids, cleaning fluids, and water.

Typical Applications:

For bearing applications requiring an extremely low friction level such as flight controls, flap/slat track rollers, landing gear joints and shock strut bearings, fuel control/pumps, and mechanisms.

Reference Kamatics Data Sheet 150

KAron F Material Data Sheet

Characteristics:

Description:

KAron F is a non-peelable, non-fabric, matrix of PTFE fibers and a polyester resin system. KAron F also employs an enriched surface of 100% PTFE that enable very low friction levels.

A. Nominal liner thickness: .010 to .015 in (.25 to .38 mm), Max .032 in.(0.81 mm)

B. Operating temperature range: -100°F to +250°F (-73°C to +121°C)

C. Coefficient of friction range: .02 to .09, depending upon temperature, pressure, and velocity. Example: Ambient Coefficient of friction is approximately 0.03 under 10000 psi (69 MPa) and uncontaminated.

D. Compatible backing substrate materials: stainless steel, carbon steel, titanium, aluminum, nickel alloys, and composites.

E. Surface speeds to 10 fpm (3.0 m/min)

Fluid Compatibility:

Compatible with aircraft hydraulic fluids, lubricating oils, fuel, and cleaning and de-icing fluids and water.

Load Carrying Capabilities:

Static Ultimate ……………………………………………60,000 psi (414 MPa)**

*Static Limit**……………………………………………..40,000 psi (276 MPa)***

Dynamic (maximum)……………………………………30,000 psi (207 MPa)

*Dynamic (continuous)***……………………………….20,000 psi (138 MPa)****

* *Equivalent to 1.5 times static limit load. Local distress may occur.*

** *Maximum load that will result in permanent set less than 0.002 in (0.05mm) after load is applied for 3 minutes.*

*** *65,000 cycles [±25° motion, 20,000 psi (138 MPa) pressure, dry, ambient temperature] for 0.0045 inch (0.11 mm) liner wear.*

Typical Applications:

For bearing applications requiring an extremely low friction level such as flap/slat track rollers, landing gear joints and shock strut bearings, fuel control/pumps, and mechanisms.

Due to its fibrous nature, Kamatics recommends the use of GO/NO-GO ring and plug gauges when measuring KAron F coated parts, as described in ARP 5448/9 Plug Gauging for Plain Bearings

(Reference Kamatics Data Sheet 107).

KAron M Material Data Sheet

Characteristics:

A. Nominal liner thickness: .010/.015 in.(.25/.38 mm), Max: .060 in. (1.5 mm)
B. Operating temperature range: -100° F to +250°F (-73°C to +121°C)
C. Coefficient of friction range: .03 to .08, depending upon temperature, pressure, and velocity.
D. Compatible backing substrate materials: stainless steel, titanium, aluminum, nickel alloys, composites.
E. Surface speeds to 10 fpm

Approximate Physical Properties:

A.	*Density:*	*1.40 gm/cc*
B.	*Hardness:*	*Rockwell 15X 60*
C.	*Compression modulus:*	*250,000 psi.*

Typical Load Carrying Capabilities:

A.	*Static Ultimate *:*	*82,500 psi (569 mPa)*
B.	*Static Limit **:*	*55,000 psi (379 mPa)*
C.	*Dynamic (max.):*	*30,000 psi (207 mPa)*
D.	*Dynamic (continuous)***:*	*25,000 psi*

** = Equivalent to 1.5 times the static limit load, local liner distress may occur. Typical liner thickness 0.012 inches.*

*** = Maximum load which will result in a permanent set in the liner no greater than .004 in. (.10 mm) after the load is applied for 3 minutes. Typical liner thickness 0.012 in. (.30 mm)*

**** = .006 in. (.15 mm) maximum wear after 5,000 cycles of oscillation at ±25° at 10 cpm (MIL-B-8943 specification requirement). Typical liner thickness 0.012 in. (.30 mm)*

Applicable Specifications:

MIL-B-8943, Bearings, Sleeve, Plain and Flanged, TFE lined (MS21240 & MS21241)

Kamatics equivalent p/n = KRJ-M- and KRJ-UDM-.

Typical Applications:

For bearing applications requiring a low rate of liner wear and a degree of ductility to accommodate system deflections such as landing gear shock struts.

(Reference Kamatics Data Sheet 138)

Miscellaneous KAron Testing

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6	*EN (European) Flight Control Bearing Dynamic Wear Test Results*
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8	*EN Flight Control Bearing Limit/Ultimate Load Test Results*
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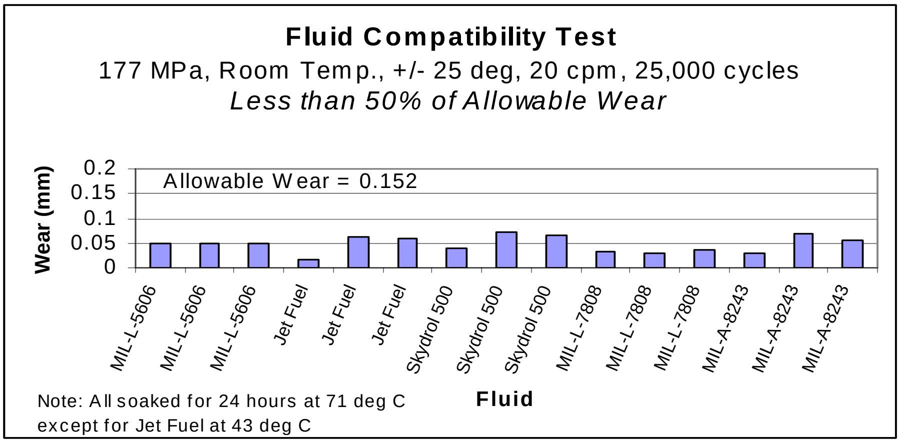
27, 28	*KAron B Grease Contaminated Endurance Test - (MIL-G-23827, MIL-G-81322, and MIL-G-81877)*
29	*KAron V High Temperature Endurance Test , +325° F, 25000 psi Pressure*
30	*KAron V (Spherical Bearing), Endurance Test (Vibration), Aircraft Rudder Control Bearing*
31, 32, 33, 34	*KAron V vs. Al/Ni/Bz Bushing Endurance Test - 300 cpm oscillation coupled with +,-.10” axial Bearing Pressures up to 4750 psi*
35, 36, 37	*KAron B Spherical Bearing Testing (Ref KER-788) -Thrust Reverser Blocker Door - CFM56 Engine*
38	*Conductive Bushing Test (Ref KER-954) - KAron Liner and Kamatics Unique Bearing Design*

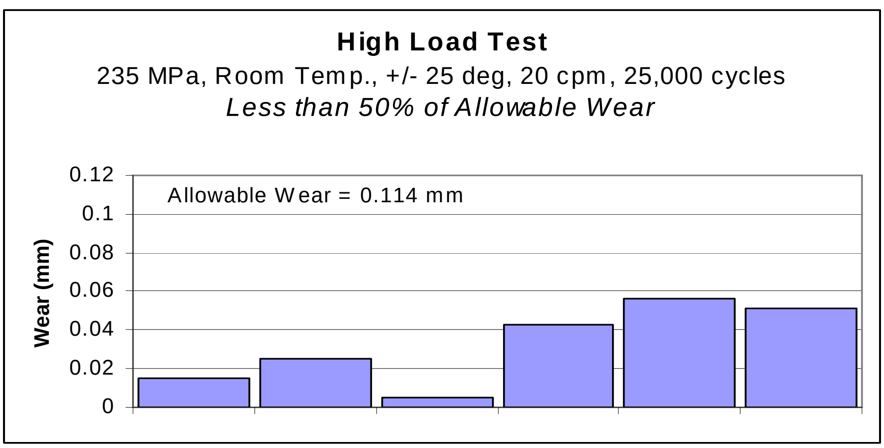
Miscellaneous KAron Testing (Continued)

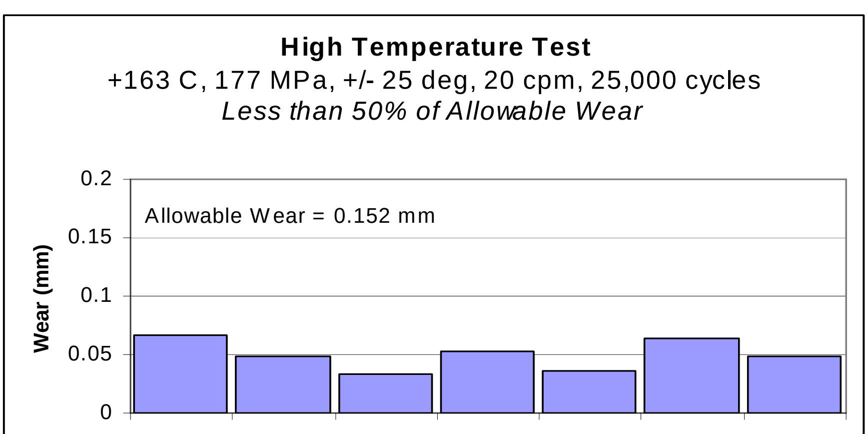
Page	*Description*
39	*Frozen Water Effects on Sealed/unsealed "KRP" Bearings*
40	*Compatibility of Kamatics self-lubricating liners with Low-Density Skydrol 5 (Ref KER-916)*
41	*KR10-CNB Spherical Bearing Axial Static Load Test - (Ref KER-872)*
42	*Copy of USDA KAron V Approval Letter - (Dated July 19, 1989)*
43	*KAron B Fluid Contamination - Endurance Testing*
44	*KAron V Fluid Contamination - Endurance Testing*
45	*KAron VS Fluid Contamination - Endurance Testing*
46	*KAron Wear Strip Edge Loaded Vibration Endurance Test*
47	*KAron V High Speed Bushing Endurance Test*
48	*KAron B & V Rudder Hinge Test*
49	*KAron B High Speed Vibration Testing – Spherical Bearing*
50, 51	*KAron B Impact Loading Evaluation - Naval Aircraft Arrestor Hook Application*
52	*KAron VS Flight Control Actuator Pins*
53	*KAron B – Hydraulic Fluid Endurance Test (MIL-H-83282A)*
54	*KAron B – Hydraulic Fluid Endurance Test (MIL-H-5606)*
55	*KAron B & V Operating Against Uncoated Titanium - Endurance Test*
56	*KAron V Operating Against Uncoated 316 Stainless Steel, 32 RMS Surface Finish - Endurance Test*

SAE AS 81820 Test Results – KAron B

All Test Results - Less Than 50% of Allowable Wear







Recent Kamatics Test Results

- *EN 4540 Airbus Flight Control Specification…*
- *A320 Aileron Servocontrol…*
- *EF2000 Typhoon Inboard Flaperon…*

Kamatics worked with its customers to develop a superior self-lube primary flight control actuator bearing.

Design goals were to address current problems seen in competing bearings.

Specifically:

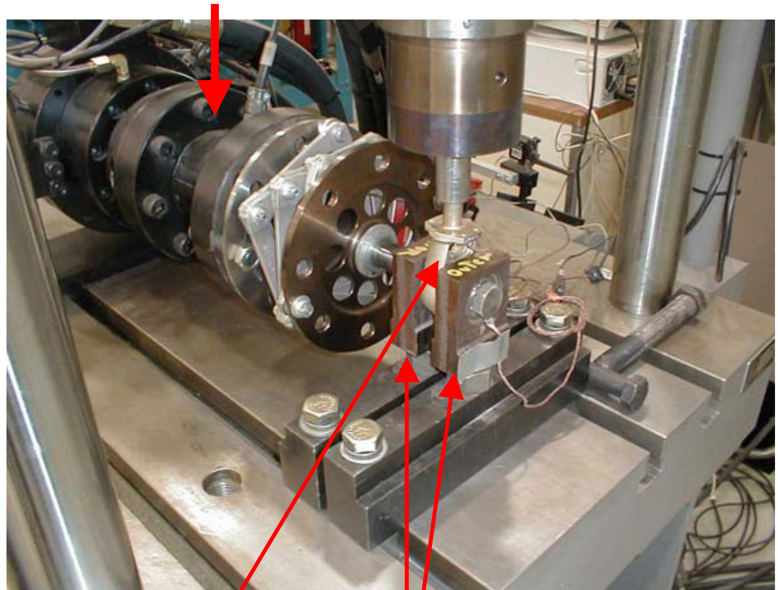
Designed to have very low friction for smaller actuator/structure size – WEIGHT SAVINGS

Very low wear rates – most aircraft are sensitive to bearing backlash

Fluid resistance – to eliminate torque changes seen in competing self lubricating bearings

Kamatics Primary Flight Control Actuator Bearing Program

Kamatics State-of-the-Art Test Equipment



- MTS Test Equipment Investment $0.25 Million US

- Purchased specifically for development and testing of flight control bearing systems

- Computer Controlled Test Spectrum and Data Acquisition

EN Flight Control Bearing Dynamic Wear Test Results

Low rates of wear on all tests – KAron VS

Part Number	Test Spectrum	Total Cycles	Measured Wear (mm (in))	Allowable Wear (mm (in))
EN 4538-2R10B (KSC405800VS-10R)	Flight Spectrum (20,000 Flt Hrs)	6,539,000	<.010 (0.0004)	0.15 (0.006)
EN 4538-2R20B (KSC405800VS-20R)	Flight Spectrum (20,000 Flt Hrs)	6,539,000	0.05 (0.002)	0.15 (0.006)
EN 4538-2R20B (KSC405800VS-20R)	Flight Spectrum (20,000 Flt Hrs)	6,539,000	0.025 (0.001)	0.15 (0.006)
EN 4538-2R20B (KSC405800VS-20R)	9789 daN (100 MPa)	250,000	0.038 (.0015)	0.05 (0.002)
EN 4538-2R20B (KSC405800VS-20R)	9789 daN (100 MPa)	250,000	0.05 (0.002)	0.05 (0.002)

EN 4538-2R20B (KSC405800VS-20R)

All Test Bearings in Excellent Condition at End of Test

Reference QTR-1023

EN (European Standard) Flight Control Bearing Friction Test Results

KAron VS Low Friction Self Lubricating Liner System

<u>Friction Levels less than 0.18 at all pressures and temperatures</u>

	BEFORE TEST (KC 7924)				
	Pressure	Friction (22°C)	Friction (-10°C)	Friction (-30°C)	Friction (-54°C)
(1.4 KSI)	10 Mpa	0.045	0.067	0.111	0.178
9 KSI	60 MPa	0.041	0.037	0.089	0.118
17 KSI	120 Mpa	0.037	0.045	0.082	0.104

AFTER TEST (KC 7924)				
Pressure	Friction (22°C)	Friction (-10°C)	Friction (-30°C)	Friction (-54°C)
10 Mpa	0.031	0.044	0.111	0.133
60 MPa	0.030	0.038	0.081	0.096
120 Mpa	0.030	0.056	0.074	0.093

BEFORE TEST (KC 7938)				
Pressure	Friction (22°C)	Friction (-10°C)	Friction (-30°C)	Friction (-54°C)
10 Mpa	0.044	0.120	0.160	0.178
60 MPa	0.041	0.081	0.104	0.126
120 Mpa	0.037	0.067	0.081	0.111

AFTER TEST (KC 7938)				
Pressure	Friction (22°C)	Friction (-10°C)	Friction (-30°C)	Friction (-54°C)
10 Mpa	0.031	0.044	0.089	0.178
60 MPa	0.030	0.048	0.059	0.111
120 Mpa	0.030	0.041	0.056	0.096

EN Flight Control Bearing
Limit/Ultimate Load Test Results

EN 4538-2R10B (KSC405800VS-10R)				
MAX TOTAL DEFLECTION UNDER 93.3 kN RADIAL LIMIT LOAD	MAX TOTAL DEFORMATION AFTER LIMIT LOAD		ULTIMATE LOADS	
	RADIAL 93.3 kN	AXIAL 17.4 kN	RADIAL 139.9 kN 2 SAMPLES	AXIAL 26.1 kN
0.259 (0.43) – SAMPLE #1 0.257 (0.43) – SAMPLE #2	0.01 (0.08) – SAMPLE #1 0.012 (0.08) – SAMPLE #2	0.090 (0.127)	NO CRACKS, NO PUSH-OUT OF THE BALL OCCURRED FOLLOWING APPLICATION OF THE LOADS	

EN 4538-2R12B (KSC405800VS-12R)				
MAX TOTAL DEFLECTION UNDER 139.7 kN RADIAL LIMIT LOAD	MAX TOTAL DEFORMATION AFTER LIMIT LOAD		ULTIMATE LOADS	
	RADIAL 139.7 kN	AXIAL 24.5 kN	RADIAL 209.5 kN 2 SAMPLES	AXIAL 36.7 kN
0.349 (0.5) – SAMPLE #1 0.335 (0.5) – SAMPLE #2	0.021 (0.08) – SAMPLE #1 0.015 (0.08) – SAMPLE #2	0.040 (0.127)	NO CRACKS, NO PUSH-OUT OF THE BALL OCCURRED FOLLOWING APPLICATION OF THE LOADS	

Seven (7) sizes tested and all meet requirements

EN 4538-2S06B (KSC405800VS-06S)

EN 4538-2R10B (KSC405800VS-10R)

EN 4538-2R12B (KSC405800VS-12R)

EN 4539-2R14B (KSC407000VS-14R)

EN 4539-2R16B (KSC407000VS-16R)

EN 4538-2R20B (KSC405800VS-20R)

EN 4539-2R24B (KSC407000VS-24R)

Test Bearings Meet Radial and Axial Load Requirements

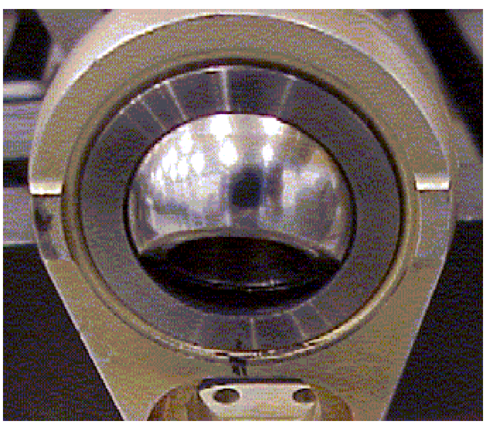
Airbus A320 Aileron Servocontrol Spherical Bearing – KAron VS

Flight Spectrum Loads and Motions
- Includes Large Angle Oscillation and Dithering Motions

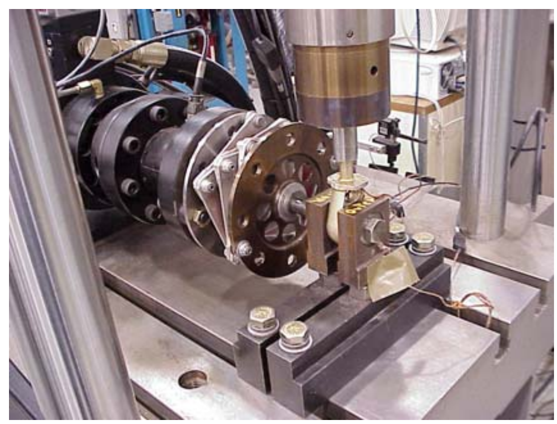
~~Operating Conditions~~
Load: Flight Spectrum 5 to 29 KN (1100 to 6500 lbs.)
Oscillation: +/- 0.5º to +/- 25º
Dithering: 1 Hz

~~Bearing Configuration/Size~~
KAron VS / Chrome Plated Ball

O.D. = 41.2mm (l.6")	*Ball Width = 22.2mm (0.87")*
I.D. = 22.2mm(0.87")	*Race Width: 19.3mm(0.75")*



Ball and Liner in Excellent Condition After 20,000 Flight Hour Test



Test Bearing in Actual Test Rig Setup

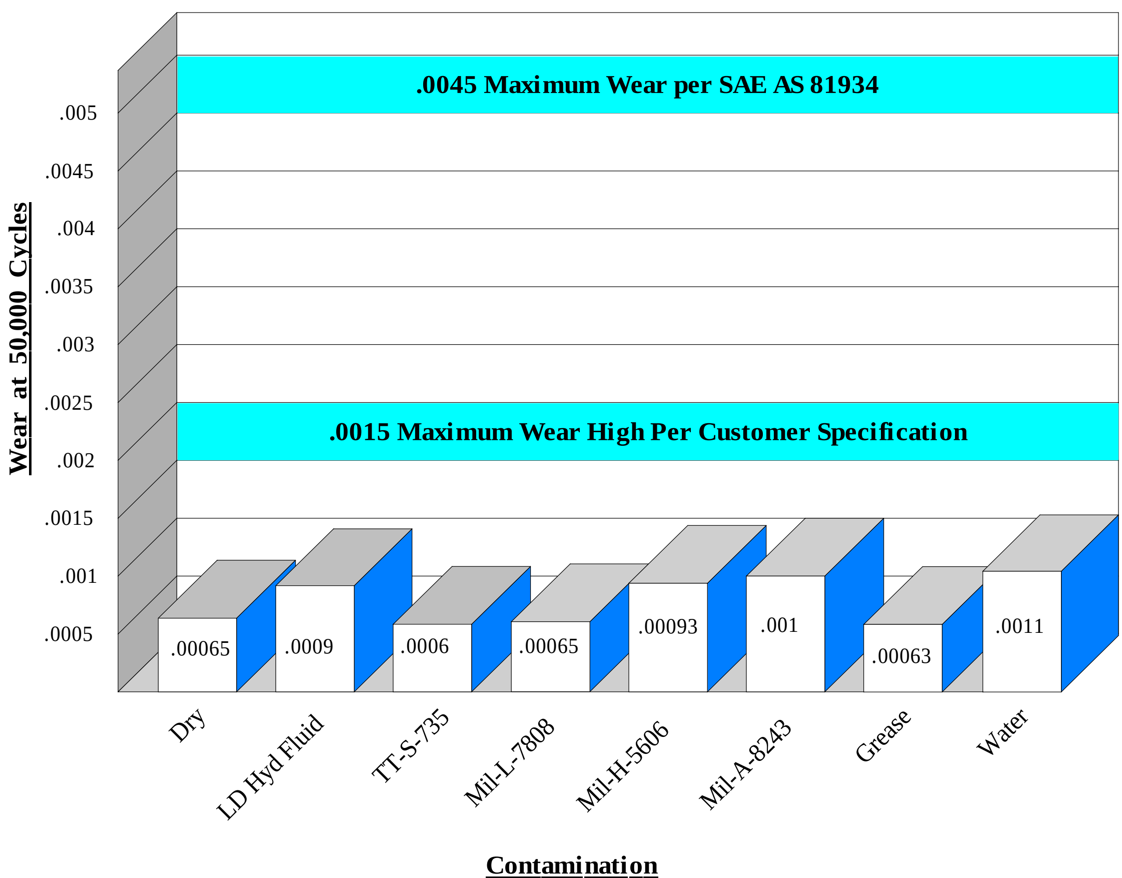
High Performance Testing

Customer Conducted High Performance Bushing Test
KAron B Bushing

New High Performance Requirements:
50,000 PSI
+/- 25 Degrees (100 Degrees total)
25,000 Cycles
Dry/Aircraft Fluids
Deicing fluid (Reduced load)

Bushing Dimensions:
KAron B
.8750 Bore
.375 Length
17.4 Substrate

SAE AS 81934 Requirements
35,000 PSI
+/- 25 Degrees (100 Degrees total)
25,000 Cycles
Dry/Aircraft Fluids
Deicing fluid (Reduced load)



MIL-STD 810 TESTING

		MIL-STD 810 TEST									
		High Temperature	Low Temperature	Solar Radiation	Blowing Rain	Fungus	Humidity	Salt Fog	Blowing Dust	Functional Shock	Ozone Resistance
		1	2	3	4	5	6	7	8	9	10
LINER TYPE	KAron B	Passed									
	KAron V	Passed									
	KAron VS	Passed									
	KAtherm T87	Passed									
	KAtherm T87S	Passed									
	P54	Passed									

Tests No. 1 through 9 per MIL-STD-810 Environmental Engineering Considerations
Test No. 10 per Telecordia General Requirements GR-487-CORE, R3-24
Qualification testing performed by Environ Laboratories, LLC of Minnesota

KAron V Fluid Contamination Endurance Test (Sheet 1 of 2)

Purpose of Test:
Testing was performed to determine the wear characteristics of KAron V liner material when operating with a variety of fluid contaminants.
Test Conditions:
Testing was performed similarly to the fluid contamination requirements of AS81820 paragraph 4.6.5.
Specimens – Three (3) specimens per Fluid – Ø1.0in [25.4mm] bore X 0.5in [12.7mm] long.
Three samples were tested without fluid contamination.
Fluid Exposure –Each specimen was soaked for 24 hours at 160°F ±5° (71° ±2.5°) except turbine fuel at 110°F [43°C]. Endurance testing was performed within ½ hour after removal from each test fluid.

Load:	20000 psi (138 MPa)
Oscillation Angle:	±25° (100° total per cycle)
Total Cycles:	25,000
Frequency:	20 CPM
Temperature:	Room Temperature

TESTED FLUID
BASELINE –NO CONTAMINATION
PHOSPHATE ESTER HYD (SAE AS1241)
SKYDROL 5 (LOW DENSITY)
TURBINE FUEL JP-4 OR JP-5
LUBRICATING OIL MIL-PRF-7808
HYDRAULIC OIL MIL-PRF-5606
ANTI-ICING FLUID MIL-A-8243
HYDRAULIC FLUID MIL-PRF-83282
GREASE (TERMALINE 2)
HYDRAULIC OIL (DOD-L-85734)
HYDRAULIC OIL (MIL-L-23699)
SALT WATER
FRESH WATER

(Reference Kamatics Data Sheet 169)

KAron V Fluid Contamination Endurance Test (Sheet 2 of 2)

Test Configuration:

Please refer to Figure 1 for the test configuration:

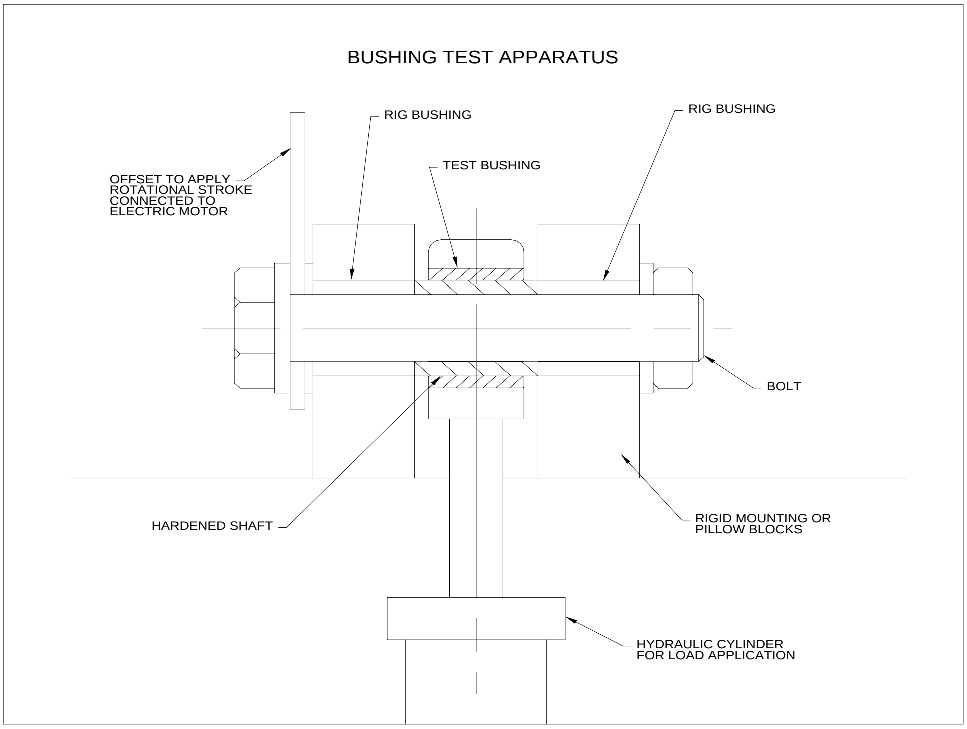


Figure 1

Test Results:

Average wear for three samples tested in each fluid is reported in Figure 2:

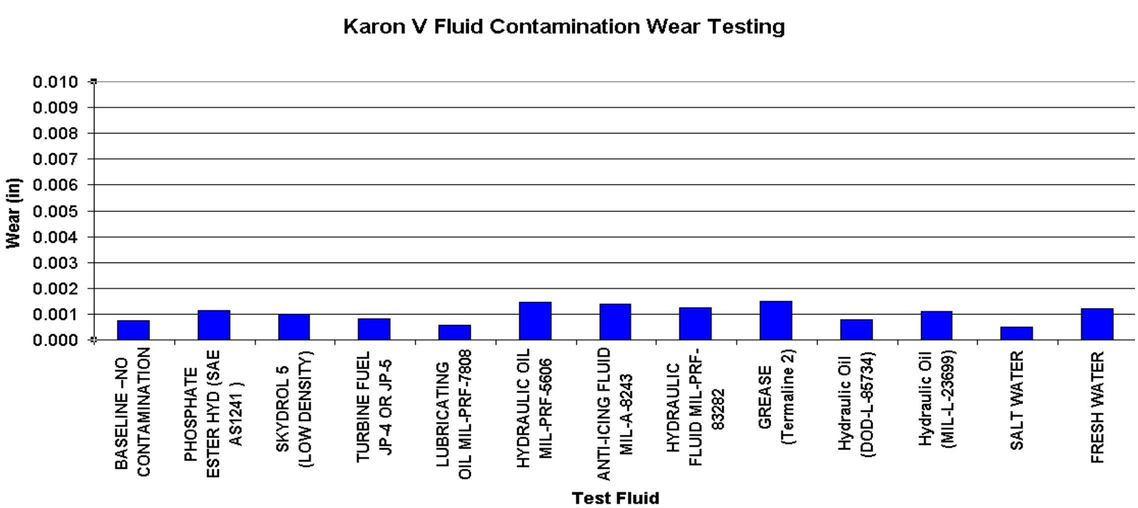
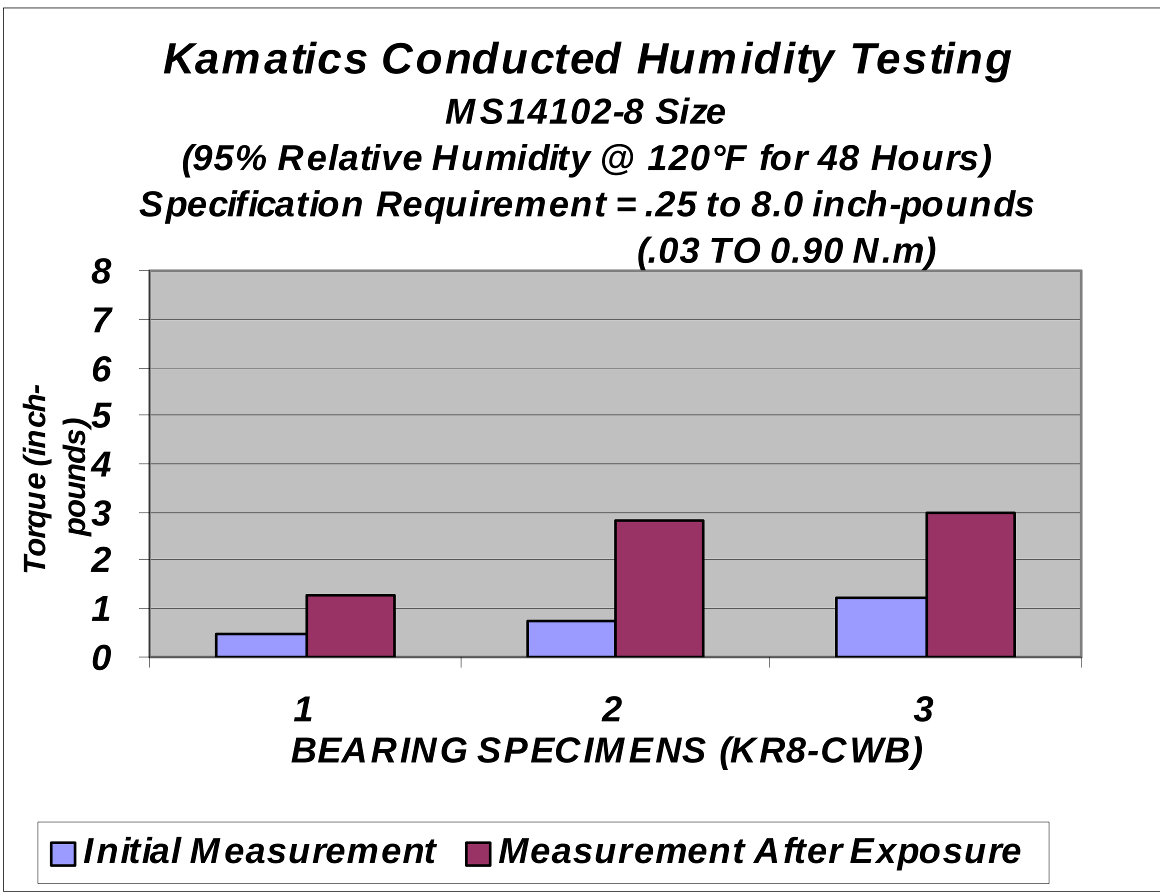


Figure 2

Relative Humidity Testing

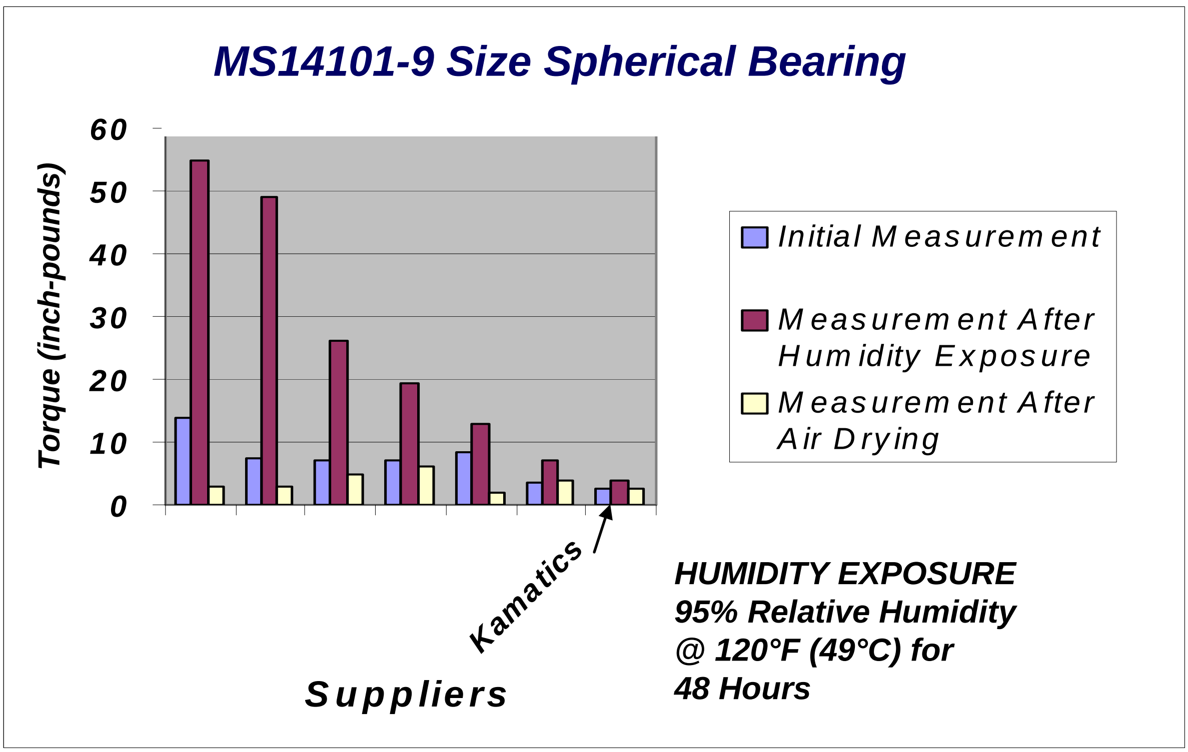
(Testing Shows Minor Effects of Humidity on
KAron Bearing Torque)



Customer Conducted Relative Humidity Testing

Comparative Relative Humidity Effects on Self-Lube (PTFE) Bearings for Seven (7) Manufacturers (Average of 3 Bearings Minimum per Supplier)

Comparison Testing Shows Superior Results of Kamatics KAron Bearings



KAron B Soak Test in Dow Corning High Vacuum Grease (Silicone Base)

Description:

Kamatics KAron® B self-lubricating bearing liner was tested to observe the effect of Dow Corning High Vacuum grease on hardness, weight gain/loss, and dimensional gain/loss. This was to determine the compatibility of KAron B and the high vacuum grease relative to its use in a bearing system.

Parameters:

Three solid KAron® B cylindrical plugs were totally immersed in a sample of the subject grease for a total of 200 hours at room temperature. Prior to and after the soak period the samples were measured for mass, dimensions and for hardness.

Test Results:

Measured Parameter	Prior to High Vacuum Grease Soak Test			After High Vacuum Grease Soak Test		
	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
Mass (grams)	1.9118	1.9088	1.9143	1.9125	1.9099	1.9161
Percent Mass Gain				0.03%	0.05%	0.09%
Dimensions (inches)	0.6287 x Ø0.400	0.6258 x Ø0.4002	0.6240 x Ø0.4011	No Change	No Change	No Change
Hardness (15X)	85-86	86-89	85-87	No Change	No Change	No Change

Conclusions:

KAron® B self-lubricating bearing liner material shows no effect when exposed to Dow Corning High Vacuum Grease in a soak test of 200 hours relative to dimensions and hardness. No other detrimental effects were observed. Thee material also shows a negligible weight gain during the same test. Therefore KAron® B and Dow Corning High Vacuum Grease appear to be compatible materials for use in a bearing system.

It should be noted that grease of any kind is always considered a contaminant which could affect the bearing material transfer properties and therefore could have an undesirable affect on wear rates and breakaway friction.

(Reference Kamatics Data Sheet 146)

Comparative Spherical Bearing Testing 747 Engine Pylon Diagonal Brace Bearing KAron B Liner vs. Metal to Metal (DFL)

Purpose of Test:
The purpose of this test is to evaluate the performance of KAron B lined spherical bearings as candidate bearings to replace existing metal to metal bearings in the engine pylon diagonal brace assembly. The present metal to metal bearing are experiencing ball migration from the outer races due a fretting condition occurring during operation.

Test Specimens:
Four (4) Boeing Spec BACB10AG-12 plain unlined spherical bearings to be used as the baseline specimens. Grease removed and replaced by dry film lube.

Four (4) Kamatics KR12-CNGB-03 KAron B lined and chrome plate on the 440C ball spherical diameter.

Test Setup:
Modification of an existing test rig per Figure 1, capable of applying a varying primary radial load coupled with a varying axial stroke of approximately .3" at approximately 1 to 5 Hz, vectored 90° from the primary load. The axial stroke is incorporated to provide out of plane ball motion, simulating the aircraft environment.

The radial load varies from +1500 to +14600 lb. at approximately one cycle per minute, 50 seconds full load/10 seconds low load, equating to bearing pressures of 3000 to 21000 psi. 21000 psi is the calculated bearing pressure experienced by the original bearing in the aircraft.

Test Condition 1:
Load = 1500 lbs (2130 psi) for 10 sec, to 14600 lbs (20700 psi) for 50 seconds
Misalignment of upper bearing +3" to -.1" (through "0"), frequency noted.

Test Condition 2:
Load = 1500 lbs (2130 psi) for 10 sec, to 20000 lbs (28400 psi) for 50 seconds
Misalignment of upper bearing +.3" to -.1" (through "0"), frequency noted.

Page 1 of 2

Comparative Spherical Bearing Testing 747 Engine Pylon Diagonal Brace Bearing KAron B Liner vs. Metal to Metal (DFL)

Test Results:
See Table 1 and 2

Table 1, (Metal to Metal/Dry Film Lube) Condition 1

Sample #	KC5855	KC5858	KC5856	KC5857
Position	Lower	Upper	Lower	Upper
Radial play, before	.001"	.002"	.001"	.001"
Frequency (Hz)	5	5	1	1
Run Time (minutes)	27	27	573	573
Radial play, after	<.001"	<.001"	<.001"	<.001"
Comments	Fretted	Fretted	Fretted	Seized

Table 2, (KAron B lined)

	Condition 1 (2130 to 20700 psi)		Condition 2 (2130 to 28400 psi)	
Sample #	KC5897	KC5898	KC5897	KC5898
Position	Lower	Upper	Lower	Upper
Radial play, before	<.0005"	<.0005"	<.001"	<.001"
Frequency (Hz)	1	1	1	1
Run Time (minutes)	1209	1209	1207	1207
Radial play (after)	<.001"	<.001"	<.001"	<.001"
*Comments	Like new	Like new	Like new	Like new

* S/N KC5897 and KC5898 were run at Condition 1 for 1209 minutes and again at Condition 2 for an additional 1207 minutes for a total of 2416 minutes without any negative signs of distress.

Page 2 of 2

KAron B and KAron V Deflection / Permanent Set Data .012" Liner Thickness (Room Temperature)

Purpose of Test:
To measure and record the amount of liner deflection and resultant permanent set under various bearing pressures.

Test Specimens:
Five (5) disks of 17-4PH Cres, Rc 40, approximately .565" diameter by .258" thick were coated with .012" thick KAron liner material. Two (2) were coated with KAron B and three (3) were coated with KAron V

Test Conditions:
The test procedure was similar to MIL-B-81820E paragraph 4.6.1, Radial Static Limit Load, which states "A preload of 4 to 6 percent of the radial static limit load shall be applied to the bearing for 3 minutes, and then the measurement device set to zero. The load shall then be increased at a rate of 1 percent of the specified load per second until it equals the radial static limit load. The total deflection shall be the reading at the radial static limit load after 2 minutes. The load shall then be reduced at the same rate to the preload value. The permanent set is the reading at preload." Per paragraph 3.5.1, radial Static limit Load, "In all instances the permanent set shall be less than .0030 inch."

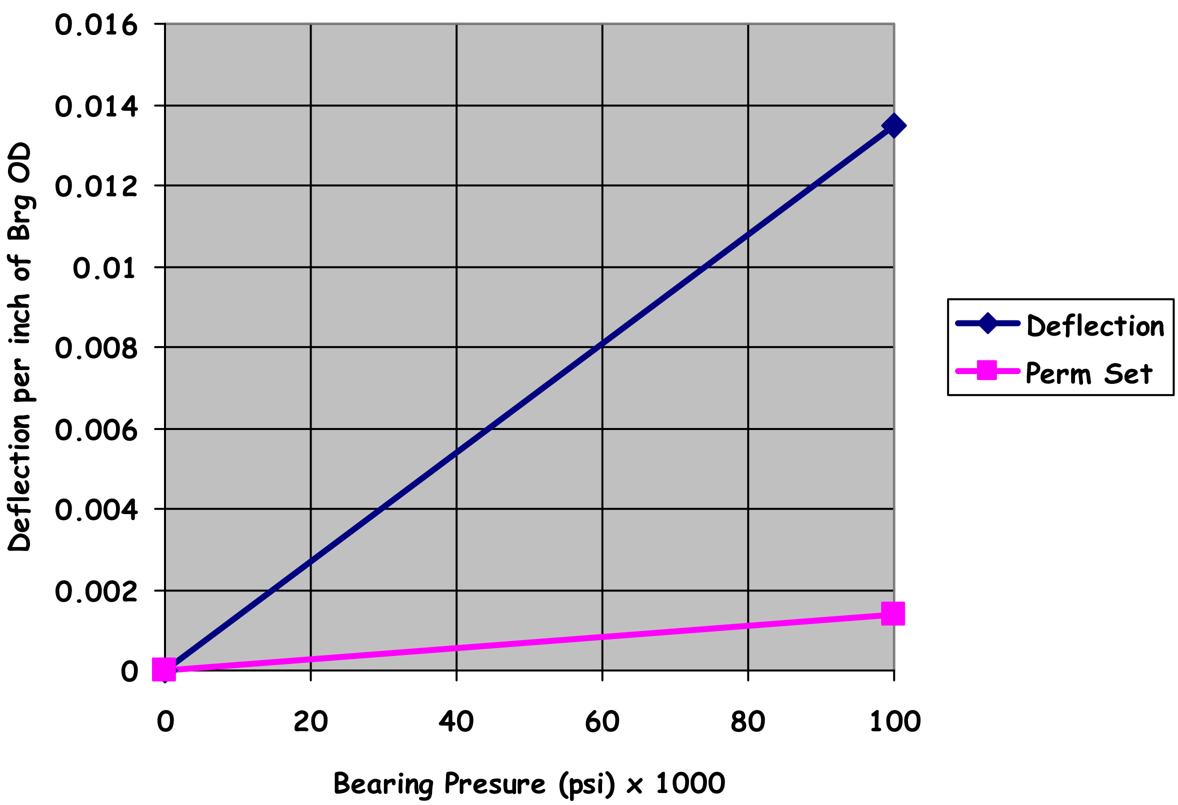
Test Set up:
The test set-up was accomplished on a Tinius Olsen testing machine equipped with a chart recorder.

Specimen	*KAron Type*	*Applied Pressure (psi)*	*Deflection (in.)*	*Permanent Set (.in)*
#1	*KAron **B***	*65000*	*.0060*	*.0005*
#2	*KAron **B***	*85000*	*.0067*	*.0006*
#3	*KAron **V***	*55000*	*.0067*	*.0008*
#4	*KAron **V***	*65000*	*.0075*	*.0010*
#5	*KAron **V***	*75000*	*.0077*	*.0011*

(Reference Kamatics Data Sheet 105)

Typical KAron B Spherical Bearing Elastic & Permanent Deformation

The chart shown below depicts the typical liner deflection and permanent deformation (set) for a Kamatics KAron B lined SAE AS-B-81820 spherical bearing at various bearing pressures.



KAron B Deflection / Permanent Set Data .050" Liner Thickness

Purpose of Test:
To measure and record the amount of liner deflection and resultant permanent set under various bearing pressures.

Test Specimens:
Three (3) journal bearings similar to M81934/1-16C016 (KRJ16-SB-016) except the liner thickness was .050" thick.

Test Set up / Conditions:
The set up was similar to that suggested in specification MIL-B-81934 for permanent set data. The 3 bearings were tested on a Tinius Olsen testing machine equipped with a chart recorder. There was approximately .001" clearance between the KAron B liner and the mating steel pin. The bearings were rotated approximately 45° for each different pressure level.

Test Results:

	Deflection (inches)		
Pressure (psi)	Bearing 1	Bearing 2	Bearing 3
2000	0.0012	0.0015	0.0013
4000	0.0018	0.0017	0.0017
6000	0.0019	0.0022	0.0020
8000	0.0022	0.0025	0.0027
10000	0.0027	0.0030	0.0029
12000	0.0031	0.0033	0.0032
15000	0.0038	0.0037	0.0042

Note: In all cases noted above, the permanent set at each pressure level was less than .0005".

(Reference Kamatics Data Sheet 98)

KAron B Permanent Set Data

KAron B self-lubricating bearing liner material was subjected to the following conditions to determine the permanent set effects of a prolonged applied load on a given liner thickness.

Condition 1

Applied pressure =	*70,000psi (483MPa) (in air)*
Duration=	*358 hours*
Original liner thickness=	*.014" (.36mm)*
Permanent set=	*.0028" (.07mm)*

Condition 2

Applied pressure =	*32,000psi (221MPa) (in seawater)*
Duration=	*1000 hours*
Original liner thickness	*.014" (.36mm)*
Permanent set=	*.001" (.025mm)*

Condition 3

Applied pressure =	*22,000psi (152MPa) (in seawater)*
Duration=	*358 hours*
Original liner thickness=	*.014" (.36mm)*
Permanent set=	*.001" (.025mm)*

Note…

Specification SAE AS-B-81820, Bearing, Plain, Self-lubricating, Self-aligning Permanent set requirement (radial) is defined as follows:

Applied pressure =	*approx 65,000 (448MPa)*
Duration=	*3 minutes*
Original liner thickness=	*approx .012" (.30mm)*
Permanent set=	*.003" (.076mm) maximum*

KAron B & V vs. MIL-L-46167 Compatibility Test (Synthetic Engine Oil) (Immersion at Room Temperature)

Purpose of Test:
To evaluate the affects of Mil-L-46167 synthetic engine oil on KAron B & V liner material after immersion in the fluid at room temperature for duration's up to 13 days.

Conclusion:
Two (2) KAron B and (2) KAron V specimens completed 13 days of immersion in the Mil-L-46167 oil at room temperature as noted in Table 1. There were no measurable changes to hardness or dimension and only minor changes to weight that could be attributed to normal measurement/equipment error.

Test Specimens:
Two (2) solid KAron B and (2) KAron V cylinders, .400" OD x .625" long.

Table 1

Specimen	Initial Wt (grams)	After 5 days	After 9 days	After 13 days
KAron B1	1.8816	1.8804	1.8813	1.8814
KAron B2	2.0440	2.0448	2.0436	2.0449
KAron V1	1.9315	1.9290	1.9305	1.9299
KAron V2	2.0978	2.0963	2.0969	2.0966

Reference Kamatics Data Sheet 122

KAron B Long Term Endurance Testing Journal Bearing Configuration

<u>Purpose of Test</u>:
To provide long term endurance test results of KAron B journal bearings.

<u>Test Specimens</u>:
Four (4) KRJ16-SB-016 KAron B lined bearings, (1.000 ID x 1.187 OD x .500 long)

<u>Test Set-up:</u>
Typical clevis mounting similar to that defined in specification MIL-B-81934. The mating pin was 440C stainless, Rc 55 minimum hardness, 8 RMS surface finish.

<u>Test Conditions</u>:
Pressure = Noted
Oscillation Angle = ±12.5° (50° per cycle)
Rate = 27 cpm
Temperature = Room
Contamination = None

<u>Test Results:</u>

Sample S/N	Pressure (psi)	Total Cycles	Wear (inches)
KC4720	10,000	1,000,000	.0030
KC4721	10,000	1,000,000	.0020
KC4716R	20,000	1,072,164	.0050
KC4717R	20,000	1,072,164	.0035

KAron B Nuclear Radiation Testing

This data sheet summarizes the effects of nuclear radiation on Kamatics Corporation's KAron B bearing liner system. A major manufacturer that designed and manufactured nuclear electrical generating plants conducted the tests. Kamatics supplied the KAron samples to the configuration required and the customer conducted the testing and supplied the results shown.

Radiation Exposure

In all cases, the KAron B bearing liner material was exposed to a total dose of 3.3×10^8 rads gamma. The radiation exposure was from a Co^{60} source. Dosimetry was carried out using Hartwell Red 4034 Perspex dosimeters calibrated directly with the NBS (National Bureau of Standards). To prevent oxidation effects, the samples were tightly wrapped with aluminum foil.

Compressive Strength

The effect of radiation on the compressive strength of KAron B was determined according to ASTM D695. The samples were solid cylinders, 0.50 inches (12.7mm) diameter and 1.00 inches (25.4mm) high. The testing was done on a Riehle testing machine. The results follow:

Table 1

Effect of radiation on the compressive strength of 5 KAron B samples

	Compressive strength (lbs/in^2)	
	As received	After 3.3×10^8 RADS
	18,300	18,400
	19,700	18,300
	18,900	18,700
	18,700	17,500
	20,500	18,700
Mean	19,220	18,300

It can be concluded from the preceding that there is a slight increase in the compressive strength of KAron B after radiation exposure. However, since the test is destructive, each sample represents a measurement on a separate sample.

KAron B Nuclear Radiation Testing (Continued)

Coefficient of Friction

The coefficient of friction was measured by the inclined plane method according to ASTM D3248. The coefficient of friction is reported as the tangent of the angle at which slippage first occurs as the inclined plane is raised. The measurements were made on steel plates that had a KAron B surface applied to one side. The measurements were made with KAron B surfaces in contact with each other.

Table 2

Effect of radiation on the coefficient of friction of 3 sets of KAron B samples

Coefficient of Friction

	As received		After $3.3x10^8$ RAD
	0.29		0.32
	0.32		0.17
	0.39		0.19
Mean	0.33	Mean	0.19

It can be concluded from the preceding that there is a reduction in the coefficient of friction of KAron B after radiation exposure. Each measurement represents individual pairs of samples.

Shear Strength

The shear strength was determined according to ASTM D732 on KAron B disks 2.0 inches (50.8mm) diameter and .18 inches (4.57mm) thick.

Table 3

Effect of radiation on the shear strength on 5 samples of KAron B

Shear Strength (lbs/in^2)

	As received		After $3.3x10^8$ rads
	8340		8510
	6860		9680
	7660		7000
	10660		8650
	7350		9100
Mean	8174	Mean	8858

Similar to compression tests previously shown, on an average, it can be concluded that there is a slight increase in the shear strength of KAron B after radiation exposure. Also, since the test is destructive, each value represents a measurement on a separate sample.

KAron B (KR8-CNB),
Grease Contaminated Endurance Test
(MIL-G-23827, MIL-G-81322, and MIL-G-81877)

Purpose of Testing:
To demonstrate the performance of KARON B lined spherical bearings when contaminated with MIL-G-23827, MIL-G-81322, and MIL-G-81877 grease.

Test Specimens:
Six (6) KR8-CNB spherical bearing assemblies.
- *ID..............= .5000/.4995"*
- *OD..............= 1.0000/.9995"*
- *Outer Race Width = .395/.385"*
- *Ball Width.......= .500/.498"*
- *Ball Diameter....= .781"*

Test Conditions:
- *Load....... = 7800 lbs*
- *Oscillation = _25° (100° total per cycle)*
- *Speed...... = 20 cpm*
- *Temperature = Ambient*
- *No. Cycles. = 25000*
- *Environment = Two (2) bearings contaminated with each of the three (3) greases noted*

Test Set-up:
Two (2) bearings were tested simultaneously in an endurance rig under a steady load of 7800 pounds. The inner races were held stationary with the outer races oscillated at a rate of 20 cycles per minute. Prior to testing, the bearings were contaminated with the noted greases by turning the balls 90° out of plane and coating the exposed surfaces of the liner with the grease. The bearings were left in this condition for a minimum of 24 hours. The balls were then turned back into plane and any excess grease wiped from the assemblies.

No-load rotational breakaway torque was measured before contamination, after contamination, and after 25000 cycles.

Conclusions:
The contamination of KAron B lined spherical bearings, when run at the conditions noted above, is not detrimental to the performance or wear rate of the liner material.

Table 1 on page 2 of this data sheet shows the results of the testing along with comments as applicable.

(Sheet 1 of 2)

KAron B (KR8-CNB),

Grease Contaminated Endurance Test
(MIL-G-23827, MIL-G-81322, and MIL-G-81877)
(Sheet 2 of 2)

TABLE 1

S/N	Grease	Cycles	Wear	No-load Torque (Inch-pounds) Dry	Contam	End	Comments
5171	MIL-G-23827	25800	<.001"	0.7	0.8	15	Note 1
5172	MIL-G-23827	25800	<.001"	0.7	0.8	4	Note 2
5173	MIL-G-81877	25000	<.001"	0.6	0.6	0.5	Note 3
5174	MIL-G-81877	25000	<.001"	0.8	0.6	0.2	Note 4
5190	MIL-G-81322	25000	<.001"	0.5	0.3	12	Note 5
5191	MIL-G-81322	25000	<.001	1.0	1.5	7.0	Note 6

Notes:

1. *Ran for an additional 75000 cycles (100000 total)...total wear on the liner was .002". One (1) inch-pound torque after completion of run, zero (0) torque after cleaning bearing.*

2. *Ran for an additional 75000 cycles, however, near the end of the run the 440C ball cracked and destroyed the liner. Total wear is not available.*

3. *Ran for an additional 75000 cycles, total wear was less than .002 inches. 20 inch-pounds torque after run, zero (0) torque after cleaning bearing.*

4. *Ran for an additional 75000 cycles, total wear was less than .002 inches. 20 inch-pounds torque after run, zero (0) torque after cleaning bearing.*

5. *Ran for an additional 61400 cycles and the rig support holding the bearing broke and the bearing was destroyed.*

6. *Ran for an additional 61400 cycles, total wear was .004". 6 inch-pounds torque after run, zero (0) after cleaning.*

(Reference Kamatics Data Sheet 95)

KAron V High Temperature Endurance Test +325° F, 25000 psi Pressure

Purpose of Test:
To determine the wear characteristics of KAron V at elevated temperature and high bearing pressures.

Test Specimens:
Three (3) KRJ16-SV-016 journal bearings, AMS 5643 (17-4PH) CRES housing, KAron V liner, 1.190" OD x 1.000"ID x .500" long.

Test Procedure:
Clevis mounted journal bearing operating against a 1.00" diameter 17-4 PH (Rc 40-47) shaft, 8 RMS surface finish, with a .0015" nominal clearance, run at the conditions noted below.

Test Conditions:

Load......................................25000 psi (12375 pounds)
Oscillation Angle.....................±25° (100° total per cycle)
Speed.....................................20 CPM
Temperature............................+325° F
Contamination.........................None

Test Results:

Specimen	Load (Lbs)	Pressure (psi)	Temp ° F	No. of Cycles	Wear (inches)
KC5333	12375	25000	325	26270	.002
KC5336	"	"	"	25220	.009**
KC5337	"	"	"	25220	.001

*** Test rig difficulties were encountered during testing of this bearing…measured wear was recorded and reported but the actual amount of wear remains questionable.*

(Reference Kamatics Data Sheet 106)

Endurance Test (Vibration)
KAron V (Spherical Bearing Configuration
Application: Aircraft Rudder Control Bearing

Purpose of Testing:
To expose KAron V liner material, in a spherical bearing configuration, to a high vibratory motion environment.
Test Condition:

Load	=	*l,000 pounds (full reversal) ≈ 20,000 psi*
Frequency	=	*100 Hz*
Temperature	=	*Ambient*
Oscillation	=	*1° (function of fitting deflection)*

Test Specimen:
KR5-CWV-04, standard MS14102-5 configuration, utilizing a 17-4PH hard chrome plated ball and a KAron V liner.

Test Setup:
The specimen bearing was installed in a customer-designed fitting to simulate actual deflections experienced on the aircraft. The fittings were then mounted on a 1,500 pound capacity M-B Electro-Magnetic Shaker and run at the parameters listed above.

Test Results:
After the design goal of 2.5 million load reversals the KAron V lined bearing exhibited 0.0017 inches of radial clearance. The bearing remained in an operable condition.

Conclusion:
The KAron V lined bearing demonstrated the capability of enduring long term, high pressure, vibratory loading and should be considered for these types of applications.

(Reference Kamatics Data Sheet 75)

KAron V vs. Al/Ni/Bz Bushing Endurance Test
300 cpm oscillation coupled with +,-.10" axial travel,
Bearing Pressures up to 4750 psi
(Sheet 1 of 4)

Purpose of Test:
To compare the performance of KAron V lined bushings with aluminum-nickel-bronze bushings for use in a high vibratory hinge joint, by simulating the joint and applying a radial bearing load to the bushings coupled with reversing axial hinge pin motion normal to the bearing load.

Test Specimens:
Six (6) aluminum-nickel-bronze and twelve (12) Cres/KAron V ID lined bushings, .6875" OD x .625" ID x .180" long.

Test Procedure:
6 test bearings were installed in a 6 lug hinge fixture simulating the application under study (see Figure 1). A radial bearing load was applied to the set-up by a hydraulic cylinder. The hinge pin was translated axially through the bearings via an eccentric linkage powered by a 300 rpm motor. During the KAron contamination sequence, the fluids/abrasive dust were liberally applied every 2 hours.

a, 6 aluminum-nickel-bronze bushings were tested for 7.5 hours to replicate the present failure mode and to establish a base line for KAron V comparison.
b, 6 KAron V lined bushings were first tested for 10.3 hours at a steady load of 750# uncontaminated, then for an additional 8 hours at 800lbs contaminated as noted below (18.3 hours total).
c, A second set of 6 KAron V lined bushings were tested at 400, 600, & 800 lbs for 9, 8, & 9 hours respectively (26 hours total).

Test Conditions:
Load.................................Varying to 5000 psi
Stroke..............................±.050" (.200" total per cycle)
Speed...............................300 CPM
Temperature......................Room
Contamination...................MIL-STD-810 dust/MIL-H-5606 & Skydrol-applied every 2 hours

(Reference Kamatics Data Sheet 109)

KAron V vs. Al/Ni/Bz Bushing Endurance Test
300 cpm oscillation coupled with +,-.10" axial travel,
Bearing Pressures up to 4750 psi
(Sheet 2 of 4)

Test Results:

Tables 1, 2, & 3 show the test results: Note that the bushings in the "end lugs" of the test fitting each react 50% of the applied load while the bushings in the "center lug" each react 25% of the applied load.

Table 1
(Aluminum-Nickel-Bronze Bushings) System Coefficient of Friction=.50 (at end of test)

Specimen	Load (Lb.)	Pressure (psi)	Temp ° F	Duration (hours)	Wear (inches)
KC5543 (End Lug)	200 300 375	2375 3550 4450	Room	4.5 4.0 1.0	.0175 Total
KC5544 (Center Lug)	100 150 188	1188 1775 2225	"	"	.0057 Total
KC5545 (Center Lug)	100 150 188	1188 1775 2225	"	"	.0098 Total
KC5546 (Center Lug)	100 150 188	1188 1775 2225	"	"	.0085 Total
KC5547 (Center Lug)	100 150 188	1188 1775 2225	"	"	.0057 Total
KC5548 (End Lug)	200 300 375	2375 3550 4450	"	"	.0185 Total

(Reference Kamatics Data Sheet 109)

KAron V vs. Al/Ni/Bz Bushing Endurance Test
300 cpm oscillation coupled with +,-.10” axial travel,
Bearing Pressures up to 4750 psi
(Sheet 3 of 4)

Table 2

(KAron V Lined - Uncontaminated) System Coefficient of Friction=.046 (at end of test)

Specimen	Load (Lb.)	Pressure (psi)	Temp ° F	Duration (hours)	Wear (inches)
KC5549 (End)	375	4450	Room	10.3	.0006
KC5550 (Ctr)	188	2230	‘	“	.0009
KC5551 (Ctr)	188	2230	“	“	.0009
KC5552 (Ctr)	188	2230	“	“	.0005
KC5553 (Ctr)	188	2230	“	“	.0003
KC5554 (End)	375	4450	“	“	.0008

(Same Bushings, Same Surface- Contaminated) System Coefficient of Friction=.09 (at end of test)

Specimen	Load (Lb.)	Pressure (psi)	Temp ° F	Duration (hours)	Additional Wear (in.)	Total Wear (inches)
KC5549	400	4750	Room	8	.0012	.0018
KC5550	200	2375	‘	“	.0008	.0017
KC5551	200	2375	“	“	.0007	.0016
KC5552	200	2375	“	“	.0006	.0011
KC5553	200	2375	“	“	.0007	.0010
KC5554	400	4750	“	“	.0019	.0027

(Reference Kamatics Data Sheet 109)

KAron V vs. Al/Ni/Bz Bushing Endurance Test
300 cpm oscillation coupled with +,-.10" axial travel,
Bearing Pressures up to 4750 psi
(Sheet 4 of 4)

Table 3 (KAron V Lined - Uncontaminated) System Coefficient of Friction=.044 (at end of test)

Specimen	*Load (Lb.)*	*Pressure (psi)*	*Temp ° F*	*Duration (hours)*	*Wear (inches)*
KC5555 (End Lug)	*200 300 400*	*2375 3550 4750*	*Room*	*9 8 9*	*.0006 Total*
KC5556 (Center Lug)	*100 150 200*	*1188 1775 2375*	"	"	*.0005 Total*
KC5557 (Center Lug)	*100 150 200*	*1188 1775 2375*	"	"	*.0003 Total*
KC5558 (Center Lug)	*100 150 200*	*1188 1775 2375*	"	"	*.0003 Total*
KC5559 (Center Lug)	*100 150 200*	*1188 1775 2375*	"	"	*.0005 Total*
KC5560 (End Lug)	*200 300 400*	*2375 3550 4750*	"	"	*.0015 Total*

(Reference Kamatics Data Sheet 109)

KAron B Spherical Bearing Testing (Ref KER-788) Thrust Reverser Blocker Door - CFM56 Engine

(Sheet 1 of 3)

Summary:

The Kamatics bearings (KSC307506B) successfully passed all of the tests that were specified in Kamatics Test Plan KTP-788. Kamatics KAron bearings exceeded the baseline metal-to-metal dry film lubricated bearings by a factor of 16:1 relative to wear, when tested in high-vibration conditions similar to thrust reverser applications. Kamatics KAron bearings were also found to have similar overall stiffness as the current metal-to-metal bearings, and had no measurable permanent deflection.

Discussion:

The purpose of this test was to demonstrate the performance improvements of a Kamatics self-lubricating spherical bearing relative to the current production approved metal to metal dry-film lube bearing). All test specimens were subjected to test conditions consistent with the CFM56 thrust reverser blocker door spherical bearing application and were conducted according to Kamatics Test Plan KTP-788.

The current CFM56 engine uses a metal-to-metal (M/M), dry film lube loader slot bearing on the thrust reverser blocker door. This spherical bearing connects the blocker door with the blocker door actuator arm (commonly referred to as the knife blade). The function of the part is to provide rotational motion and misalignment capability to rotate the thrust reverser blocker door into position during thrust reverser actuation and also provides for the rotational motion and misalignment for retraction. Each aircraft has a total of 10 blocker doors per engine and there is one spherical bearing per door for a total of 20 parts per aircraft. These M/M bearings were experiencing excessive wear and are replaced every C-check (approximately 1 year of service) per information gathered from a large fleet operator. One year of service would be approximately 1500 thrust reverser applications based on 4 flights per day.

Back to back tests have been performed to evaluate the performance of a Kamatics KAron self-lubricating spherical bearing against that of the current approved M/M bearing, for substantiation of a direct replacement for the current M/M bearing.

Test Procedure

The test procedure was detailed in Kamatics KTP-788 and submitted to the FAA for approval prior to testing. Testing was conducted on both the current M/M bearings and the KAron bearings, and consisted of a static load test and a dynamic endurance test.

Static Load Test

The static load test was conducted at the Kaman Aerospace Facility using a calibrated Tinius Olsen static load test machine. A quantity of one (1) bearing was tested of each the current M/M bearing and the Kamatics self-lubricating bearing. The static load test was conducted by placing the bearing in a steel test housing and inserting a hardened steel shaft (pin) through the ball with the shaft supported by a test fixture. (See Figure 1)

The static load test was conducted in accordance with methods prescribed by SAE AS81820 (formerly MIL-B-81820), which is the aerospace specification for qualification of self- lubricating spherical bearings. The bearing was preloaded to 5% of the total applied load (5% of 2,540 lbs = 127 lbs) will be applied and held for 3 minutes. The measurement device was then set to zero. The load was then increased to the maximum static load (2,540 lbs) and held for 2 minutes. The load was then returned to the preload value and the deflection was measured.

KAron B Spherical Bearing Testing (Ref KER-788)
Thrust Reverser Blocker Door - CFM56 Engine

(Sheet 2 of 3)

Dynamic Endurance Wear Test

Each spherical bearing was installed in a steel test housing. A stainless steel shaft (pin) was inserted through the ball and the ball was firmly clamped on the side faces of the ball. A radial load of 1,270 lbs was applied to the housing and the bearing ball was oscillated through an angle of 50 degrees relative to the outer race of the bearing to simulate the actuation and retraction of the blocker door. A simultaneous out of plane oscillation (misalignment) of the bearing was imposed on the bearing to simulate the vibration that the bearing would see during operation. This vibration is due to the force of the air loads and associated buffeting in the fan airflow that is acting on the blocker doors. The bearing was actuated through the range of motions by the use on an electric motor driven eccentric. The test setup and test conditions are noted below: (See Figure 2)

Oscillation (Rotation in Plane) = 0º - 50º - 0º (100° total per cycle)
Oscillation Speed = 17 cpm
Misalignment (Out of Plane) = ± 0.5°
Misalignment Speed = 1750 cpm
Applied Load = 1,270 lbs
Number of Cycles = 30,000
Number of Bearings to be Tested = Qty of 2 for current approved M/M bearing
Qty of 2 for Kamatics KSC307506B bearing

Test Results:

Static Load Test

Both the M/M bearing and the KAron bearing were static tested and found to have no measurable permanent set. This is clearly within the allowable 0.003-inch maximum range that was established by SAE AS81820 (MIL-B-81820).

Dynamic Endurance Wear Test

Two samples of the M/M bearing and the KAron bearing were tested for dynamic endurance. Wear was measured as the change in the diameter of the inner race from the beginning of the test to the end of the test.

Sample Number	Construction	Test Cycles	Measured Wear (in)
KC7698	Metal-to Metal	7500	0.0112
KC7699	Metal-to-Metal	7500	0.0117
KC7700	KAron	30000	0.0018
KC7701	KAron	30000	0.0022

Conclusion:

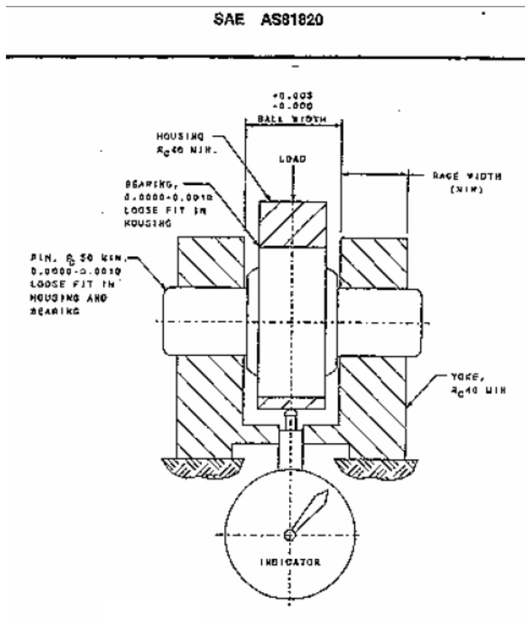
The metal-to-metal bearings are considered to be the baseline for evaluating the success of the KAron bearings. Both of the metal-to-metal bearings experienced considerable wear after only 7,500 cycles. One part was deformed to the point that the inner race could not be rotated out of plane in a way that is required to remove it from the outer race. All of the dry-film lubricant had been worn away and friction levels were rising to the point that the test could not be continued to the full duration without jeopardizing the test equipment.

Both of the KAron bearings were able to operate throughout the full duration of the test (30,000 cycles). The measured wear of the KAron bearings, was considerably less than that measured on the metal-to-metal bearings that only ran ¼ of the cycles that were run on the KAron bearings. Both KAron bearings remained fully functional at the completion of the test.

KAron B Spherical Bearing Testing (Ref KER-788)
Thrust Reverser Blocker Door - CFM56 Engine

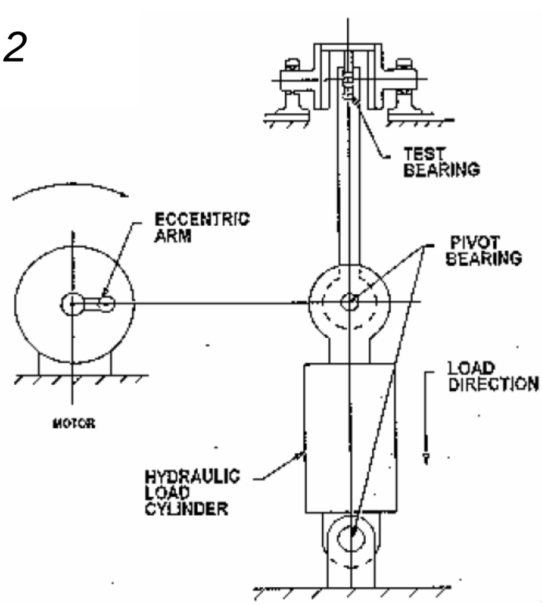
(Sheet 3 of 3)

Figure 1



Radial static limit load test fixture.

Figure 2



Conductive Bushing Test (Ref KER-954)
KAron liner and Kamatics unique bearing design

Results:
A revised configuration for a conductive KAron liner system with a copper nickel tin bushing has successfully completed high load and high oscillation cycle testing. The bearing remained conductive throughout the test. The resistance of the bushing started at 0.0 ohms and was measured to be 0.0 ohms at the completion of the test. The bearing measured .025mm (.001 inches) of wear after 120,000 cycles. There was normal KAron transfer from the bearing to the shaft. The load zone of the shaft is in excellent condition. The conductive KAron® liner system utilizing a KAron® V and a copper nickel tin bushing performed extremely well. After the bushing was evaluated and documented it was placed back into the test fixture for endurance testing. The endurance test is currently at 1.8 million cycles with approximately .178mm (.007inches) of wear and a conductivity of less than 0.1 ohms.

Objective
Measure the resistance (ohms) of KJB667816V-TEST when the bearing is new, during the testing cycle and once the testing is completed.

Test Conditions:
The bushings were oscillated +/-50 degrees, for 120000 cycles. The load on the bearings was 43720N (9830lbs) radial. The material mating pin was 15-5PH hardened to H1025. The resistance of each bushing was measured at the start of the test, the conclusion of the test and periodically during testing.

Test Results
The KAron V lined copper nickel tin conductive bushing successfully passed the testing required and remained conductive throughout the test. The resistance was measured at the start of the test to be 0.0ohms and measured 0.0ohms at the conclusion of the test period. The liner wear was measured to be .025mm (.001inches) after 120,024 cycles. The coefficient of friction was 0.08. The mating shaft was in excellent condition. There was good KAron transfer from the bushing to the shaft and no evidence of scoring or fretting on the shaft. The concentric rings allowed for constant contact with the mating shaft. With the concentric ring design this allowed for "self-cleaning contacts" ensuring a good conducive circuit between the bushing and the shaft.

Once the bearing was analyzed and all data recorded the bushing was reinstalled into the test fixture to under go further endurance testing. The test was then stopped at 1.0 million cycles and a hard measurements were taken for wear, which was .127mm (.005 inches) total wear (.025mm (.001inches) of that wear is from the first test). The endurance test continued and at 1.8 million cycles approximately .178mm (.007inches) total wear and a coefficient of friction of 0.08 was recorded. The conductivity has remained less than 0.1 ohms through out the test.

Frozen Water Effects on Sealed/unsealed "KRP" Bearings
(Reference KEM 692-99)

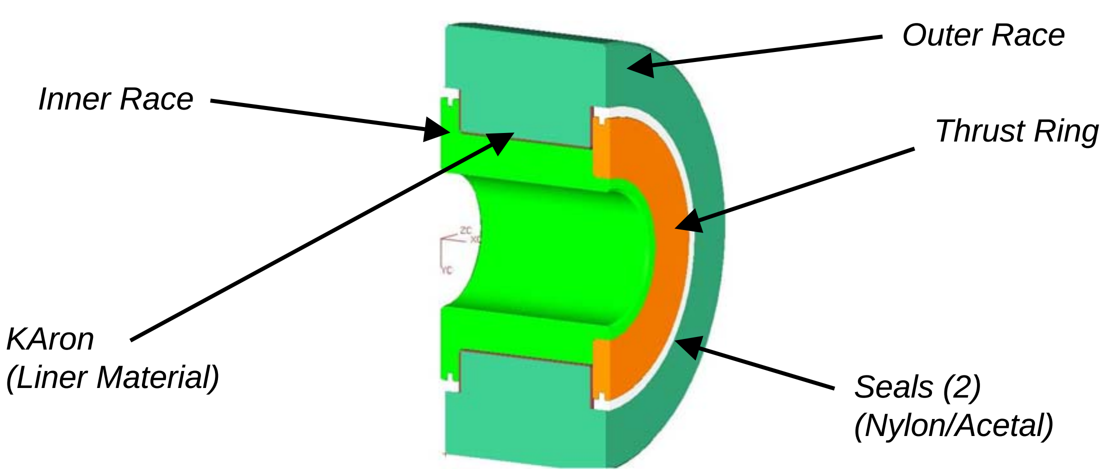
Per a customer request, Kamatics performed a cold/freeze test on two identical size Kamatics KRP unique roller replacement bearings, one sealed with the Kamatics labyrinth seal configuration and the other not sealed. The bearing part numbers were KRPI366O8VT (unsealed) and KRP1727O8VTZ (sealed), both free to turn by hand without catching or binding at room temperature at the start of the evaluation.

Both bearings were set horizontally on a table (ID axis vertical) to allow "pooling" of the water on the side faces of the rollers. Both bearings were vigorously sprayed with tap water to the degree that the surfaces could not hold any additional water. The bearings were then placed in a freezer and held at zero (O)°F overnight (approximately 16 hours).

Breakaway torque was measured on both assemblies while still in the freezer. The sealed bearing, KRP1727O8VTZ, measured 5 inch pounds of breakaway torque. The unsealed bearing, KRP1366O8VT measured 30 inch pounds.

An additional test was conducted on the same bearings by saturating the bearings with water while they remained frozen, immediately after taking the original torque readings noted above. The sealed bearing measured between 5 and 9 inch pounds and the unsealed bearing remained at 30 inch pounds.

It should be further noted that during normal flight, the torque to rotate would be higher that either the 5 or 30 inch pounds of torque due to loads, geometry and running coefficient of friction. This would tend to actually nullifying the "frozen" effect condition.



Compatibility of Kamatics self-lubricating liners With Low-Density Skydrol 5 (Ref KER-916)

Background

With the introduction of new KAron and KAtherm types of self-lubricating liner systems, and introduction of a new Skydrol fluid, the question of compatibility has been raised. This test was meant to establish fluid compatibility of Kamatics products and phosphate-ester hydraulic fluid (Skydrol 5).

Test Specimens

The following liner materials tested were : KAron B, KAron SP, KAron V, KAron VS and KAtherm T87

Submersion Test Procedure

- *Two samples of each liner material were manufactured. The samples were machined to .400 inch diameter by .625 inch long cylindrical test pieces.*
- *Each sample was weighed, dimensionally measured, and measured for hardness using a Rockwell indenter on a 15X scale.*
- *Both samples of each material were submerged in low-density phosphate-ester hydraulic fluid (Skydrol 5) for 24 hours at 160°F. Testing was performed at elevated temperatures to simulate long-term exposure at ambient temperatures.*
- *After exposure to the test fluids, the samples were measured, weighed, and checked for hardness again.*

Wear Test Procedure

- *Four bearings of each liner type (KRJ16-08) were manufactured. All bearings were permanently identified, dimensionally inspected and the corresponding inner diameters were recorded.*
- *Two bearings of each liner type were submerged in low-density phosphate-ester hydraulic fluid (Skydrol 5) for 24 hours at 160°F. All test containers were covered in a well ventilated area to minimize any fumes. A total of 10 bearings were soaked and 10 bearings un-soaked.*
- *All 20 bearings were cycle tested, consistent with the parameters of MIL-B-8943. The bearings were loaded to 24,000 psi, and oscillated ±25º for 5,000 cycles.*

After cycling, all bearings were dimensionally inspected and the corresponding amount of wear was recorded.

Conclusion

The tested KAron and KAtherm liner systems show no signs of accelerated wear, softening, weight change or swelling after exposure to the low density phosphate-ester hydraulic fluid (Skydrol 5). In addition, bearings that were soaked in the low density Skydrol did not exhibit a tendency to wear any faster than bearings that were not soaked.

KR10-CNB Spherical Bearing Axial Static Load Test

(Ref KER-872)

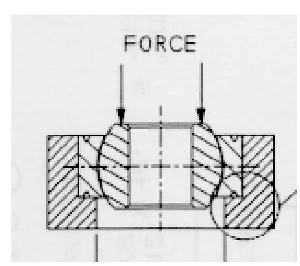
Introduction:

For a particular application, t he customer wanted axial static load capability of Kamatics part number KSC267900B-09GC has resulted in this test. Four KR10-CNB bearings were taken from stores and used for the testing. The test bearings are similar to the subject bearing for all the variables that effect the axial capability: ball diameter, race width, and liner material. The main difference between both parts is that the subject bearing KSC267900B-09GC has a non-standard bore.

Test Specimens:	*KSC267900b-09GC*	*KR10-CNB*
Bearing OD	*1.1875*	*1.1875*
Ball Diameter	*0.982*	*0.968*
Outer Race Width	*0.491*	*0.500*

Test Procedure:

The KR10-CNB spherical bearing was static load tested (axial direction) in a Tinius-Olsen tensile test machine at room temperature. This apparatus records load vs. deflection during the test cycle. The bearing was installed in a test fixture and pre-loaded to 4% of the total axial load to take out initial slack in the test equipment and fixture, per standard MIL-B-81820 self lubricating spherical bearing specification test procedures. The load was then subsequently increased until the maximum level (7,570 pounds) was reached, and held at this level for a period of 3 minutes. The load was then reduced back to the pre-load condition to determine the permanent set in the bearing.



Test Results:

The average permanent set observed from the Tinius-Olsen test measurement was approximately .005 inches. No metallic deformation was evident on the test bearings.

Conclusion:

After the axial load of 7570 lbs was applied to tested bearing, the average permanent set was .005 inches. This meets the requirements of MIL-B-81820 bearing specification.

Copy of USDA KAron V Approval Letter

(Dated July 19, 1989)

United States Department of Agriculture

Food Safety and Inspection Service

Washington, D.C. 20250

July 19, 1989

Dr. John C. Kornegay, P.E.
Kamatics Corporation
P.O. Box 3
Bloomfield, CT 06002

Dear Dr. Kornegay:

Thank you for your letter, brochures and samples showing the KAron V bearing liner material.

We have no objection to it on bearings which are component parts of equipment accepted for use in Federally inspected meat and poultry plants.

Sincerely,

Ronald M. Partyka
Industrial Specialist
Equipment Branch
Facilities, Equipment and Sanitation Division
Technical Services

KAron B Fluid Contamination Endurance Testing

<u>Purpose of Test:</u>
Testing was performed to determine the wear characteristics of KAron B liner material when operating with a variety of fluid contaminants.

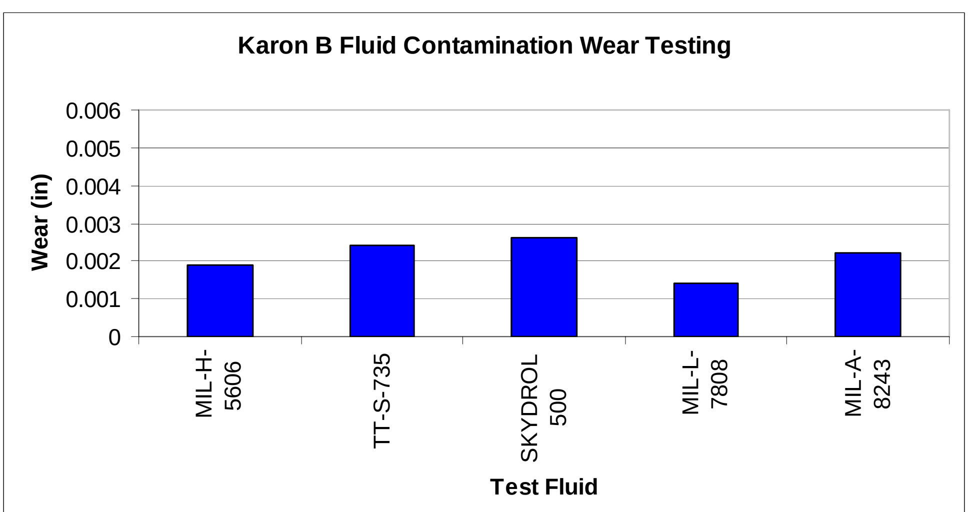
<u>Test Conditions:</u>
Testing was performed similarly to the fluid contamination requirements of AS81820 paragraph 4.6.5.

<u>Specimens</u> – Three (3) specimens each per fluid – Ø1.0in [25.4mm] bore X 0.5in [12.7mm] long. Three (3) specimens were tested without fluid contamination.

<u>Fluid Exposure</u> – Each specimen was soaked for 24 hours at 160°F ±5° (71° ±2.5°) except turbine fuel at 110°F (43°C). – Endurance testing was performed within ½ hour after removal from each test fluid.

<u>Test Parameters:</u>

Load:	*25,000 psi (172 MPa)*
Oscillation Angle:	*±25° (100° total per cycle)*
Total Cycles:	*25,000*
Frequency:	*20 CPM*
Temperature:	*Room Temperature*
Test Fluids	*Mil-H-5606, TT-S-735, Skydrol 500, Mil-L-7808, Mil-A-8243*



Ref Kamatics Data Sheet 170

KAron V Fluid Contamination Endurance Test

Purpose of Test:
Testing was performed to determine the wear characteristics of KAron V liner material when operating with a variety of fluid contaminants.

Test Conditions:
Testing was performed similarly to the fluid contamination requirements of AS81820 paragraph 4.6.5.

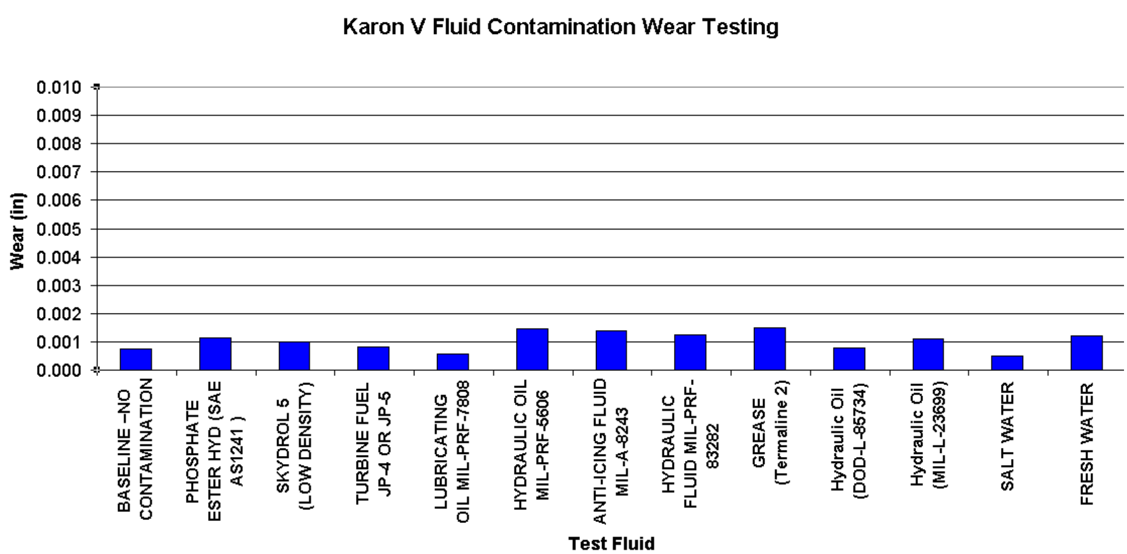
Specimens – *Three (3) specimens per Fluid – Ø1.0in [25.4mm] bore X 0.5in [12.7mm] long. Three specimens were tested without fluid contamination.*

Fluid Exposure –Each specimen was soaked for 24 hours at 160°F ±5° (71° ±2.5°) except turbine fuel at 110°F [43°C]. Endurance testing was performed within ½ hour after removal from each test fluid.

Test Parameters:

Load:	*20000 psi (138 MPa)*
Oscillation Angle:	*±25° (100° total per cycle)*
Total Cycles:	*25,000*
Frequency:	*20 CPM*
Temperature:	*Room Temperature*
Test Fluids:	*Phosphate Ester Hyd (SAE AS1241),Skydrol 5, JP-4 or JP-5, Mil-PRF-7808, Mil-PRF-7808,Mil-PRF-5606, Mil-A-8243, Mil-PRF-83282,Termaline 2 grease, Hyd Oil DOD-L-85734, Mil-L-23699, Salt Water, Fresh Water*

Test Results:
Average wear for three samples tested



Ref Kamatics Data Sheet 169

KAron VS Fluid Contamination Endurance Test

Purpose of Test:
Testing was performed to determine the wear characteristics of KAron VS liner material when operating with a variety of fluid contaminants.

Test Conditions:
Testing was performed similarly to the fluid contamination requirements of AS81820 paragraph 4.6.5.

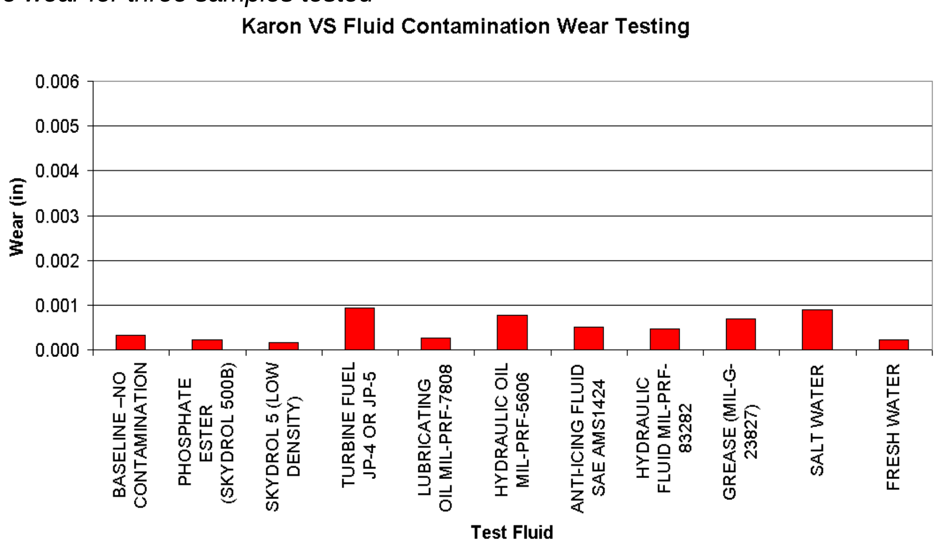
Specimens – *Three (3) specimens per Fluid – KRJ16-SVS-016 Ø1.0in [25.4mm] bore X 0.5in [12.7mm] long. Three specimens were tested without fluid contamination.*

Fluid Exposure –Each specimen was soaked for 24 hours at 160°F ±5° (71° ±2.5°) except turbine fuel at 110°F [43°C]. Endurance testing was performed within ½ hour after removal from each test fluid.

Test Parameters:

Load:	*12000 psi (82.8 MPa)*
Oscillation Angle:	*±25° (100° total per cycle)*
Total Cycles:	*25,000*
Frequency:	*20 CPM*
Temperature:	*Room Temperature*
Test Fluids:	*Phosphate Ester Hyd (SAE AS1241),Skydrol 5, JP-4 or JP-5, Mil-PRF-7808, Mil-PRF-7808,Mil-PRF-5606, Mil-A-8243, Mil-PRF-83282,Termaline 2 grease, Hyd Oil DOD-L-85734, Mil-L-23699, Salt Water, Fresh Water*

Test Results:
Average wear for three samples tested

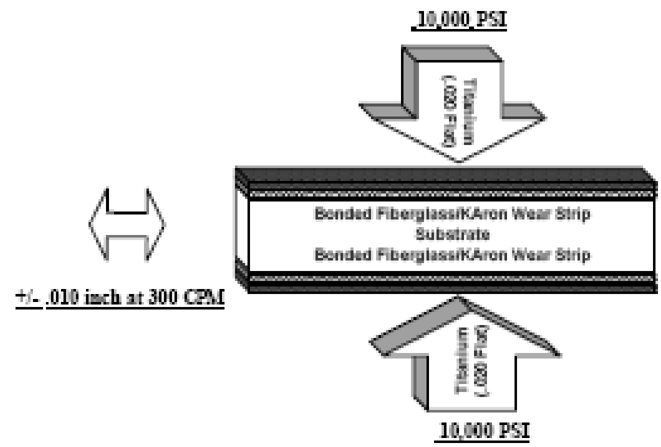


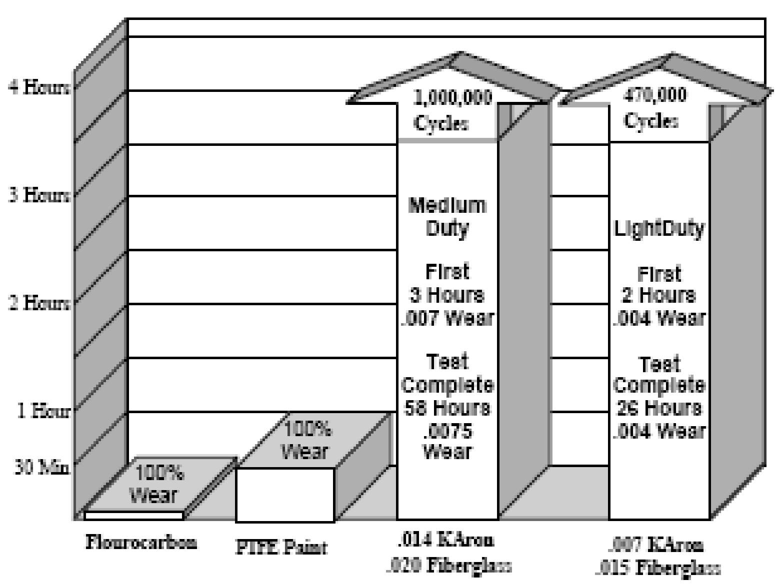
Ref Kamatics Data Sheet 164

KAron Wear Strip Edge Loaded Vibration Endurance Test

(Reference Kamatics Data Sheet 114)

Problem: *The airlines were reporting extensive fretting damage at the interface between the titanium fan cowl support beam (6AL-4V Annealed) and the aluminum front engine inlet cowl. The knife edge contact (Approximately .020 inches wide [.50 mm] wide) combined with high vibrations was the causing the damage. It was decided to compare the anti-fretting/wear properties of a Fluorocarbon wear pad, TFE paint and KAron wear strips. After 24 hours the wear strips would be evaluated, failure would be a complete wear through of the coating.*





The customer selected the KAron Light Duty Wear Strip for production and retrofit.

Kamatics High Speed KAron V Bushing Test

Application
C5 Landing Gear Door System U-Joint

Problem
Premature wear of existing bushing causing premature overhaul

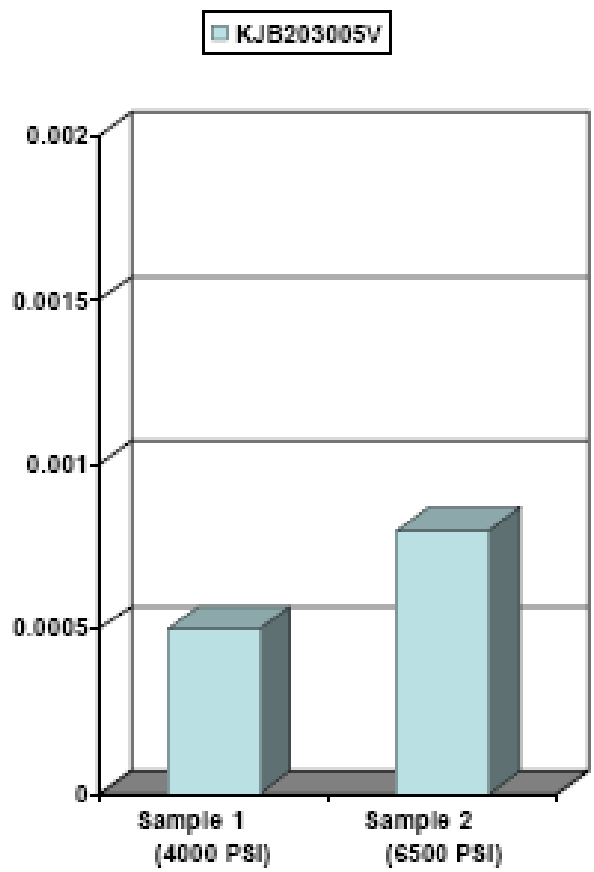
Test Plan
Duplicate operating parameters in a laboratory environment

Test Specimen = Flanged Bushing
Bore dia (ID) = .3125 inches
Length = .250 inches
Housing material = 17-4PH Stainless Steel
Liner = KAron V

Test Conditions and Results
Sample 1 = 4000 psi
Sample 2 = 6500 psi
Room (Ambient) Temperature
Cycle Rate = 1100 cpm

Duration
Sample 1 = 2.6 Million Cycles
Sample 1 = 8.5 Million Cycles

Liner Wear
Sample 1 = 0.0005 inches
Sample 1 = 0.0008 inches



Reference Kamatics Data Sheet 62

Kamatics Rudder Hinge Test
KAron B and KAron V

<u>Application</u>: E2-C2 Naval aircraft rudder hinge spherical bearings

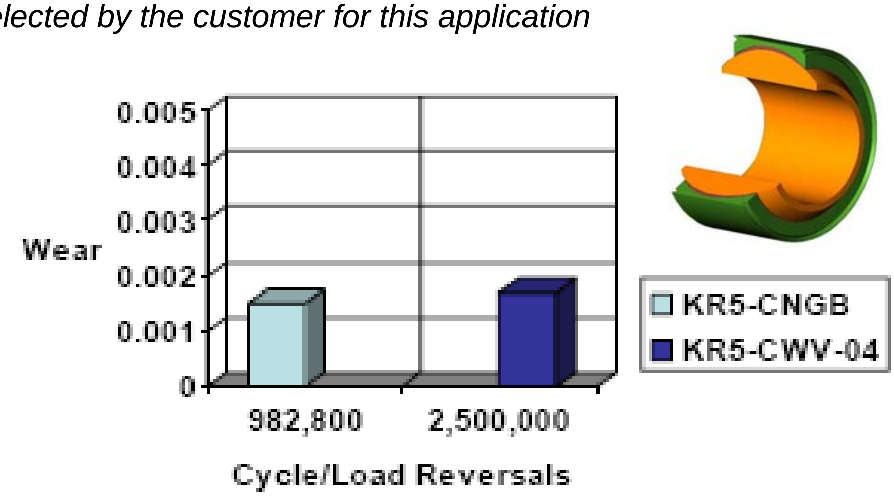
<u>Problem</u>: The existing metal to metal bearings on the 4 vertical rudders are failing prematurely. Considered cause is the pulsating load introduced by the propellers, engine exhaust, marine environment and lack of lubrication.

<u>Test Plan</u>: Evaluate both KAron B and KAron V lined bearings for this application. The customer supplied the test fittings and load spectrum.

<u>Test Specimens:</u>
1, KR5-CNGB, .3125 in. ID, Ball = 440C, Outer Race= 17-4PH, Liner = KAron B
2, KR5-CWV-04, .3125 in. ID, Ball =17-4PH plus chrome plate, Outer Race= 17-4PH Liner = KAron V

<u>Test Conditions:</u>
Load = ± 1000 pounds (approximately 8500 psi)
Cycle Rate = 100 Hertz
Oscillation Angle = 1° total (fitting deflection under load)
Temperature = Ambient (room)

<u>Results</u>: Both KAron liner systems performed well under these conditions. Due to a fatigue failure of the fitting containing the KAron B specimen, this test was terminated at 982,800 cycles. The KAron V evaluation was terminated after successfully completing 2.5 million cycles. The KAron V bearing (KR5-CWV-04) was selected by the customer for this application



Reference Kamatics Data Sheet 75

Kamatics High Vibration Spherical Bearing Test

Application; Aircraft engine controls spherical bearing

Problem; High vibrations from the engine operation are causing the existing metal-to-metal spherical bearings to seize in service causing premature removal.

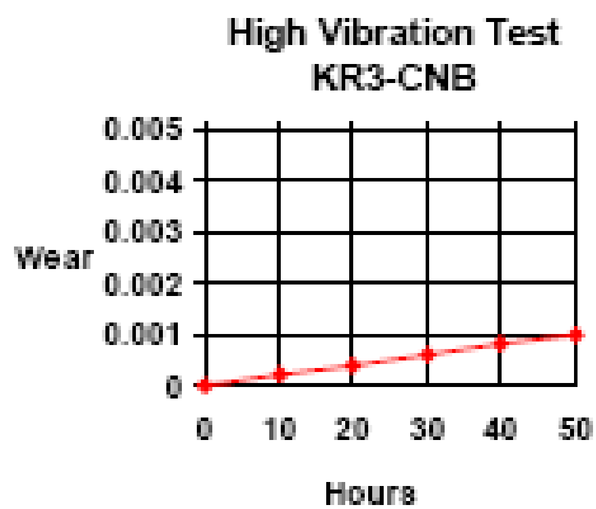
Test Plan: Evaluate the customer supplied metal-to-metal spherical bearing with a similar size Kamatics KAron B lined spherical bearing and duplicate the operating environment.

Bearings: KR3-CNB (.190 in ID, 440C Ball, 17-4 PH Outer Race, KAron B Liner System.
Metal-to-metal bearing, Carbon steel/ tin nickel plated, stainless steel outer race

Test Conditions:
Load = 100 pounds (1250 psi)
Cycle Rate = 300 cpm
Oscillation Angle = ± 2°
Temperature = Ambient (room)
Duration = 50 hours

Test Results:
KR3-CNB
Less than 0.001 in liner wear.
Ball and liner in excellent condition.
Free movement of bearing

Metal-to-Metal (not shown in chart)
Bearing exhibits severe fretting.
Corrosion damage.
Ball difficult to move.



KAron B Impact Loading Evaluation
Naval Aircraft Arrestor Hook Application
(Sheet 1 of 2)

Purpose of Test:

To evaluate the performance of a KAron B liner in a spherical bearing used in an assembly for a very high impact loaded naval aircraft arrestor hook application.

Test Specimens:

Two (2) KR16-CWGB spherical bearings, dimensionally equivalent to MS14103-16, AMS 5643 (17-4PH) CRES outer race, KAron B liner, AMS 5630 (440C) ball and one (1) KRJ20-SB-032 sleeve bearing dimensionally equivalent to M81934/1-020C032, AMS 5643 (17-4PH) CRES outer housing and a KAron B ID liner.

Test Procedure: (See Figure 1)

The first spherical bearing, (KC5581) was tested for a required 7500 minimum cycles and removed from the test fixture for examination. The second bearing, (KC5582) was tested for an extended period of time to develop long term results.

The spherical test bearing was mounted in a moveable link that connected the link to a hydraulic cylinder. The link was then pinned to a rigid restraint as shown. The hydraulic cylinder was attached to a restraint on the opposite end of the fixture and was free to pivot as the load was applied. The cylinder and link were positioned so that the link/cylinder connection containing the test spherical bearing was free to drop (relax/gravity) three (3) degrees prior to applying the load. As the load was applied, the link and cylinder rotated three (3) degrees into a straight line between the two rigid end connections. A load (force) of 0 to 40,000 pounds was applied within 0.025 seconds and held for a 2 second time period, removed for 2 seconds and repeated continuously in this "2 seconds on – 2 seconds off" mode for the duration of the test.

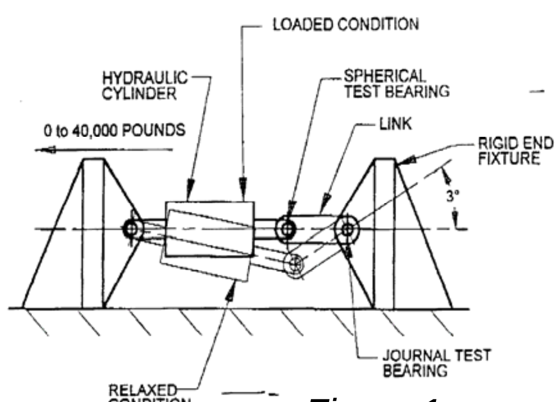


Figure 1

KAron B Impact Loading Evaluation
Naval Aircraft Arrestor Hook Application
(Sheet 2 of 2)

Approximately mid way through the testing of the second spherical bearing (KC5582), a KAron B lined sleeve bearing (KC5594) was installed at the link-to-end restraint location to generate results of the impact loading on a sleeve (journal) bearing. The bearing was a Kamatics KRJ20-SB-032. The mating shaft was made from AMS 5643 (17-4PH), 8 RMS surface finish, Rc 40 hardness.

Test conditions:

Load=	*0 to 40,000 pounds (0 to 22,575 psi spherical, 0 to 32,000 psi journal)*
Oscillation Angle=	*3° (6° total °per cycle)*
Speed=	*0.025 seconds 0 to 40,000 pounds*
Stroke=	*2 seconds on, 2 seconds off*
Temperature=	*Ambient (room)*

Test Results:

Specimen	Bearing Type	No. of Cycles	Load (pounds)	Bearing Pressure (psi)	Wear (inches)
KC5581	Spherical	7560	0 to 40,000	0 to 22,575	<0.001
KC5582	Spherical	119160	0 to 40,000	0 to 22,575	0.001
KC5594	Journal	51480	0 to 40,000	0 to 22,575	0.001

Conclusions:
The three bearings listed, at the conditions and number of cycles noted, exhibited no distress to either the ball or shaft surfaces upon completion. The ball/shaft were free to rotate without resistance and the liners were in excellent operating condition. Based on these results, KAron B liners system should be considered for use in this type of sudden, high impact loading applications.

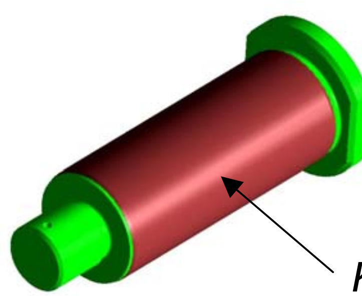
Ref Kamatics Data Sheet 110

KAron VS Flight Control Actuator Pins

- *Tested and qualified by Airbus in Hydraulic Fluid (Skydrol), Jet Fuel, Lubricating Oil, De-Icing Fluid, and Dust*
- *KAron VS exhibited an excellent coefficient of friction at both ambient (room) and cold temperatures*
- *Low friction reduces aircraft weight, reduced size/weight actuators, reduced size/weight supporting structure*
- *KAron VS Pins provide for primary rotation motion on flight control actuators*
- *KAron VS Pins are used on*
  - *Ailerons*
  - *Elevators*
  - *Rudders*
  - *Spoilers*

Qualification Test Results

- *Coefficient of Friction*
  - *Requirement: 0.18 max. at -54ºC (-65ºF)*
  - *Measured: 0.12 (33% less than requirement)*



KAron B – Hydraulic Fluid Endurance Test (MIL-H-83282A)

Purpose of Test:

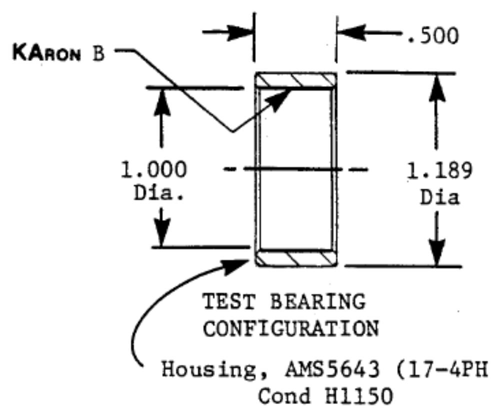
To determine the suitability of KAron B for applications involving MIL-H-83282A hydraulic fluid as a contaminate.

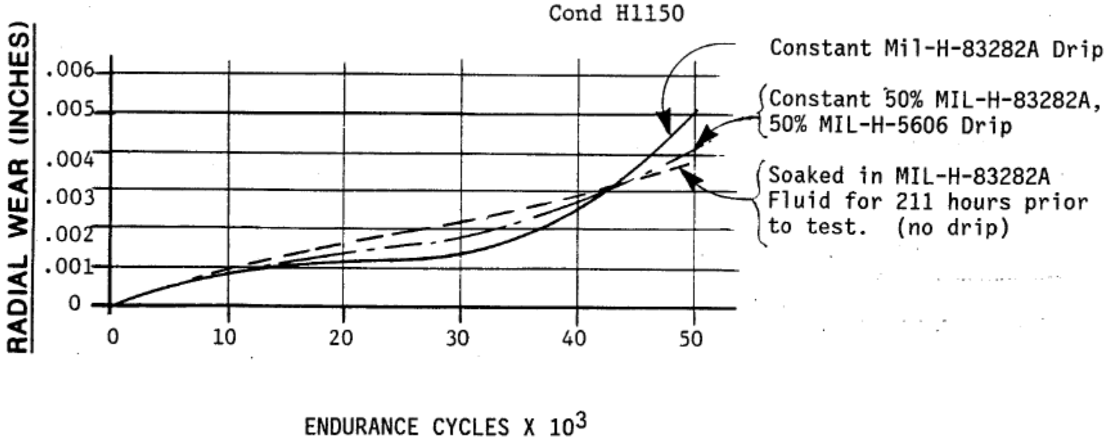
Test Conditions:

Speed =	*20 cpm*
Oscillating Angle =	*± 25° (100° total)*
Load =	*12,500 pounds (25,000 psi)*
Temperature =	*Ambient (room)*
Contamination =	*MIL-A-83282A Hydraulic fluid*

Test Results:

3 KAron B lined journal bearings were contaminated as notes in the chart below for approximately 50,000 cycles. The maximum measured liner wear on the 3 samples was 0.005 inches. The KAron B liner exhibited a smooth polished contact area. The mating shaft (AMS5643, 17-4PH, Rc 40-47) was unaffected by the testing.





Ref Kamatics Data Sheet 55

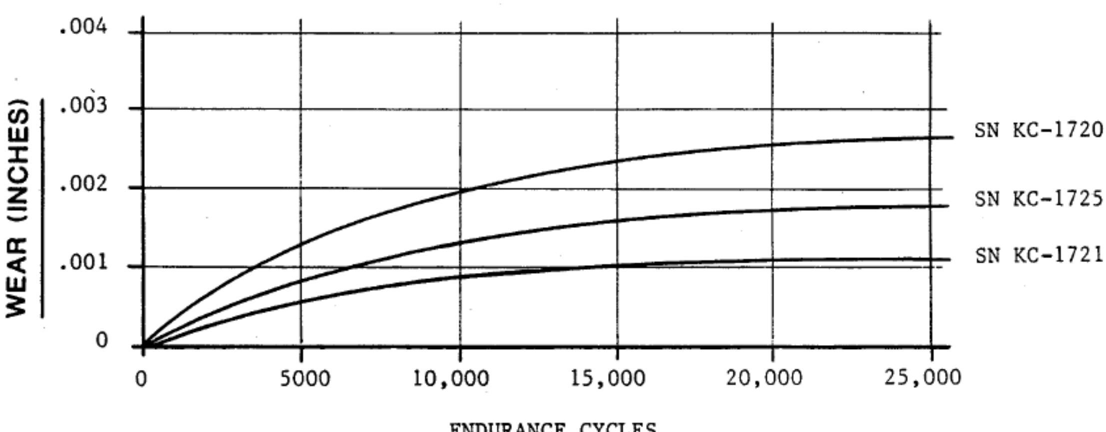
KAron B – Hydraulic Fluid Endurance Test (MIL-H-5606)

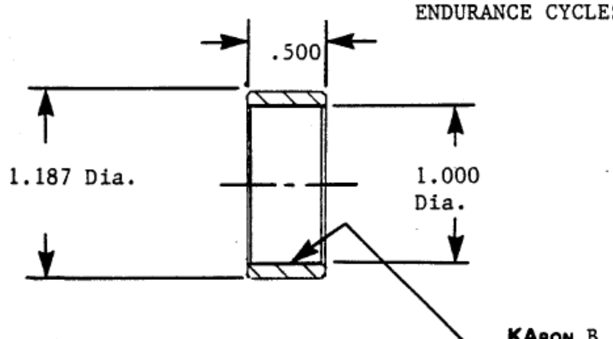
<u>Purpose of Test:</u>
To determine the suitability of KAron B for applications involving MIL-H-5606 hydraulic fluid as a contaminate.

<u>Test Conditions:</u>

Speed =	*20 cpm*
Oscillating Angle =	*± 25° (100° total)*
Load =	*18,000 pounds (36,000 psi)*
Temperature =	*Ambient (room)*
Contamination =	*MIL-A-5606 Hydraulic fluid (constant drip)*

<u>Test Results:</u>
3 KAron B lined journal bearings were contaminated as notes in the chart below for 25,000 cycles. The maximum measured liner wear on the 3 samples was 0.0028 inches. The KAron B liner exhibited a smooth polished contact area. The mating shaft (AMS5643, 17-4PH, Rc 40-47, 16 rms finish) was unaffected by the testing.





Materials:

Housing, AMS5643 (17-4PH) Cond H1150
Liner, KAron B
Test Shaft, AMS5643 (17-4PH) Cond H900
16 RMS

Test Bearing
Configuration

Ref Kamatics Data Sheet 56

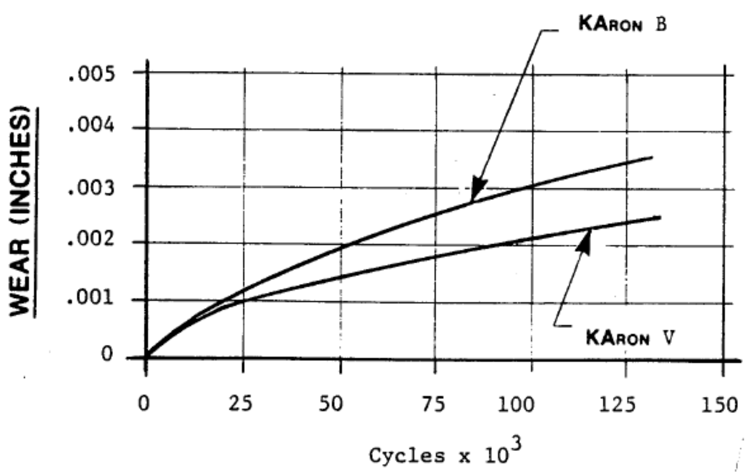
KAron B & V Operating Against Uncoated Titanium - Endurance Test

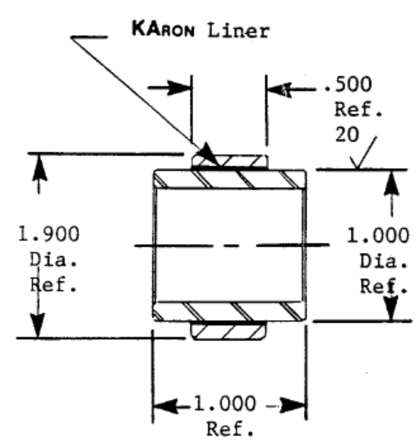
<u>Purpose of Test:</u>
To determine the wear characteristics of KAron B and V when operating against Bare uncoated 6Al-V titanium. Also to observe the effects, if any, on the surface of the titanium.

<u>Test Conditions:</u>

Speed =	*20 cpm*
Oscillating Angle =	*± 25° (100° total) (inner sleeve oscillation)*
Load =	*2,500 pounds (5,000 psi)*
Temperature =	*Ambient (room)*
Contamination =	*none*

<u>Test Results:</u>
The KAron B & V lined journal bearings were run against a ground bare titanium inner sleeve with an approximately 20 rms surface finish for 131,000 cycles. There was no distress to the mating titanium surface at the conclusion of the test. The KAron B specimen exhibited approximately 0.0036 inches of wear. The KAron V specimen exhibited approximately 0.0025 inches of wear.





Test Bearing Configuration

Bearing Housing Material
17-4PH

Inner Sleeve Material
6A1 - 4V Titanium

Ref Kamatics Data Sheet 48

KAron V Operating Against Uncoated 316 Stainless Steel, 32 RMS Surface Finish - Endurance Test

Purpose of Test:

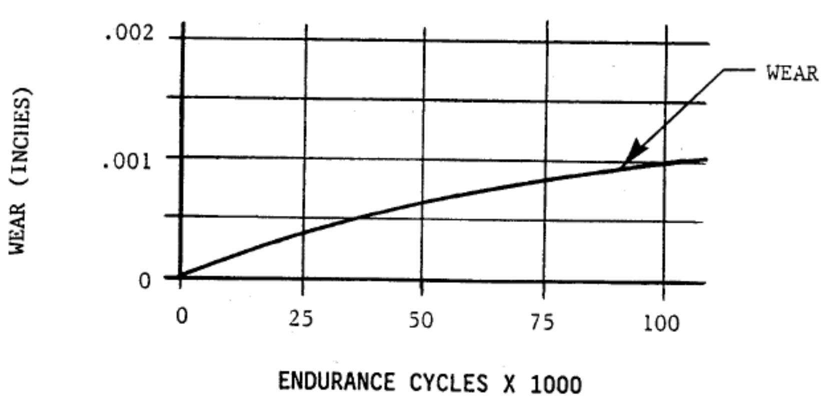
To determine the wear characteristics of KAron V when operating at moderate bearing pressures against a 316 stainless steel mating surface with a Brinell hardness of 150 and a 32 rms surface finish.

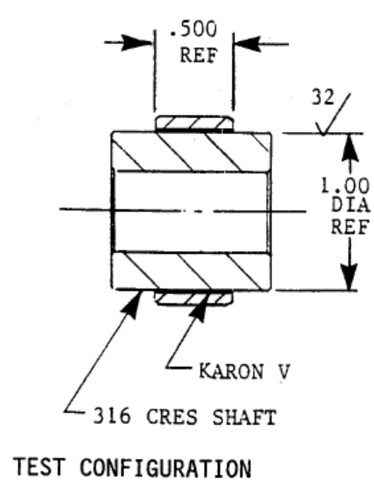
Test Conditions:

Speed =	*20 cpm*
Oscillating Angle =	*± 25° (100° total) (inner race oscillation)*
Load =	*5,000 pounds (10,000 psi)*
Temperature =	*Ambient (room)*
Contamination =	*none*

Test Results:

The KAron V liner was subjected to the noted conditions for a total of 100,000 cycles. The measured wear at the conclusion of the test was 0.001 inches as indicated on the chart below. There was minor polishing of the contact surface on the mating 316 stainless bearing surface.





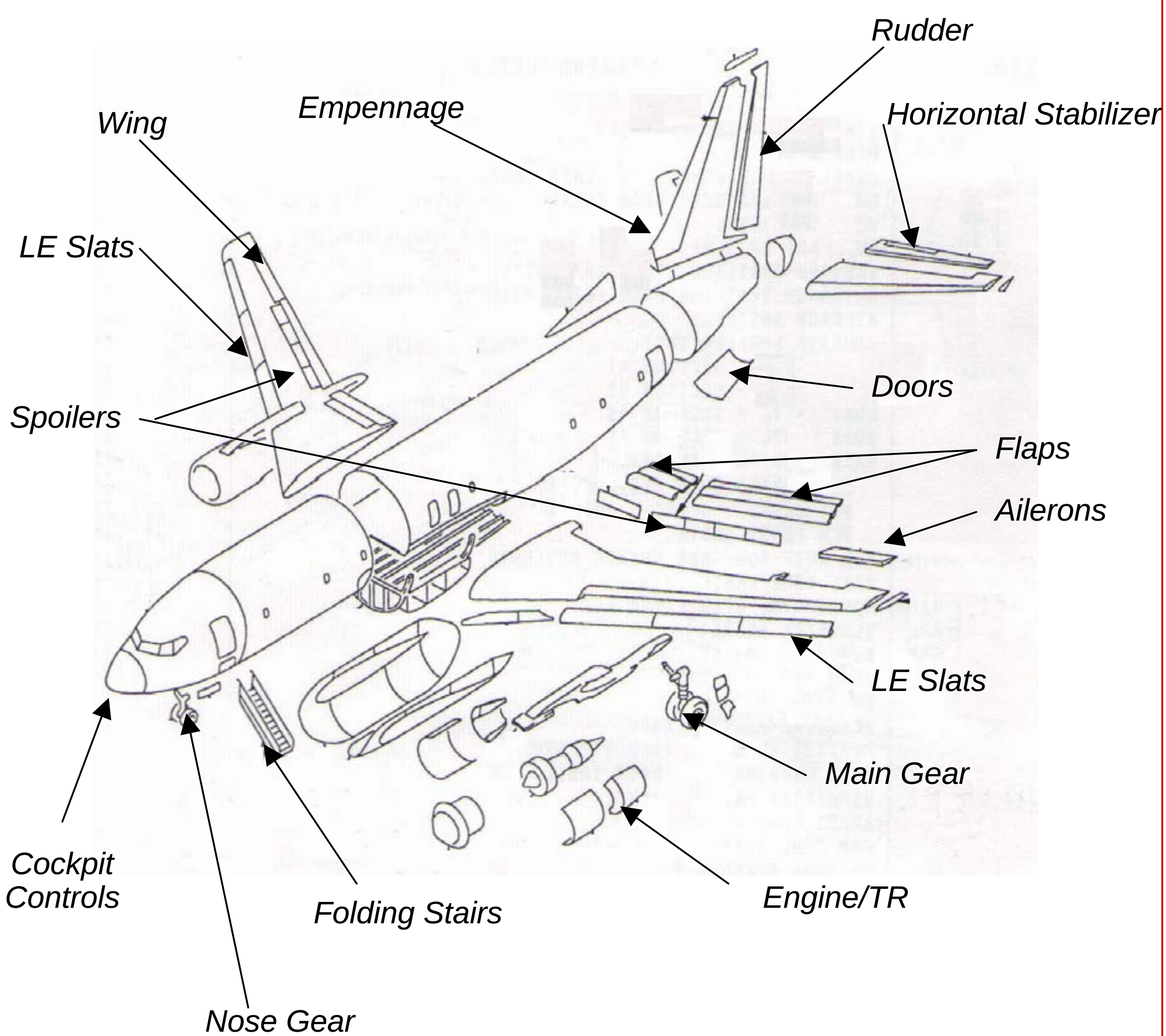
Ref Kamatics Data Sheet 66

Miscellaneous KAron Applications

Page	Description
1, 2	*Miscellaneous KAron Applications Index Sheet*
3	*Typical aircraft locations for Kamatics products*
4	*Tail Skid Split Bearing*
5	*Flap Side Load Roller Option*
6	*MLG Truck Beam Bushings*
7	*Outboard Engine Pylon Diagonal Strut Spherical Bearing*
8	*Flap Carriage Bearing (Potential Housing Salvage)*
9	*System 80 Nuclear Power Plant Applications*
10	*Various KAron Lined Landing Gear Bearing Configurations*
11	*Typical Kamatics Self-Lube Bearings For “Special/Difficult” Applications*
12	*KAron Liners on a Variety of Complex*
13	*Typical Kamatics KAron Landing Gear Applications*
14	*KAron Lined Landing Gear Strut, Steering & Actuator Cylinder Bearings*
15	*Special-Unique Applications Perfect for Kamatics Liner Systems*
16	*F15 Steering Collar Salvage*
17	*737 “Dry Wing” Installation*
18	*KAron Self-Lube Flight Control Bearings*
19	*Some 757 Applications, Some 747 Applications*
20	*Some 767 Applications, Some 777 Applications*
21	*Some AIRBUS A320 Series Applications, Some Bombardier RJ Applications*
22	*Typical KAron Lined Actuator Components*
23	*KAron Engine Applications*
24	*Nacelle & Thrust Reverser Applications*
25	*Demanding Military Aircraft Applications*
26	*F-18 Applications, F-22 Applications*
27	*Tornado Applications, EF2000 Typhoon Applications*
28	*JAS39 Gripen Applications, C-17 Applications*
29	*B-2 Applications, F-117 Applications, T-45 Applications*
30	*Kamatics KAron Lined Cruciform for Universal Joint*
31	*Kamatics Newest Product …RELIAMET*
32	*Reliamet (continued)*
33	*First Marine Applications (25 Years Ago)*
34	*Kamatics Marine Applications*

Aerospace Applications

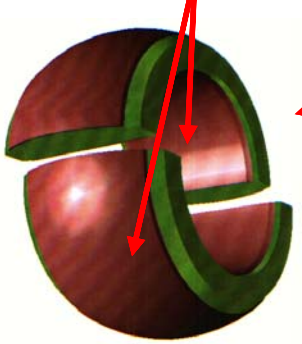
Typical aircraft locations for Kamatics products



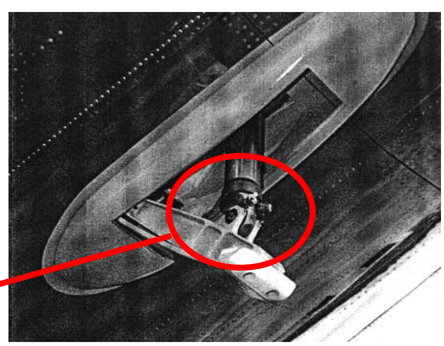
Tail Skid Split Bearing

KAron applied directly to Split Ball OD & ID.
Saves weight of Tail Skid Housing (No Outer Race).
Easy replacement of Ball if Damaged.
No need to Nitride inner spherical surface of Housing.

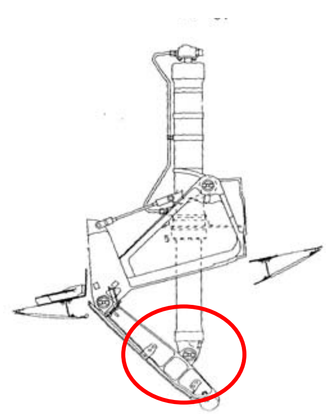
KARON LINER ON ID & OD



SPLIT BALL



VIEW LOOKING UP AT SKID MECHANISM

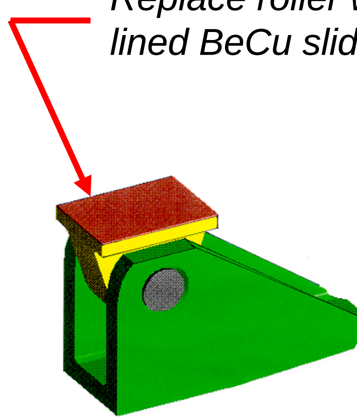


CUT-AWAY VIEW

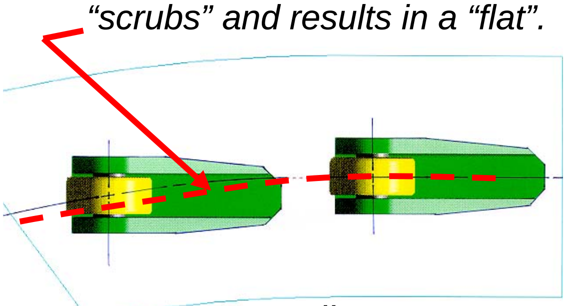
Flap Side Load Roller Option

Flat Spot on both needle and self-lube rollers

Replace roller with KAron lined BeCu slider

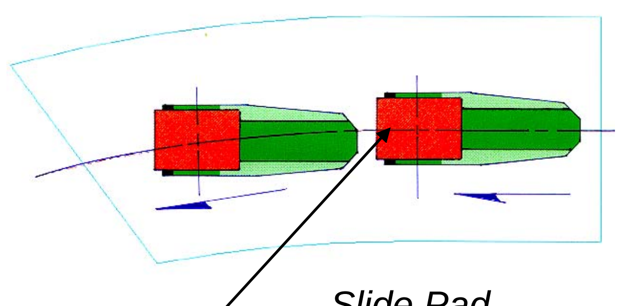


Track direction not in line with path of roller. The roller OD “scrubs” and results in a “flat”.



Roller

Not a problem for a KAron lined slider (a big problem for a roller)



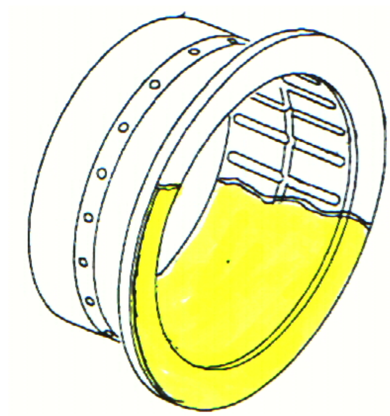
Slide Pad

MLG Truck Beam Bushings

Originally a greased beryllium copper bearing system. Severe impact loading from rough runways caused grease to be expelled from the load zone. Severe damage occurred to the bearings and fire to landing gear.

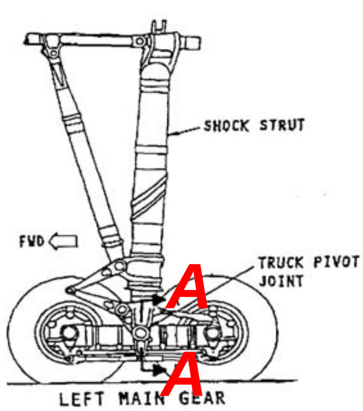
KAron V applied to the ID and flange face to act as a lubricant during high impact occurrences.

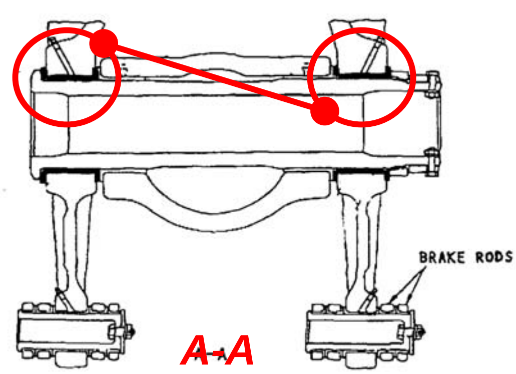
<u>Extensive rig and actual flight test evaluation with excellent results.</u>



KAron Liner .005" (0.127mm) thick applied directly over BeCu substrate

2 Sets of "back to back" Bushings each gear.

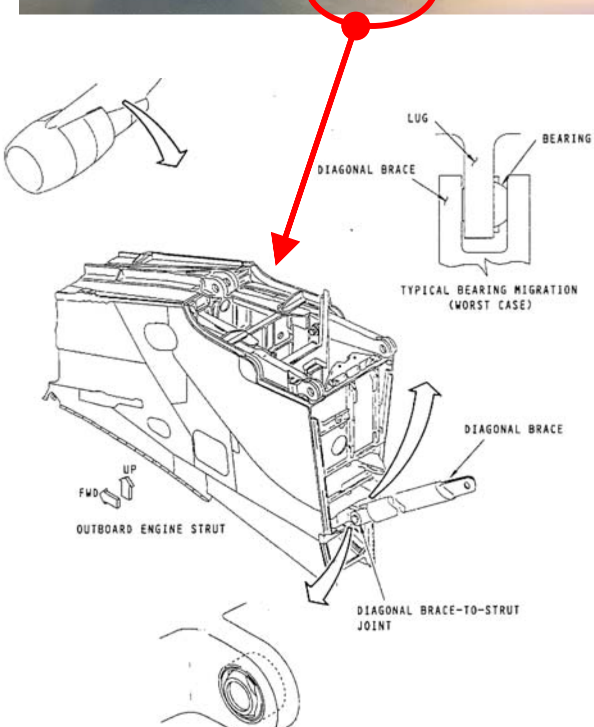




Outboard Engine Pylon Diagonal Strut Spherical Bearing

Kamatics conducted half scale test comparing KAron B lined spherical and metal / metal dry film lubricated spherical. Kamatics results outstanding.

Customer conducted extensive full scale testing of Kamatics KAron VS. actual production metal / metal DFL spherical. Kamatics results outstanding. Service Bulletin 747-54-2181 released to replace original bearing with Kamatics bearing. (Ref. Kamatics Data Sheet 127 for additional details.)

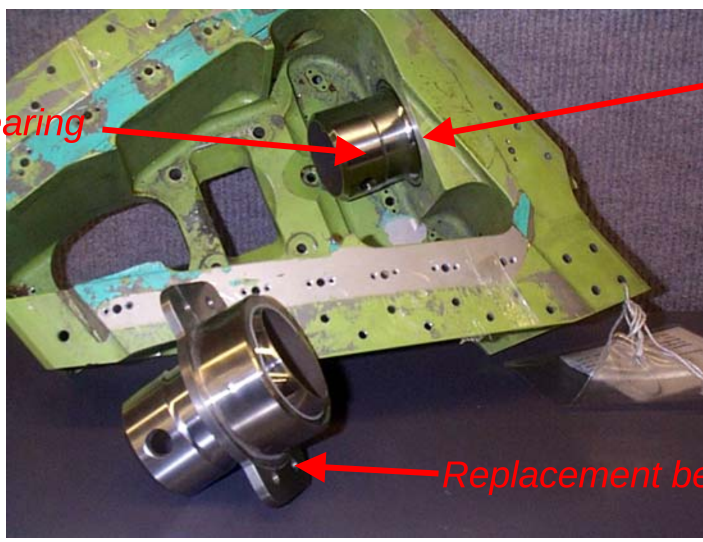


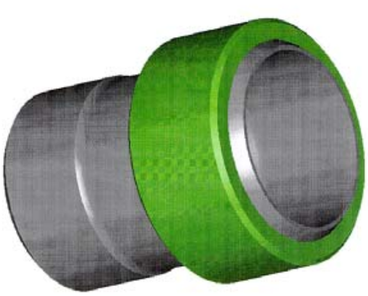
Flap Carriage Bearing (Potential Housing Salvage)

Corrosion to aluminum housing between bearing OD and mating bore. The existing overhaul technique limits the life of the housing. It is very costly to replace the housing.

The addition of the flange to the bearing outer race allows additional overhaul to the housing.

Under customer authorization, a flight evaluation is in process with over 7000 flight cycles.

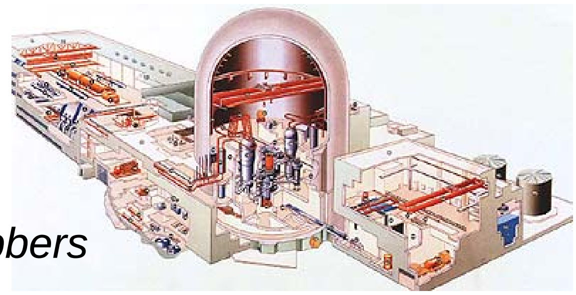




Original Spindle Bearing

Flanged Spindle Bearing

System 80 Nuclear Power Plant



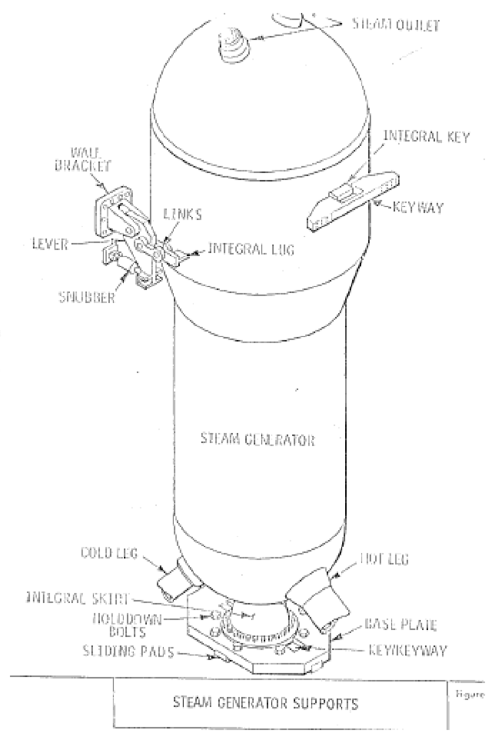
Current Applications

•Reactor Mounts

•Circulation Pump Mount Snubbers

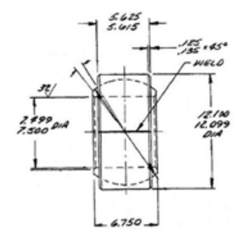
•Instrumentation Monitor Tube Supports

•Monitoring System Linkages



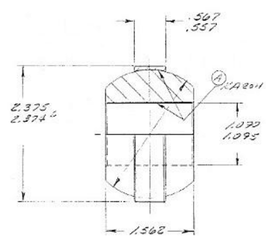
<u>KAron B</u>

Shock Absorber/Snubber



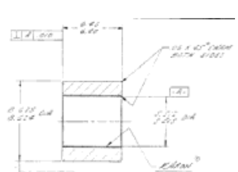
<u>KAron GP</u>

High Misalignment Spherical for Refueling Rod System

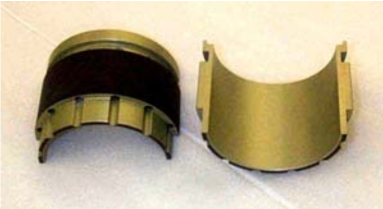


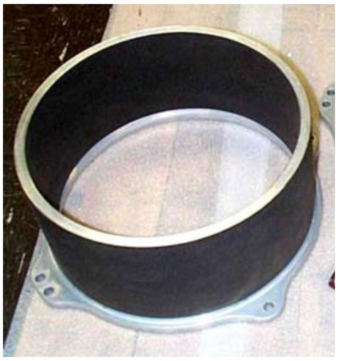
<u>KAron B</u>

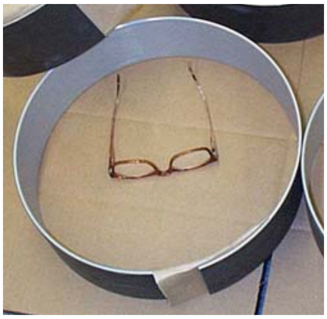
Linkage Bushing

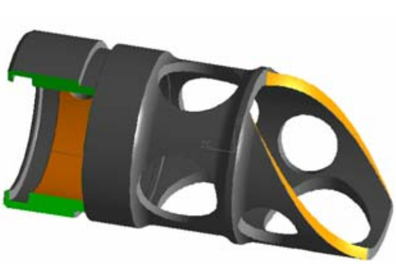


Various KAron Lined Landing Gear Bearing Configurations



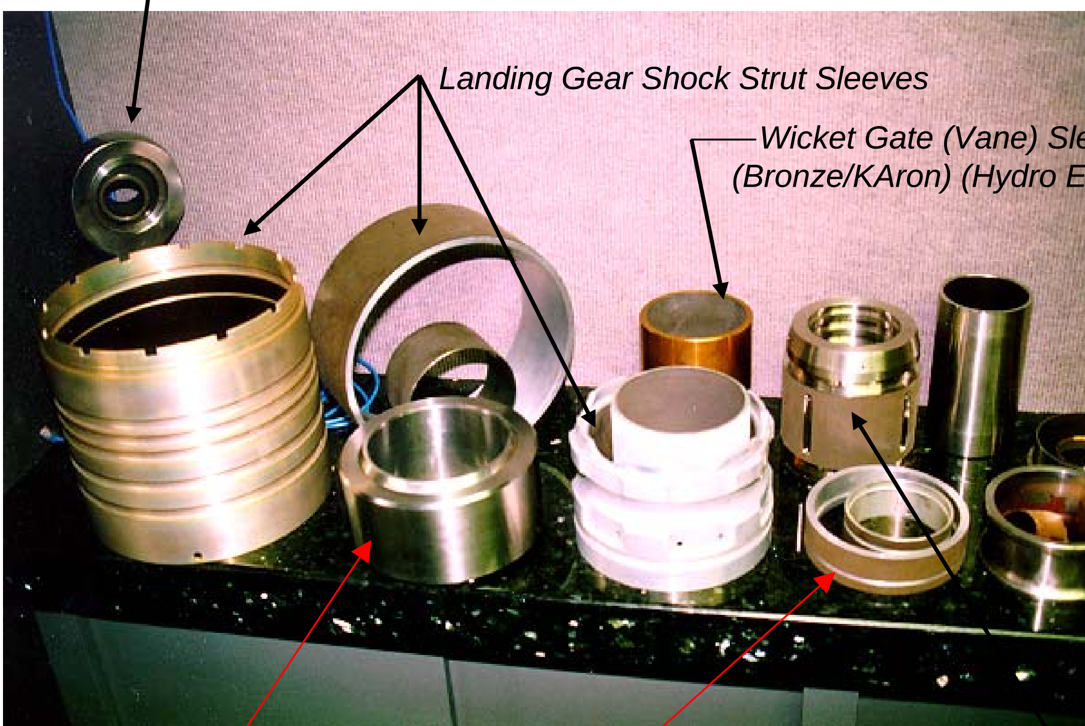






Typical Kamatics Self-Lube Bearings For Those "Special/Difficult" Applications

Space Shuttle Booster
Rod End (18" Long)
Inconel 718

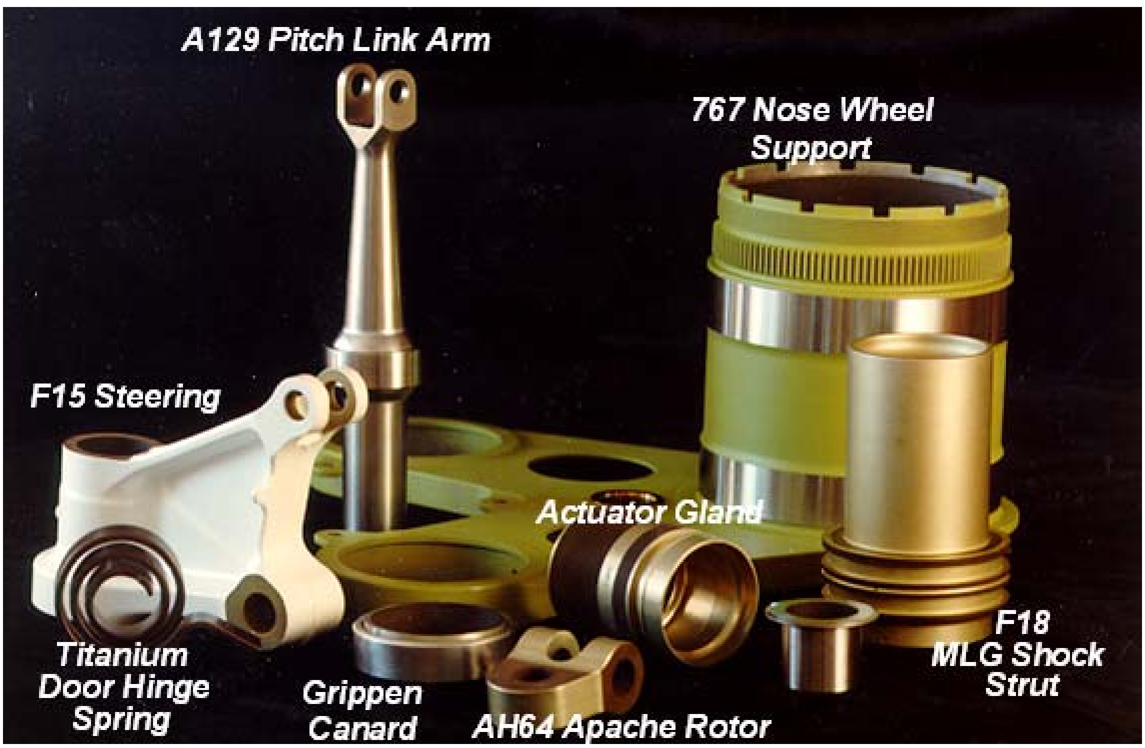


Submarine Rudder Linkage Spherical

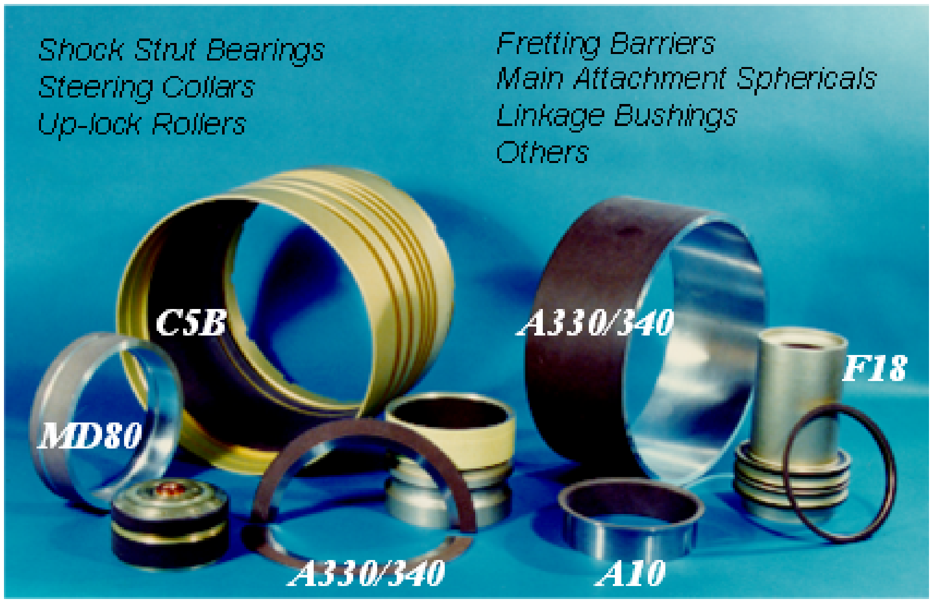
Hydraulic Cylinder Glands

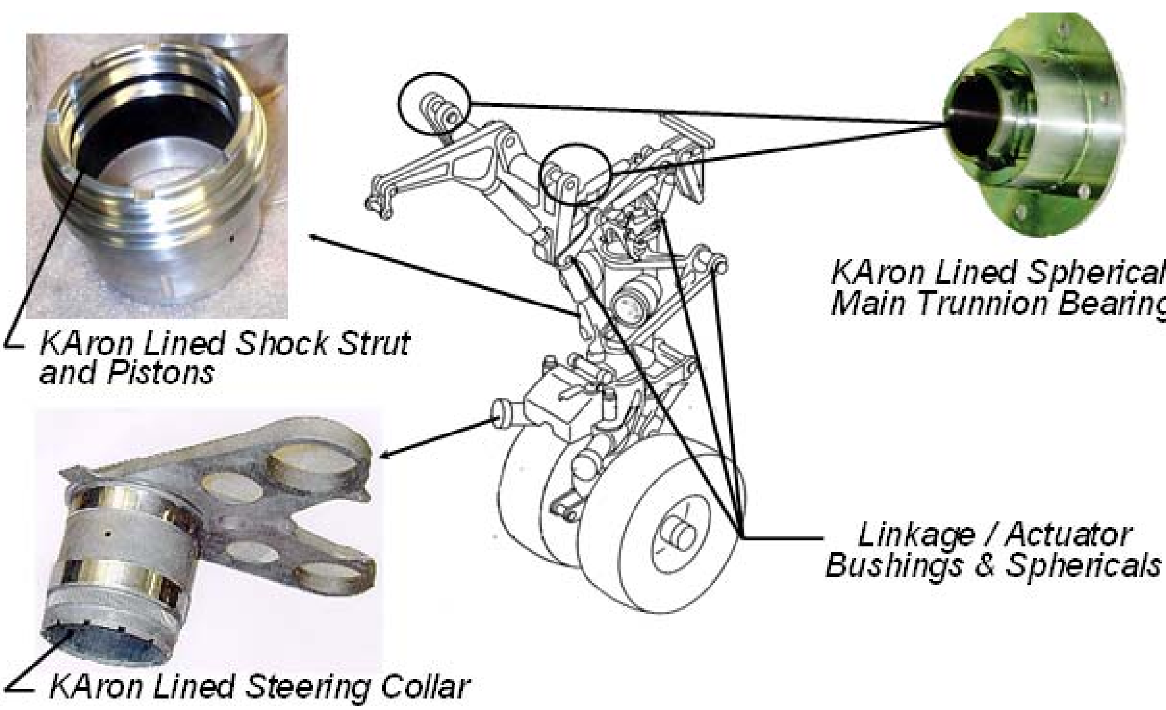
Pelton Nozzle Sleeve (Hydro Electric)

KAron Liners on a Variety of
Complex Configurations…and…
Most Expensive Housings can be Refurbished

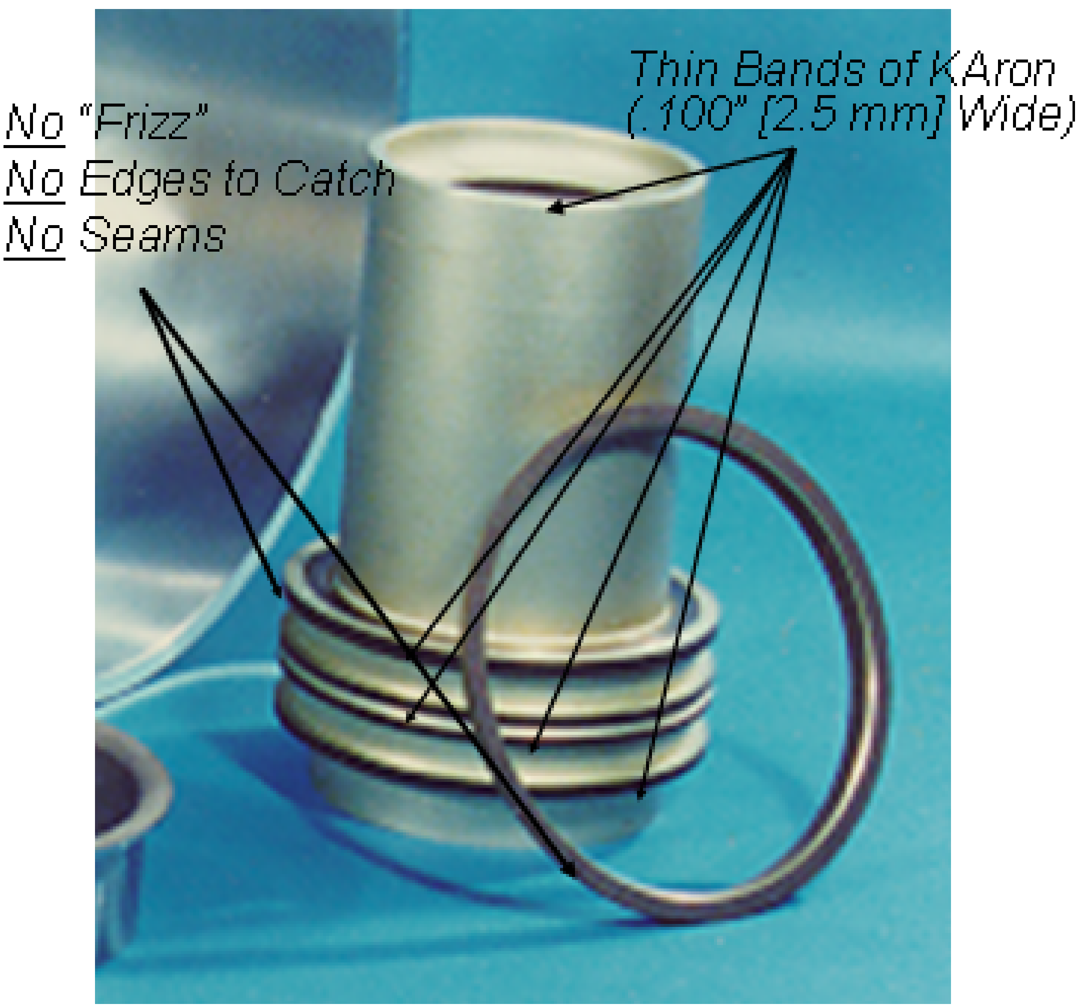


Typical Kamatics KAron Landing Gear Applications



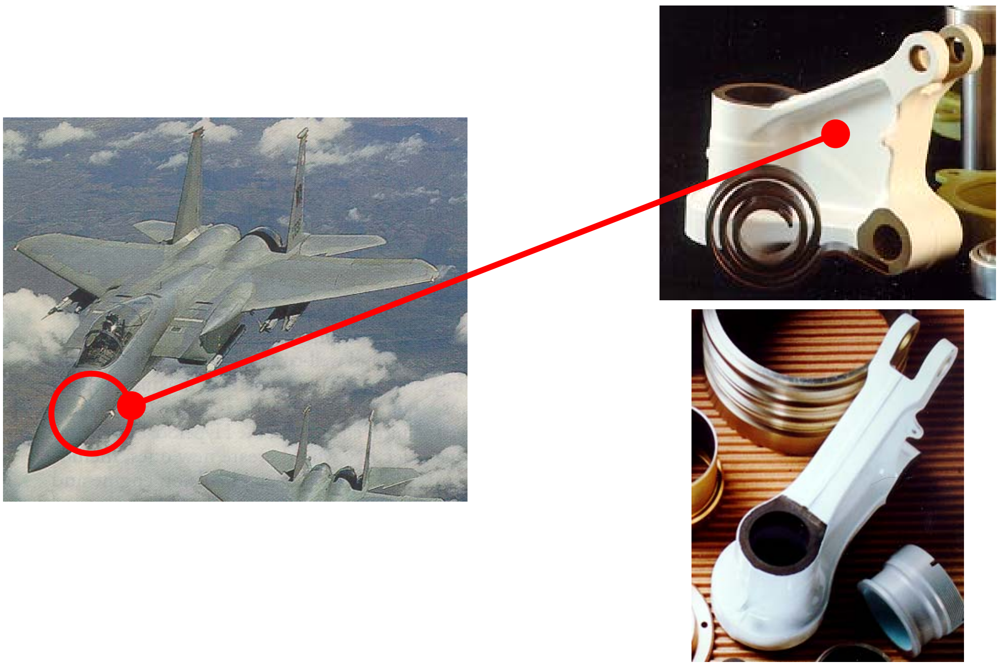


KAron Lined Landing Gear Strut, Steering & Actuator Cylinder Bearings



Special-Unique Applications Perfect for Kamatics Liner Systems

F15 Steering Collar Salvage

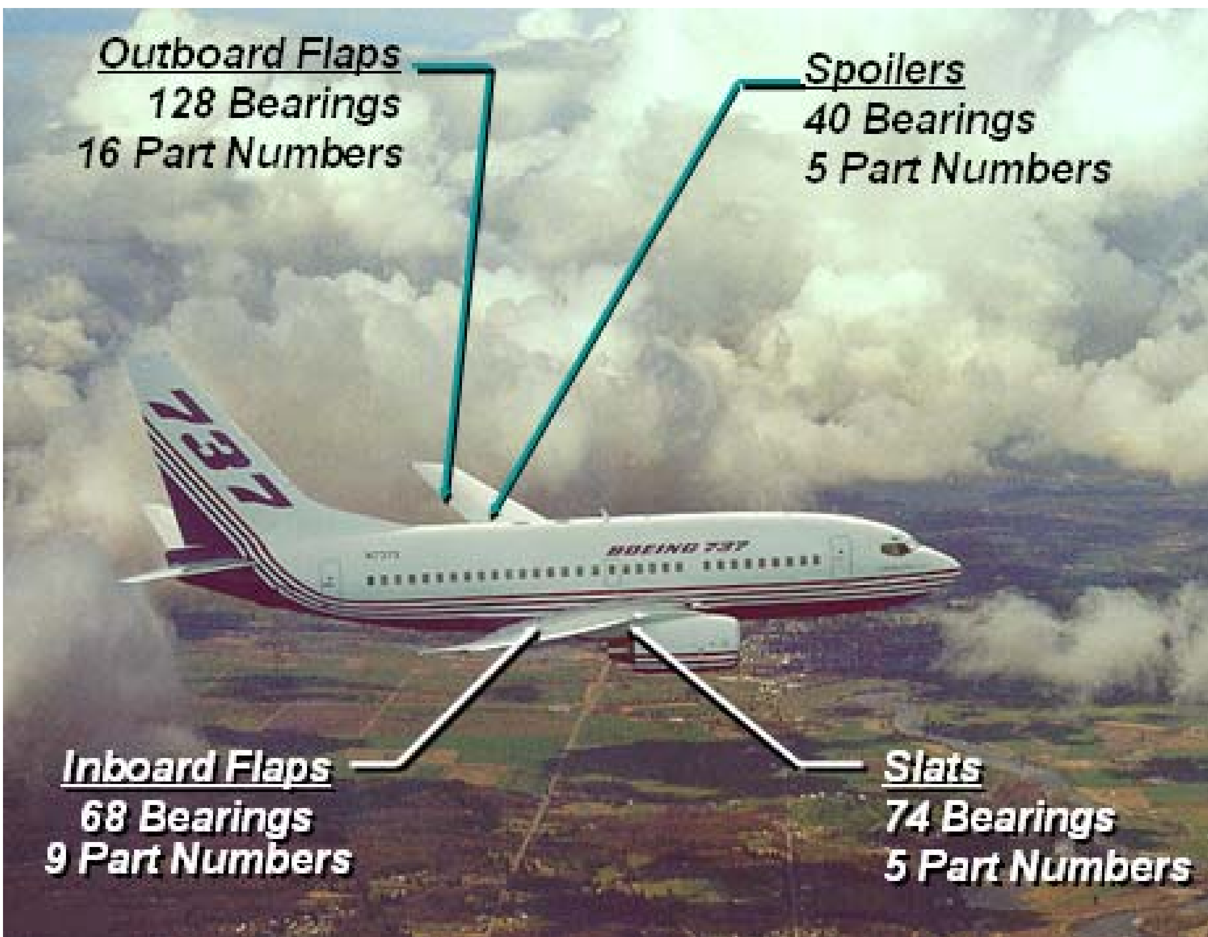


<u>Nose Landing Gear Steering Collar Salvage Program</u>

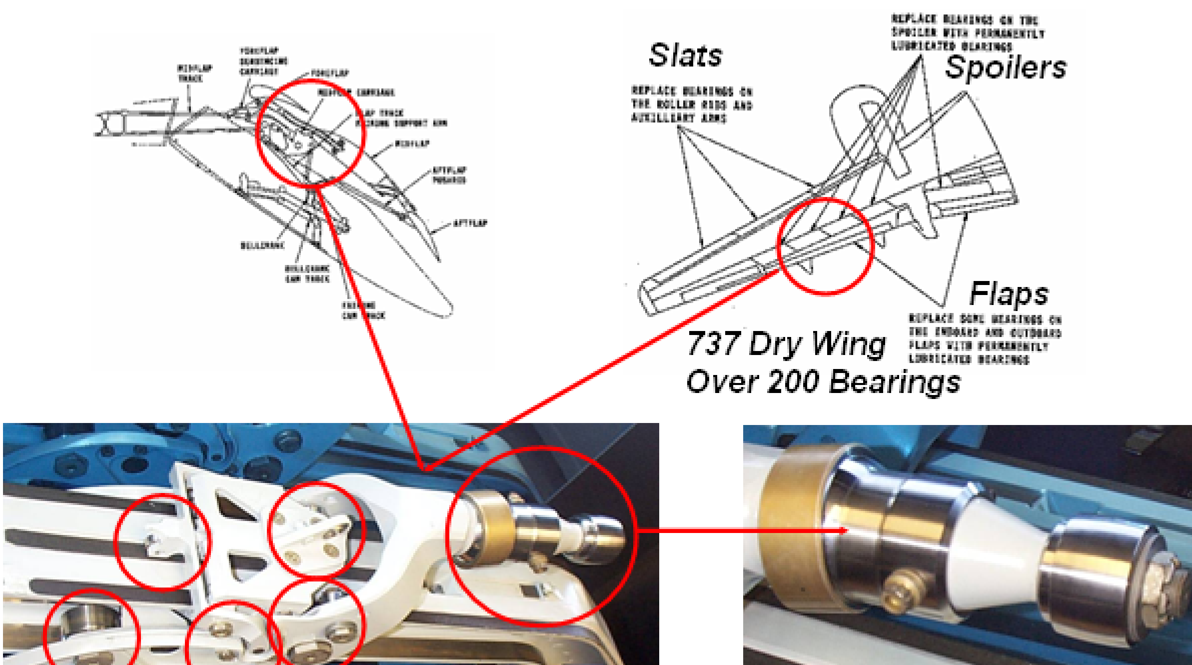
A complete manufacturing lot of F-15 steering collars were manufactured with a 0.060 inch (1.5mm) oversize bore. This created a potential aircraft line stoppage early in the aircraft development program..

The landing gear manufacturer contacted Kamatics to see if the KAron liner system was capable of filling the void created by the machining error and successfully carry the applied loading with the increase thickness. Over 60 critical forgings salvaged and delivery met on time.

737 "Dry Wing" Installation
(Not including over 250 additional original equipment bearings)

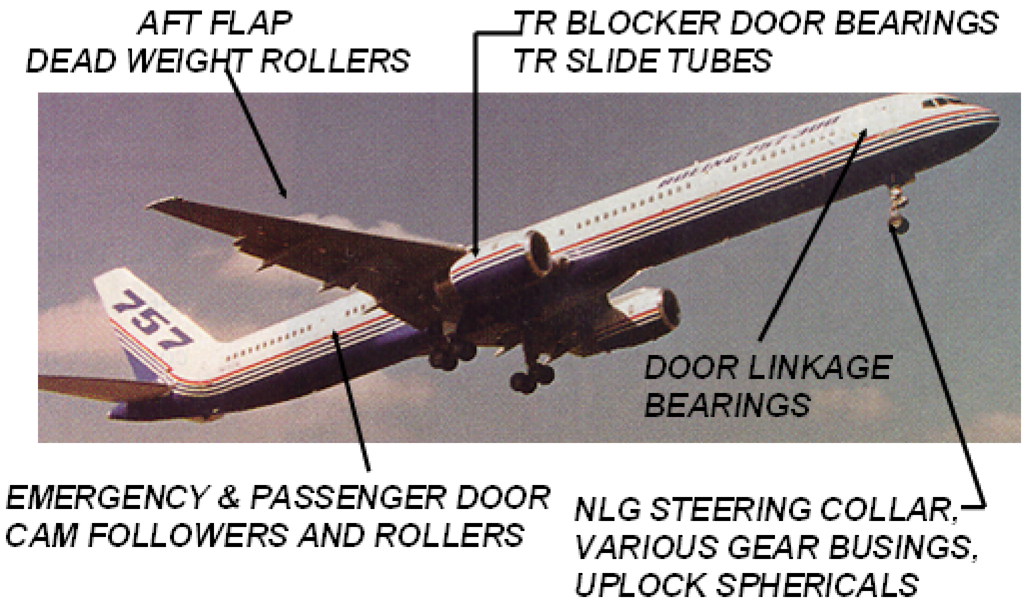


KAron Self-Lube
Flight Control Bearings

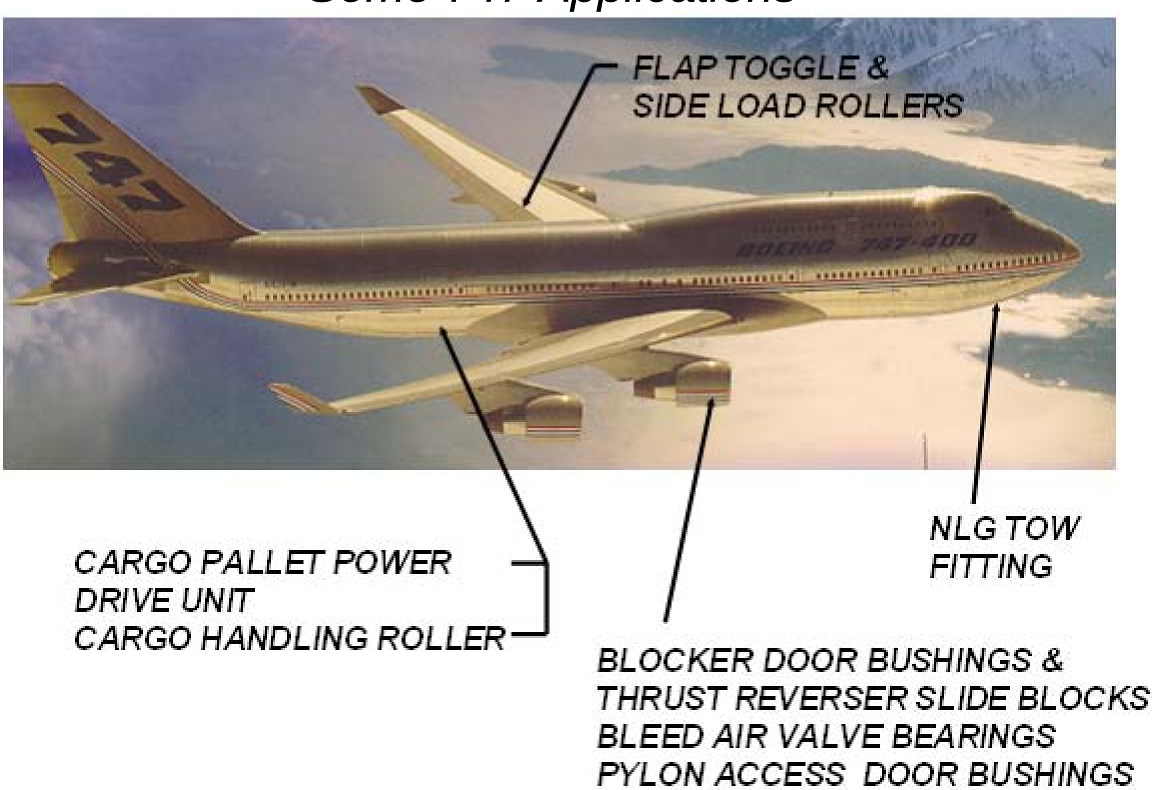


Flap Spindle Bearings

Some 757 Applications



Some 747 Applications



Some 767 Applications

- *Cockpit Window Roller*
- *Blocker Door Bushings*
- *Door Rollers & Rod Ends*
- *Throttle Control Cam Follower*
- *Throttle Control Cam Follower*
- *Engine Exhaust Nozzle Wear Pad*
- *Leading Edge Slat Actuator*

Some 777 Applications

Kamatics supplies over 600 Bearing Products for each 777 Aircraft

- *Flight Control Hinge Bearings*
  - *Aileron*
  - *Elevator*
  - *Rudder*
  - *Horizontal Stabilizer*
- *Tail Skid Split Ball and Bushings*
- *Uplock Landing Gear Bushings*
- *Passenger Door Pin Pads*
- *Nose Landing Gear Trunnion Bearing*
- *Thrust Reverser Blocker Door Bushings*
- *Door Piston/Clutch Bearings*
- *Door Clutches*
- *Door Linkage Bushings*
- *Flaperon Head End Bearing*
- *Spoiler Actuator Pillow Block Bearing*
- *Landing Gear Tow Fitting*
- *Nose Landing Gear Torque Tube*
- *Main Landing Gear Forward Trunnion Sleeve*
- *Flap Position Indicator Bushing*
- *Door Stop Roller*
- *Slat Skew Loss Detection Piston & Sleeve*
- *Flight Deck Sliders*
- *Cockpit Window Roller*
- *Flap Rollers*

Some AIRBUS A320 Series Applications

Some Bombardier RJ Applications

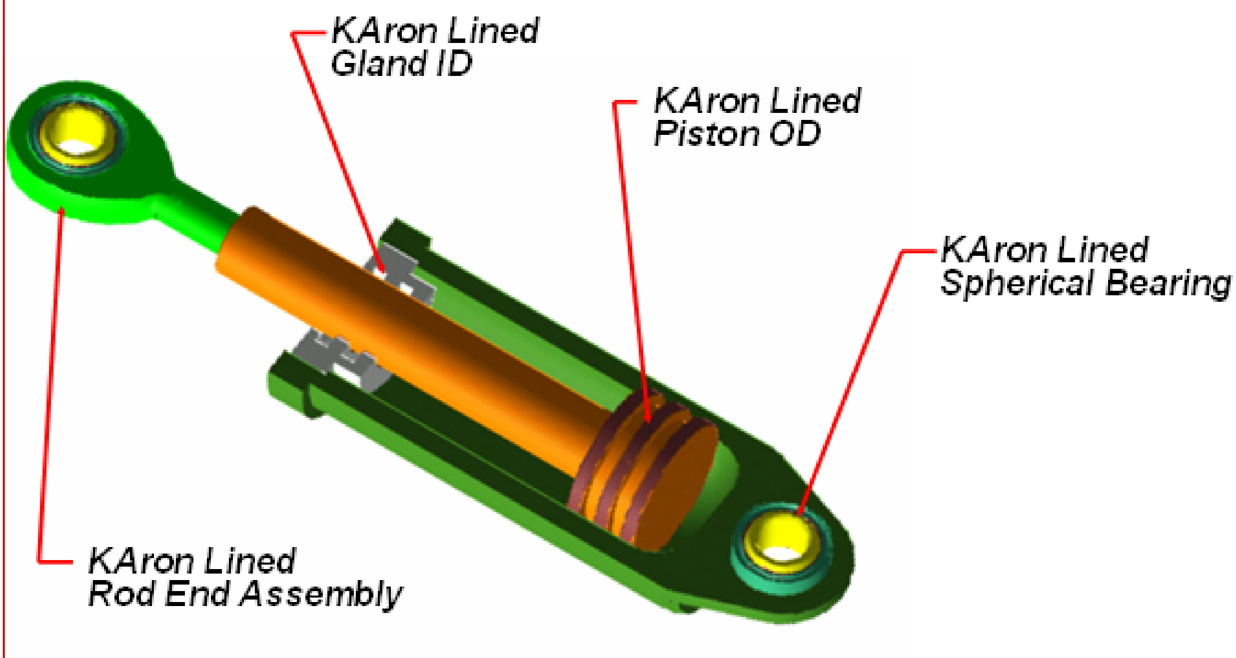
Canadair RJ / Challenger

- Flap Hinge
- Blocker Door Bushings
- Thrust Reverser Slide Block
- Door Rollers
- Service Door - Various

Canadair CRJ-700

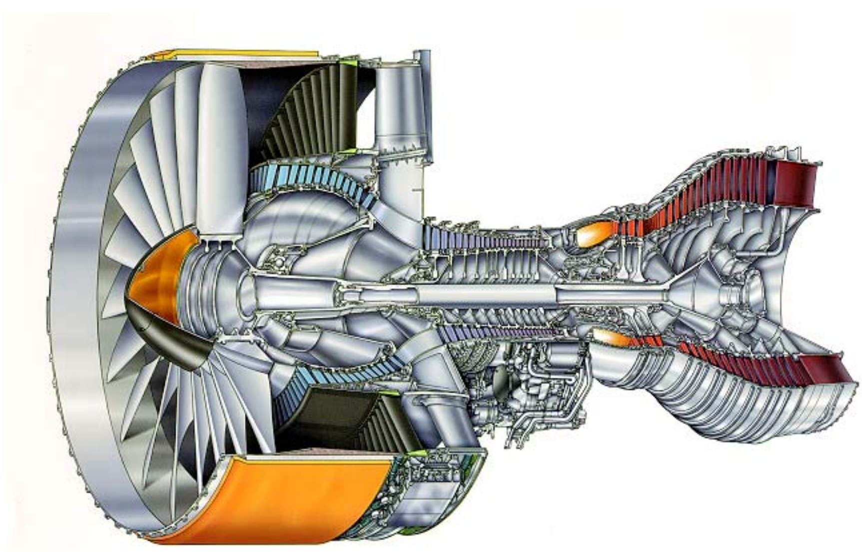
- Flight Control Bushings
- NLG Upper Shock Strut
- Flap / Slat Actuator
- Flap Hinge
- R/H Service Door - Various
- MLG Uplock Roller
- Flap Track Rollers
- Airframe Sphericals/Bushings

Typical KAron Lined Actuator Components



KAron Engine Applications

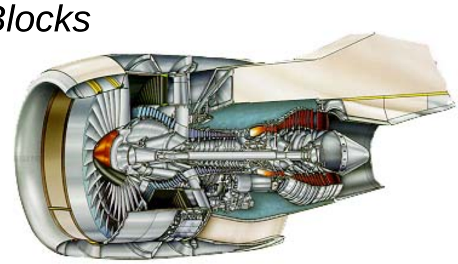
- ***Vane Trunnion Brgs***
- ***Variable Guide Vane Linkage Brgs***
- ***Bellcrank/Pivot Brgs***
- ***Torque Tube Brgs***
- ***Thrust Reversers***
- ***Composite Wear Pads***
- ***Afterburner Cam Followers / Linkages***



Nacelle & Thrust Reverser Applications

Kamatics KAron Self Lubricating Bearings have been successfully used in a variety of Engine Nacelle applications.

- *Wear Strips*
- *Wear Pads*
- *Thrust Reverser Slide Tubes / Blocks*
- *Composite Backed Bearings*
- *High Temperature Bearings*



·*Applications*

·*737, 777 Blocker Door Bushings/Pins*

·*747 Hinge Pins*

·*A320/Hispano Suiza Nacelle Bushings*

·*Canadair RJ, Challenger Nacelle Bushings*

•*747 Diagonal Brace Spherical Bearing*

•*777/Rolls Trent KAron Coated Ball Loader Slot Bearing*

• *A340/Hispano Suiza Door Rollers*

Features:

•*KAron/KAtherm Bearings can be used at higher loads offering a weight reduction for the use of smaller bearings*

• *-100°F to 600° F operating range (-73°C to 315°C)*

•*No periodic lubrication results in reduced maintenance costs*

•*Can be used in difficult to access/maintain areas*

Demanding Military Aircraft Applications

F/A-18
- Nose Landing Gear Launch Bar Latch
- Nose Landing Gear Shock Strut
- Rudder Hinge Bearing
- Arresting Gear Door Hinge
- Main Landing Gear Downlock Actuator Bushing
- Nose Landing Gear Steering Collar

B-2 , F-17
- Flight Controls
- Bellcrank
- Multiple Applications, Locations Unknown

F-15
- Main Landing Gear Steering Support Arm
- Main Landing Gear Piston Head
- Main Landing Gear Strut Sleeve

F-22
- Rudder/ Aileron/ Flaperon / Horizontal Stabilizer Pins

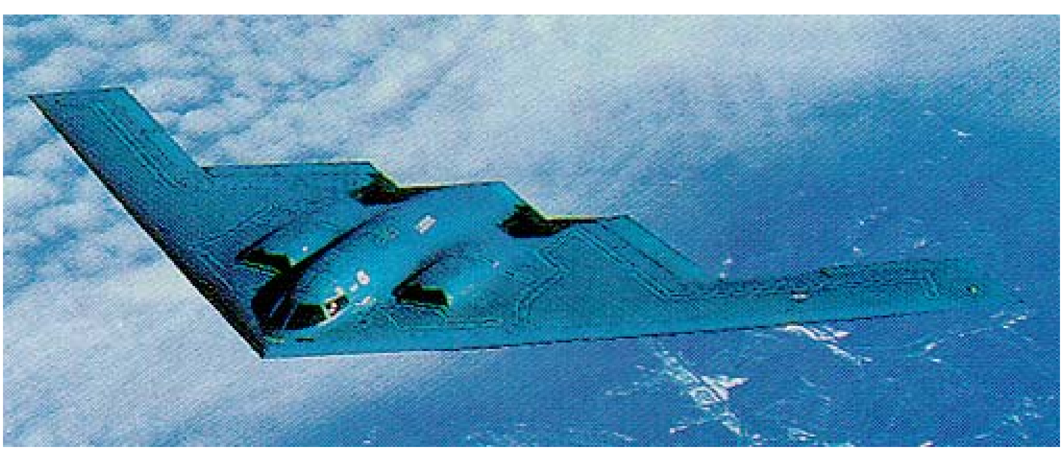
T-45
- Nose Landing Gear Launch Bar Crank Assy
- Nose Landing Gear Retract Actuator
- Main Landing Gear Retract Actuator
- Arresting Hook Actuator
- Speed Brake Disk Bushing
- Slat Actuator

EF2000 (EFA)
- Flap Track Rollers
- Wear Strips/pads

Tornado
- Flap Track Rollers
- Wear Strips
- Wing Control Bearings

Gripen
- Canard Sphericals

Rafale (Naval)
- Arresting Hook Spherical



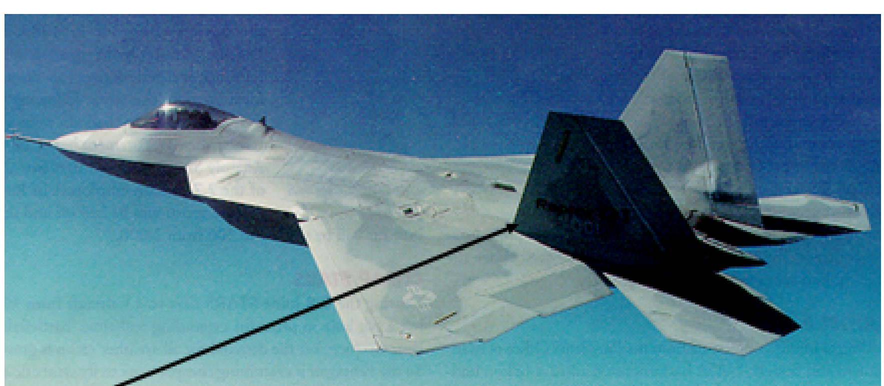
F18 Applications

Over 60 Different Part Numbers Supplied

Nose Landing Gear Launch Mechanism Bushings
Nose Landing Gear Shock Strut Sleeves
Rudder Hinge Bearings
Arresting Gear Door Hinges
Main Landing Gear Downlock Actuator Bushing
Nose Landing Gear Steering Collar

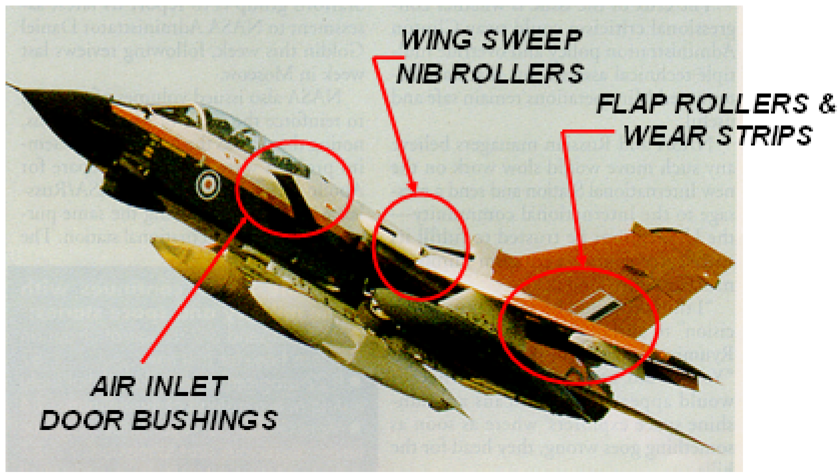
F22 Applications

Over 20 Part Numbers Supplied



- *Rudder/Aileron/Flaperon/Horizontal Stabilizer Shafts (KAron OD Lined)*
- *Various Bushings*
- *Wear Strips*

Tornado Applications



Over 50 Different Part Numbers Supplied

EF2000 APPLICATIONS

Over 20 different Part Numbers Supplied

Flap Track Rollers

- Landing Gear Sleeves
- Bushings
- Wear Strips

JAS39 GRIPEN

Canard Pivot Bearings — *Landing Gear Bearings*

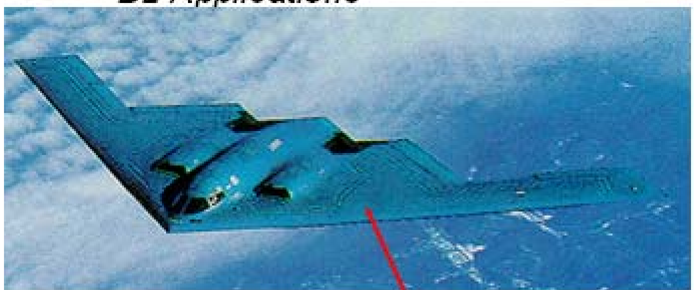
Titanium Ball & Outer Race
KAron V Liner
Chrome Oxide Ceramic Coating on Ball OD

C17 Applications

Aileron Hinge Sphericals

Over 50 Different Part Numbers Supplied for Various Applications, both Spherical and Journal Bearings

B2 Applications



- Flight Control Bushings
- Bellcrank Bushings
- Multiple Other Applications- Locations Unknown

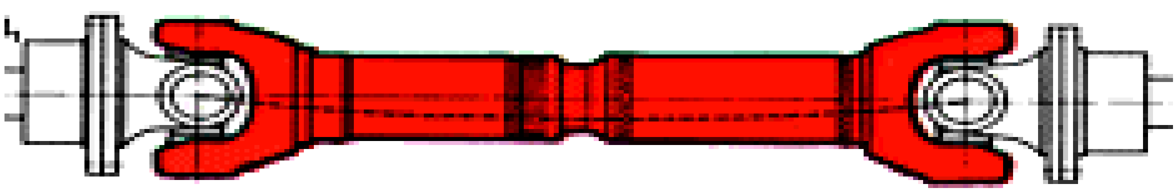
F117 Applications

T-45 Applications

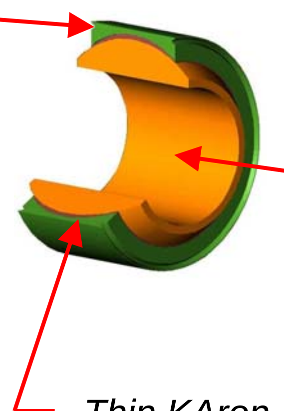
Over 50 Different Part Numbers Supplied

- Nose Landing Gear Launch Bar Crank Assembly
- Nose Landing Gear Retract Actuator
- Main Landing Gear Retract Actuator
- Arresting Hook Actuator
- Speed Brake Disk Bushing
- Slat Actuator

Kamatics KAron Lined Cruciform for Universal Joint
Tested and Selected for A380 Flap Drive System



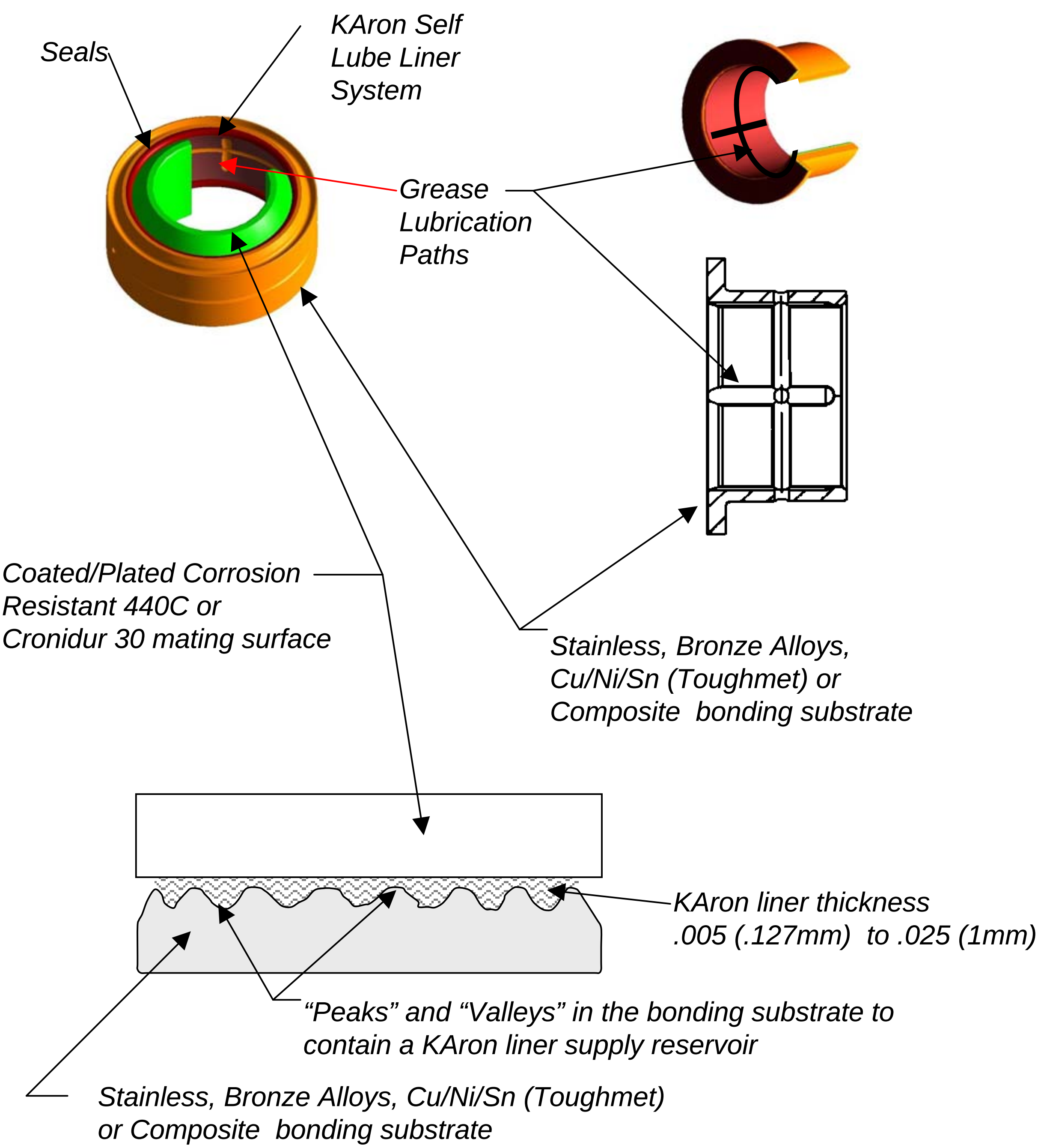
Kamatics Newest Product …RELIAMET™ !!
A Sensible Option to Metal-to-Metal Bearings (Journal or Spherical Configuration, Dry Film Lube or Grease)



- *Provides bearing stiffness similar to metal-to-metal bearings.*
- *Cost competitive drop-in replacement for metal-to-metal bearings that are constructed from corrosion resistant materials.*
- *Eliminates lubricant migration from the wear/load zone.*
- *Self-lubrication eliminates difficult to access grease locations.*
- *Prevents fretting, seizing, rotation and migration of the bearing in its housing.*
- *Results in a durable, problem solving bearing solution.*

Kamatics RELIAMET™ Patent Pending

- *Thin KAron Liner with provisions for lubrication if required.*
- *Bushing, Spherical Bearing or Wear Pad Configurations*
- *All Corrosion Resistant Alloys*



First Marine Applications
(25 Years Ago)

Kamatics Tested by US Navy for Hydrofoils 15X improvement
Amphibious Fleet Successfully Tests and Incorporates Kamatics Bearings

Kamatics Marine Applications

- *Steering and Diving*
- *Rudders*
- *Retractable Bow Planes*
- *Elevators*
- *Stern Gate Hinges*
- *Un Rep Winches*
- *Watertight Doors*

KAron Liner Track Rollers and Cam Followers

Page	Description
1	KAron Liner Track Rollers and Cam Follower Index Sheet
2	Track Roller Bearings - Description-
3	KAron Lined Track Roller/Cam Follower Typical Configurations
4	KAron Self Aligning Track Rollers
5	Comparative Track Roller Endurance Test KAron V lined verses Greased Packed Needles
6	Customer Conducted Comparative Track Roller Endurance Test KAron V lined verses Greased Packed Needles
7	Delta MD-88 Flap/Slat Self-Aligning Track Roller Field Experience
8	Next Generation Track Roller Configuration
9	KAMATICS A340-600 Flap Track Roller Qualification Test Results 737 Maintenance Free Wing
10	C17 Applications Airbus “Beluga” Self Aligning Main Cargo Door Rollers
11	Airbus A380 KAron VS Low Coefficient of Friction Liner Track Rollers Embraer EMB 135 and 145 Flap Track Roller with Side Bumper Guide
12	Common Installation Arrangements for Track Roller Assemblies
13	KAron V Track Roller Testing in Various Contaminates (0.875 inch OD)
14	Customer conducted KAron V Track Roller Testing in a Hostile Environment (1.375 “ OD)
15	Customer conducted Comparative Track Roller Testing - KAron V, Self-Lube Competitors and Conventional Needle Rollers (1.375 inch Roller OD)
16	KAron V Track Roller OD Endurance Testing (2.000 inch OD)

Track Roller Bearings - Description-

Aircraft and other mechanisms that utilize moveable control surfaces normally require that they be guided and supported by track rollers and/or cam follower bearings. The roller bearing translates along a track (or cam) that is fixed to a stationary member such as a wing, or to the moveable surface.

Conventional track roller/cam follower bearings which are used have generally been constructed of a full complement of needle rollers along with a hardened inner and outer race. Although these bearings are acceptable for many applications they are prone to problems and failure. This is because of their sensitivity to the requirements of re-lubrication, foreign contamination such as cleaning and de-icing fluids, corrosive environments, end loading and static brinelling.

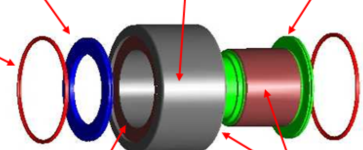
The Kamatics KAron lined track roller is constructed with a high load, long life liner system combined with corrosion resistant materials. The Kamatics roller, due to its internal construction, has a maximum static radial limit load rating approximately 4 times that of a conventional needle roller.

The axial static limit load capability exhibited by the Kamatics KAron rollers is substantially greater than that of a needle bearing due to separate thrust surfaces that are 90° to and independent of, the radial load carrying surfaces. Any thrust capacity of a needle bearing is dependant upon the rolling/scrubbing action of the needles against the end rings of the assembly.

Needle rollers require the rolling action to pull lubricant into and between the contacting surfaces of the needle, outer and inner races. The rolling action also causes needles to contact their neighboring needles which are, in fact, rolling in opposite directions, causing possible local overheating and resulting in dissipation of the lubricant, internal friction, possible needle skewing and heavy end loads on the retaining rings. The Kamatics KAron liner roller assemblies are not effected by any of the above and operates under severe adverse environments for an extended life expectancy relative to a needle roller.

<u>Important Features of a Kamatics KAron Lined Roller</u>

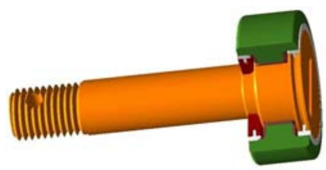
- *KAron liner on OD of inner race and thrust surfaces*
- *Self-lubrication means low maintenance*
- *Uniform coefficient of friction through out life of rollers*
- *Sealed to minimize contaminate migration into the bearing*
- *Independent radial <u>and</u> axial capacity*
- *Corrosion resistant construction*
- *An optional unique self-aligning feature aligns the outer race on the track thereby reducing loading on the track and prevents skidding*
- *High static load capacity.*
- *Smaller roller OD vs. needle rollers.*
- *Potential weight savings, both for the rollers and structure.*
- *Cost Savings…greasing provisions not required.*
- *No <u>Brinelling</u> of races.*
- *Maintenance free.*
- *KAron lined rollers <u>do not</u> attract or collect dirt/debris.*
- *Compatible with all aircraft fluids.*
- *No catastrophic failures.*



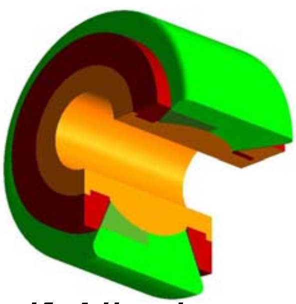
Typical Roller Construction

KAron Lined Track Roller/Cam Follower Typical Configurations

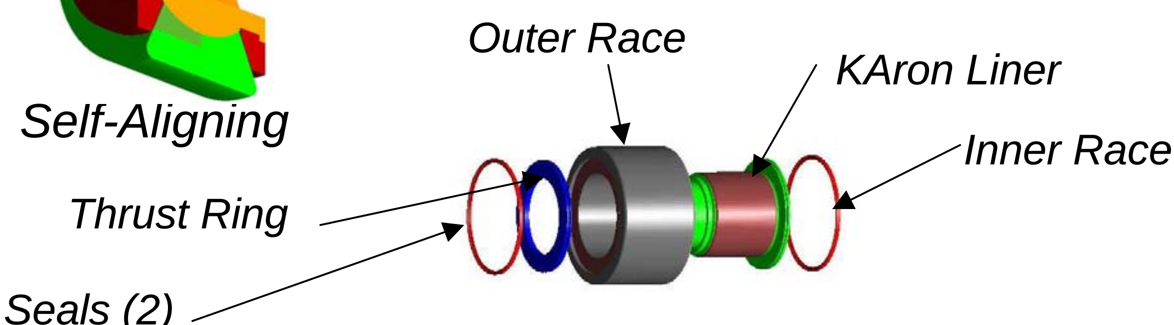
Non-Studded



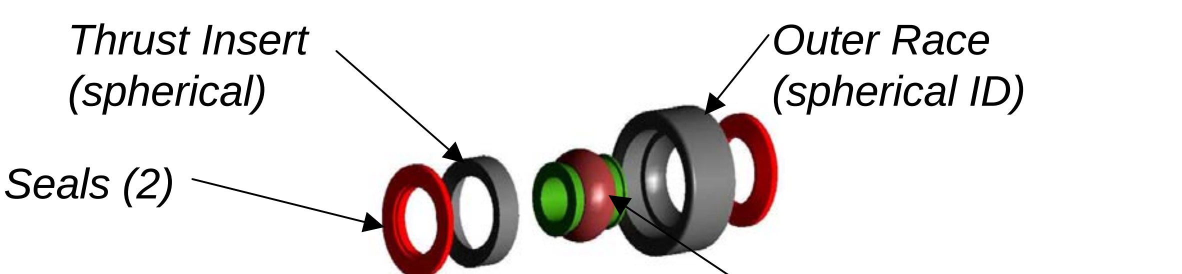
Studded



Self-Aligning



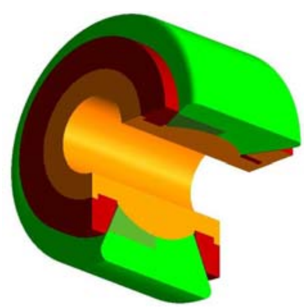
Typical Track Roller Construction

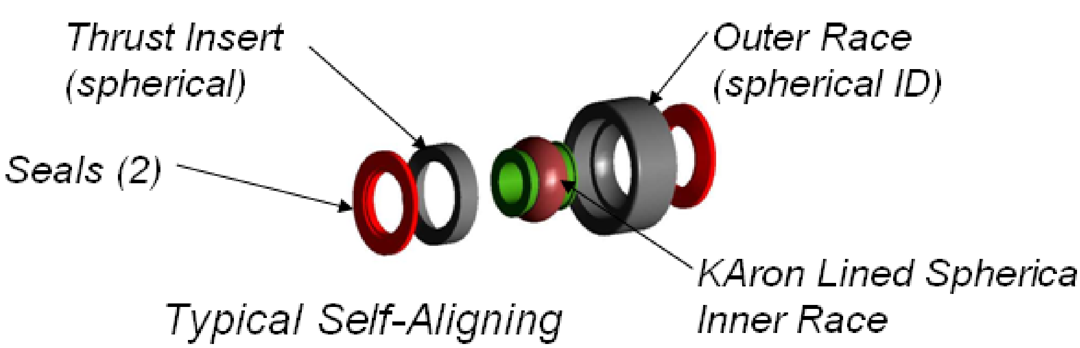


Typical Self-Aligning Track Roller Construction

KAron Self Aligning Track Rollers

- *Used on 737 "Dry Wing" Option.*
  (Compensates for difficult rigging problems)
- *Used in Various Naval Classified Applications.*
  (Compensates for track irregularities and deflections)
- *4+ Years Service Evaluation on MD80 Series Slats by American, Continental, and Delta Airlines.*
  (Minimizes expensive Titanium track damage)
- *Selected as Roller of Choice for the DeHavilland Dash 8-400.*
  (Concerns about crowned roller high roller "Hertz" stresses
- *Used in Critical Door Mechanism Cam on Boeing Aircraft.*
  (Eliminates roller damage to "key" Aluminum cam)
- *Selected by the US Army Corps of Engineers for problem Navigation Lock Mooring Bit Rollers.*
  (Eliminates dangerous Mooring Bit "hang-ups")
- *Selected by Airbus Industries for critical A300- "Beluga" Main Cargo Door attachment joint.*
  (Greatly reduced "Hertz" stresses on latch attach fittings)





Typical Self-Aligning Track Roller Construction

Comparative Track Roller Endurance Test
KAron V lined verses Greased Packed Needles

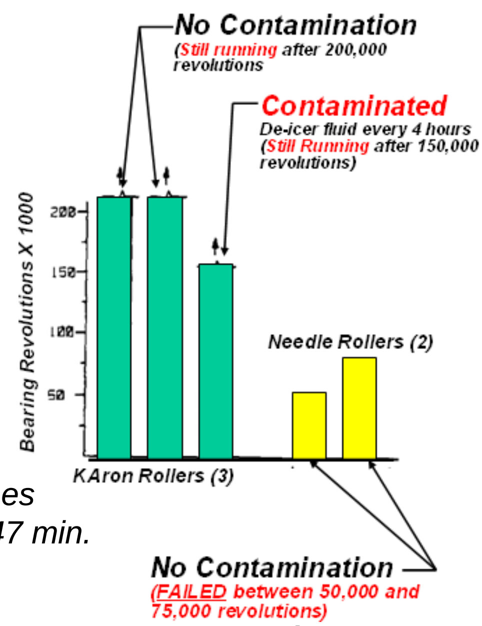


Figure 1

Purpose of Test:
To comparative test KAron lined track rollers and standard grease packed needle track rollers

Bearing Information:
KAron Bearing: Three (3) bearings tested
Outer Diameter ----- 1.312 inches
Outer Race Width -- 0.600 inches
Bearing Area--------- 0.430 square inches
Outer Race Material - AMS 5617 (Custom 455) Rc 47 min.

Needle Bearing: Two (2) bearings tested
Size --------Identical envelope dimensions as KAron bearing
Materials - Standard "MS" track roller materials

Test Conditions:
- *Needle bearing lubricated at start of test, no additional lubrication during test.*
- *Rolling speed 17 RPM, reversing every 5 rev.*
- *Applied Load 4300 pounds steady*
- *One (1) KAron bearing contaminated as shown in Figure 1*
- *No contamination of needle bearings*

Test Results:
- *Three (3) KAron track rollers (one contaminated) successfully completed in excess of 150,000 rev*
- *Two needle bearings failed within approximately 75,000 revolutions with no contamination.*

Customer Conducted Comparative Track Roller Endurance Test KAron V lined verses Greased Packed Needles

Purpose of Test:

To comparatively test KAron lined track rollers and standard grease packed needle track rollers under similar load conditions.

Bearing Information:

***KAron Bearing**: One (1) tested*
Outer Diameter - 2.000 inches
Outer Race Width – 1.125 inches
Outer Race Material - AMS 5617 (Custom 455) Rc 47 min,

***Needle Bearing**: Three (3) tested*
Size - Identical envelope dimensions as KAron bearing
Materials - Standard "MS" track roller materials

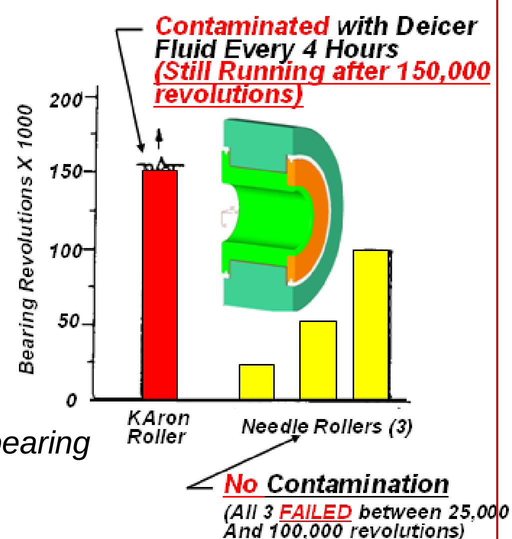


Figure 1

Test Conditions:

- *Needle bearings lubricated at start of test, no additional lubrication during test.*
- *Rolling speed 17 RPM, reversing every 5 rev,*
- *Applied Load 6300 pounds steady*
- ***One (1)-KAron bearing contaminated as noted***
- ***No contamination of needle bearings***

Test Results:

- *One (1) KAron track roller (contaminated) successfully completed in excess of 150,000 rev. as shown in Figure 1,*
- *Two needle bearings failed within less than 50,000 revolutions*
- *One needle bearing failed in approximately 100,000 revolutions*

Delta MD-88 Flap/Slat Self-Aligning Track Roller Field Experience

Bearings - Kamatics Self Aligning Track Rollers (KRP158309VT, KRP158512VT, KRP135812VT, KRP135910VT - Qty 16 total, 4 pcs ea.

Installed Aircraft - Delta A/C 9013, 9014

Time in Service - 4.4 years (2/93 - 2/97) (qty. 16 bearings, 4 pcs. ea.)

A/C Hours - 11,690 to 11,926 hours

A/C Cycles - 9,450 to 9,558 cycles

Measured Liner Wear - Most .001-.002 in (0.025 – 0.051 mm). (max .0035" (0.089 mm) on 1 bearing)

Calculated Bearing Life - 38,000 cycles/17.6 years (to 80% wear of minimum liner thickness)

Ref KER-599 Rev.A

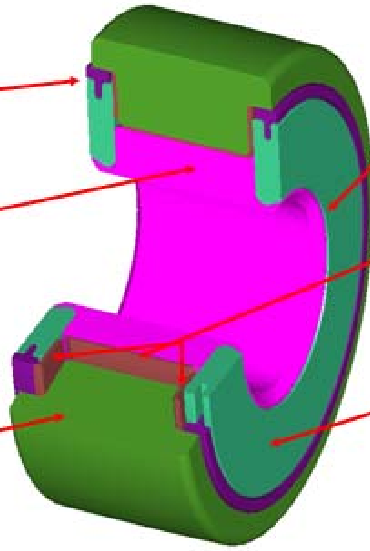
R/H Lower Aft Flap Track

L/H Slat Track #4

L/H Upper Aft Flap Track

Ref KER-599 Rev. .A

Next Generation Track Roller Configuration



Features:

- *Low friction KAron VS self lubricating liner system*
- *Increased hardness and superior corrosion resistant Cronidur 30 outer race*
- *Fail safe design (redundant bearing surface) with unique CuNiSn (Toughmet or similar) inner race*
- *Low drag labyrinth seals to prevent ingress of solid contaminants*
- *Reduced cost construction – swaged track roller design (no E.B. weld)*
- *Low friction levels enabled by special processing technology*
- *Low coefficient of friction at low temperatures*
  - *Coefficient of friction = 0.1 at -65ºF (-54ºC), 10,000 PSI (69 MPa), measured during actual track roller testing*
- *Fully machinable self- lubricating liner system, homogeneous matrix throughout liner thickness*
- *The same chemical resistance as KAron V and KAron B*

KAMATICS A340-600 Flap Track Roller Qualification Test Results

- *Kamatics successfully qualified via test to 2 times aircraft life at failure loads with aerospace fluids and grit contamination.*
- *Kamatics track roller is the only competing product able to qualify to the A340-600 specification **without a life restriction.***

KAron Low Friction Trailing Edge Track Rollers
Only Track Roller Rated for Life of the Aircraft

737 Maintenance Free Wing

Boeing "Dry Wing" Service Bulletin 737-57-1227
15,000 plus cycles on Next Generation Track Rollers

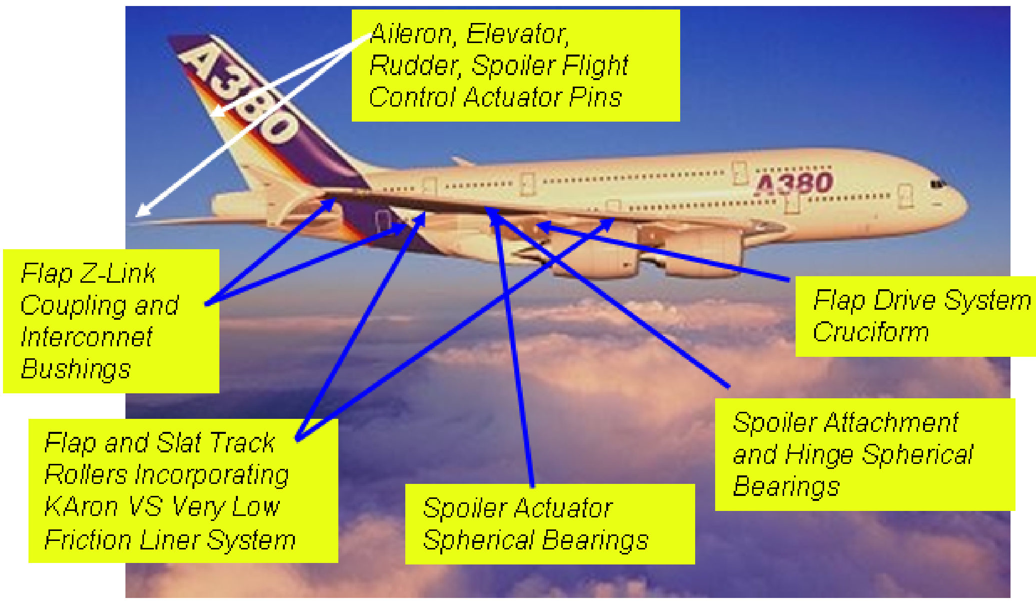
100% Self Lube Track Leading Edge Track Rollers
100% Self Lube Trailing Edge Track Rollers.
Bushings and Sphericals


C17 Applications
AIR FORCE
0106
Leading Edge Slat
Self Aligning Rollers

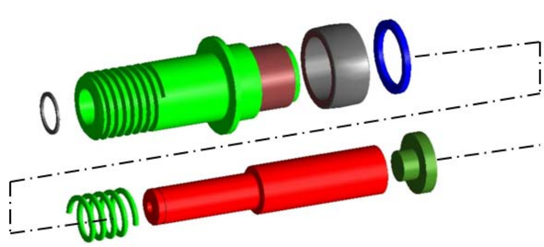

Airbus “Beluga”
Self Aligning Main Cargo Door Rollers
Door Locking Mechanism
AIRBUS INDUSTRIE
SKYLINK
2

Airbus A380 KAron VS Low Coefficient of Friction Liner Track Rollers

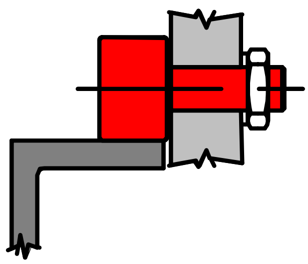
A380 Freighter to have KAron flap/slat track rollers due to higher loads and for reduced weight. Dry wing option with KAron track rollers also requested by several airlines.



Embraer EMB 135 and 145 Flap Track Roller with Side Bumper Guide

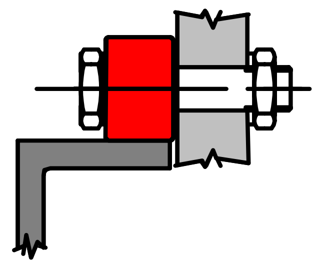


Common Installation Arrangements for Track Roller Assemblies



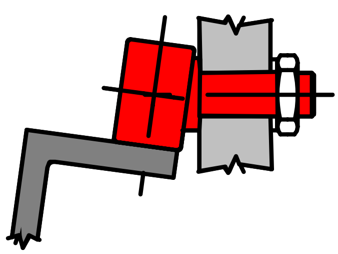
VIEW A

STUDDED ROLLER
CANTILEVER INSTL



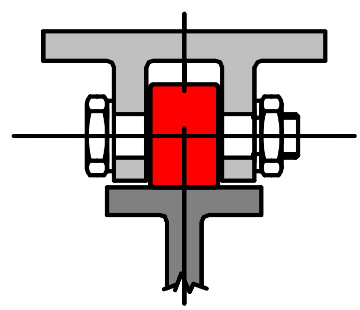
VIEW B

NON STUDDED ROLLER
CANTILEVERED INSTL



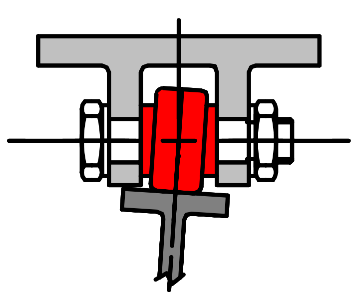
VIEW C

SELF-ALIGNING
STUDDED ROLLER
INSTL



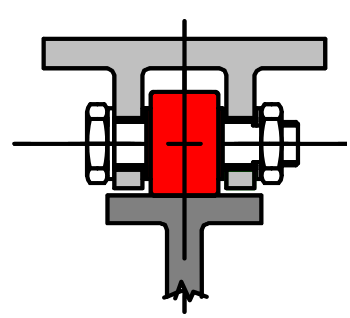
VIEW D

CARTRIDGE ROLLER
CLEVIS INSTL



VIEW E

SELF-ALIGNING
CARTRIDGE ROLLER
INSTL

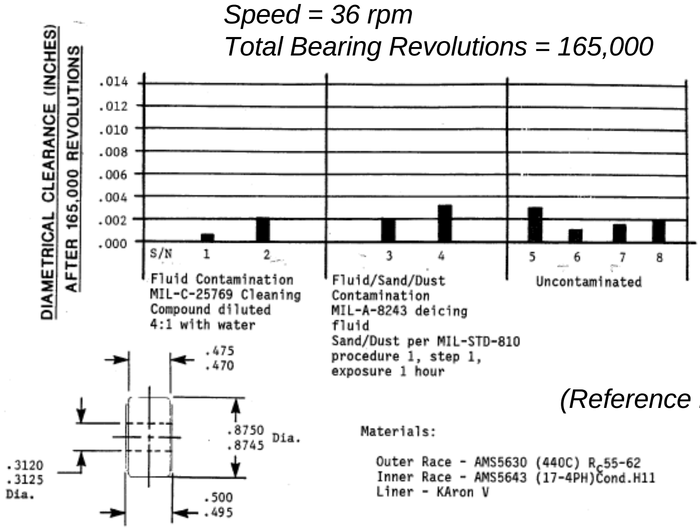


VIEW F

CLAMP-UP BUSHING
CARTRIDGE ROLLER
INSTL

KAron V Track Roller Testing in Various Contaminates (0.875 inch OD)

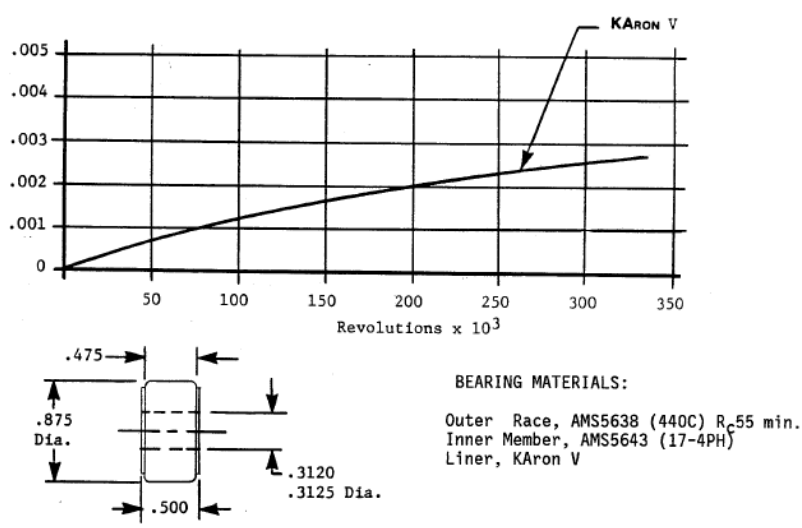
Test Conditions:
Load (Steady) = 500 pounds (2600 psi)
Speed = 36 rpm
Total Bearing Revolutions = 165,000



(Reference Kamatics Data Sheet 46)

KAron V Track Roller Testing At Moderate Speeds (0.875 inch OD)

Test Conditions:
Load (Steady) = 500 pounds (2600 psi)
Speed = 43 rpm (Reversing direction every 4 revolutions)
Total Bearing Revolutions = 304,000
Wear=.0026 inches



(Reference Kamatics Data Sheet 52)

Customer conducted KAron V Track Roller Testing in a Hostile Environment (1.375 inch OD)

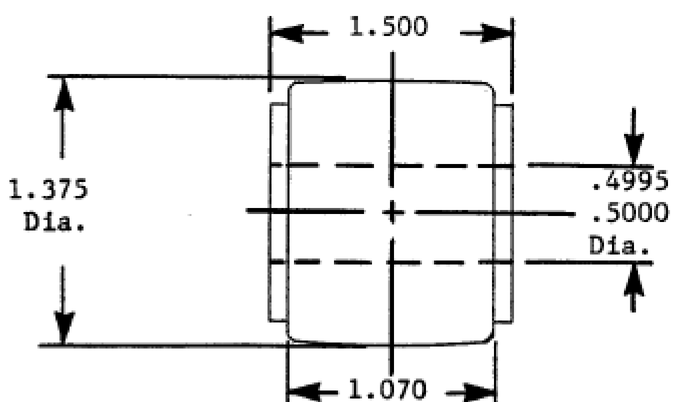
__Purpose of Testing:__

To determine wear characteristics of a KAron lined track roller assembly (KRP115000V-2) when used as an aircraft flap/slat track roller. The bearings were periodically contaminated with de-icing fluid, cleaning fluid and a sand/dust mixture as noted below. The bearings were also "tipped" 1° to induce an end load.

__Test Conditions:__
Load (Steady) = 5000 pounds (5000 psi)
Speed = 36 rpm (Reversing direction approximately each revolution)

Contamination =	*Bearing A*	*-Subject to cleaning solution every 40,000 revolutions. Prior to running, immerse in the solution for 15 minutes. MIL-C-25769 diluted 1 part to 4 parts water.*
	Bearing B	*-Subject to de-icing fluid every 40,000revolutions. Prior to running, immerse in the solution for 15 minutes. (MIL-A-8243)*
	Bearing A & B	*-every 80,000 revolutions, within 30 minutes after immersion in solutions above, subject the bearing to a sand/dust treatment for 5 minutes to one side of the outer race and 5 minutes to the other.*

__Test Results:__
The Kamatics KAron lined KRP115000V-2 Bearings were endurance tested for more than 400,000 revolutions at the above stated conditions. Actual customer wear measurements indicated less than 0.003 inches radial wear and less than 0.002 inches of axial wear. Friction levels were reported to be constant throughout testing.



Bearing Configuration

4.5.0

MATERIALS:

Outer Race, AMS5630 (440C) R_C 55 min.

Inner Member, AMS5643 (17-4PH)

Liner - KAron V

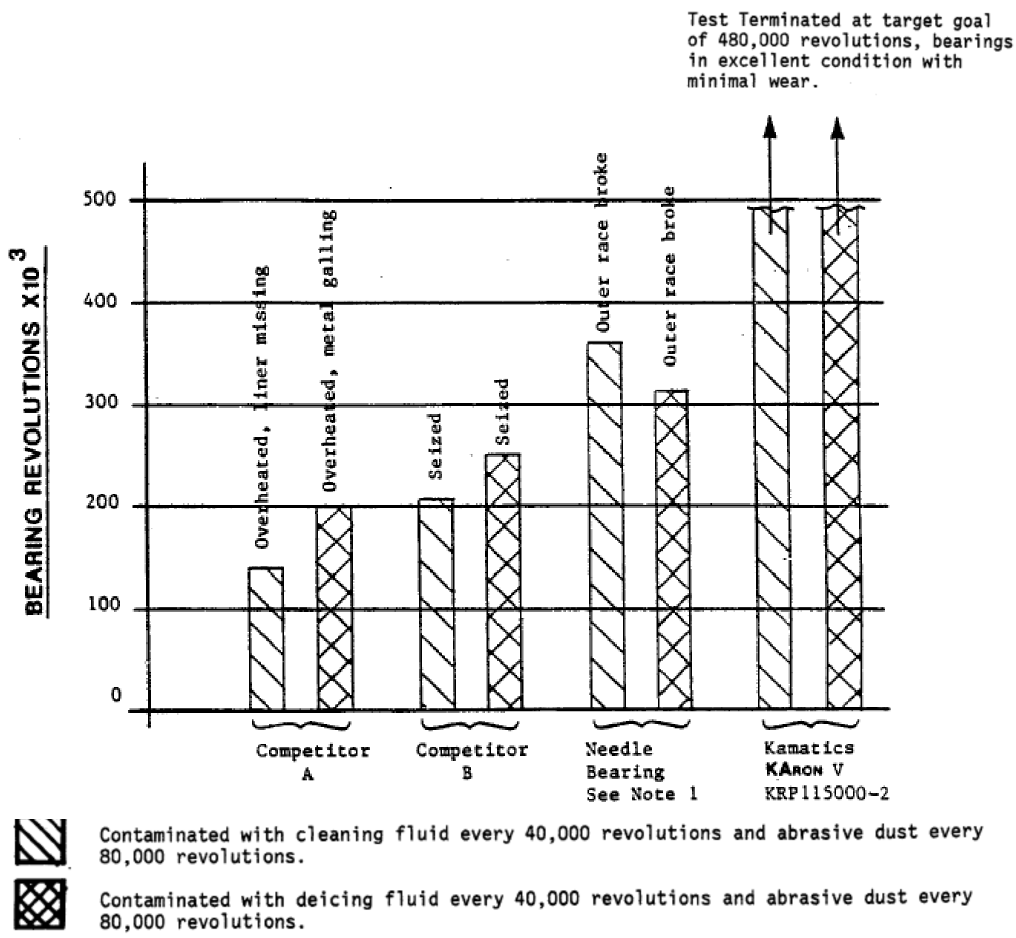
(Reference Kamatics Data Sheet 50)

Customer conducted Comparative Track Roller Testing KAron V, Self-Lube Competitors, and Conventional Needle Rollers (1.375 inch Roller OD)

<u>Purpose of Testing:</u>

To determine wear characteristics of a KAron lined track roller assembly (KRP115000V-2) when used as an aircraft flap/slat track roller. The bearings were periodically contaminated with de-icing fluid, cleaning fluid and a sand/dust mixture as noted below. The bearings were also "tipped" 1° to induce an end load. This sheet shows additional data comparing Kamatics results to 2 self-lube fabric bearing manufacturers and standard needle rollers. See also Kamatics Data Sheet 50 on Page 14)

<u>Test Conditions:</u>
Load (Steady) = 5000 pounds (5000 psi)
Speed = 36 rpm (Reversing direction approximately each revolution)



Note 1. Needle bearings were periodically re-lubricated during the test.

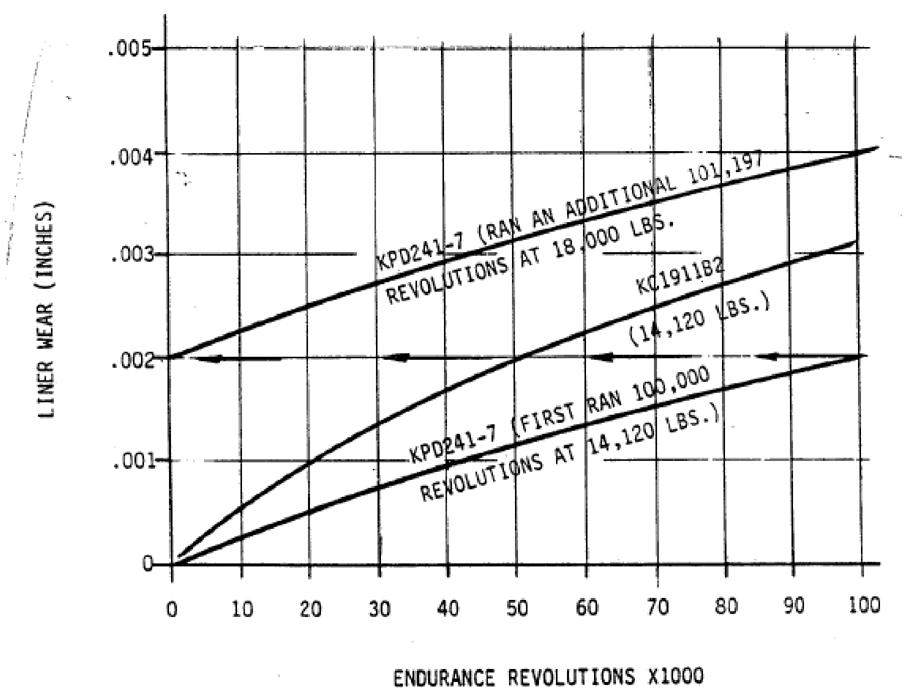
(Reference Kamatics Data Sheet 60)

KAron V Track Roller OD Endurance Testing
(2.000 inch OD)

Purpose of Testing:
To determine wear characteristics of a KAron lined track roller assembly in a moderate size track roller configuration.

Track Roller Size (similar to MS24465-14):
OD = 2.000 inches
ID = 0.875 inches
Outer Race Width = 1.060 inches
Inner Race Width = 1.125 inches

Test Conditions:
Speed = 20 rpm
Load = as noted below
Contamination = none

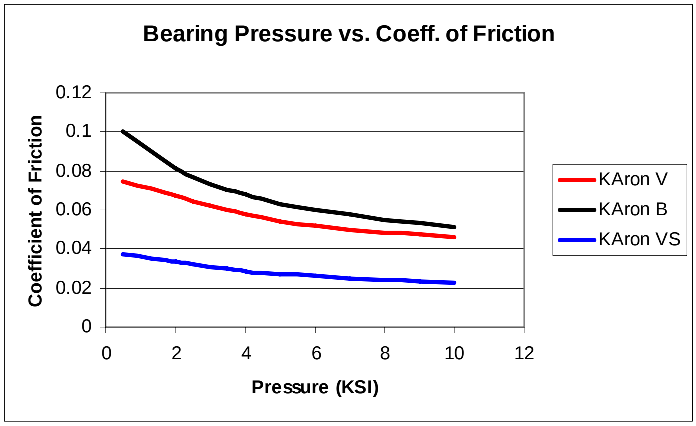


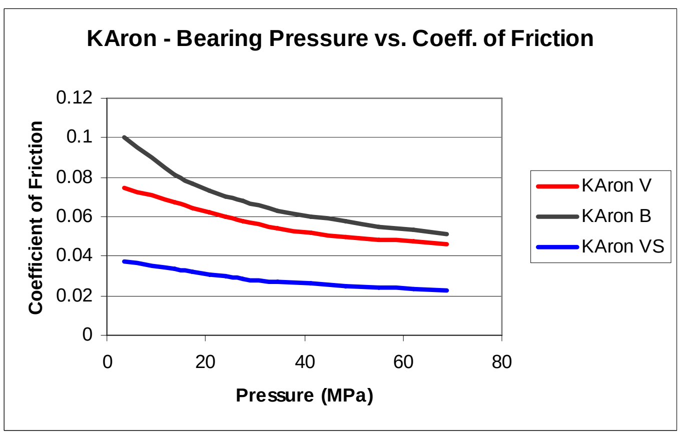
(Reference Kamatics Data Sheet 67)

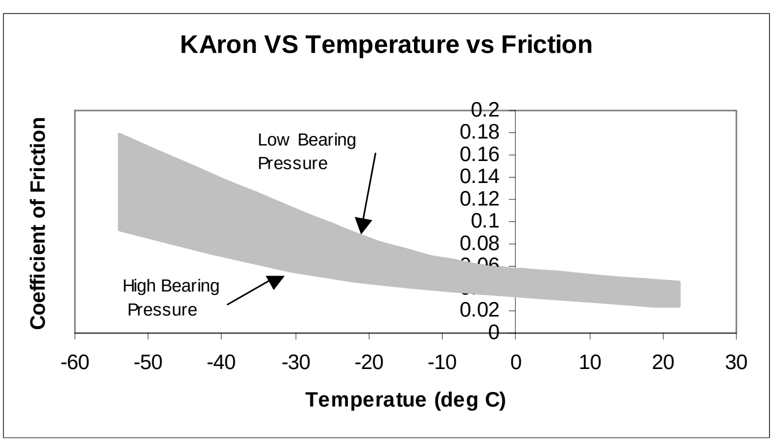
Miscellaneous KAron Information/Data

Page	*Description*
1	*Miscellaneous KAron Information/Data Index Sheet*
2	*Comparative coefficient of friction of various KAron liner systems*
3	*Suggested Parameters of Mating Surfaces to Minimize Liner Wear*
4	*Approximate Load Capability verses Temperature for Selected KAron Liner Systems*
5	*KAron B… High-Load, Self-Lubricating, Low Friction, Liner System*
6, 7, 8	*Advantage of Machinable Liners*
9, 10	*Sizing Spherical Bearings for Aerospace Applications*
11	*Example: The evolution of a difficult-to-line landing gear bearing*
12	*KAron Spherical Bearing Construction*
13	*KAron Journal/sleeve manufacturing process*
15, 16	*Roll Swaging Tool*

Comparative coefficient of friction of various KAron liner systems







KAron VS friction is very low for a wide temperature range at both high and low bearing pressures

Suggested Parameters of Mating Surfaces to Minimize Liner Wear

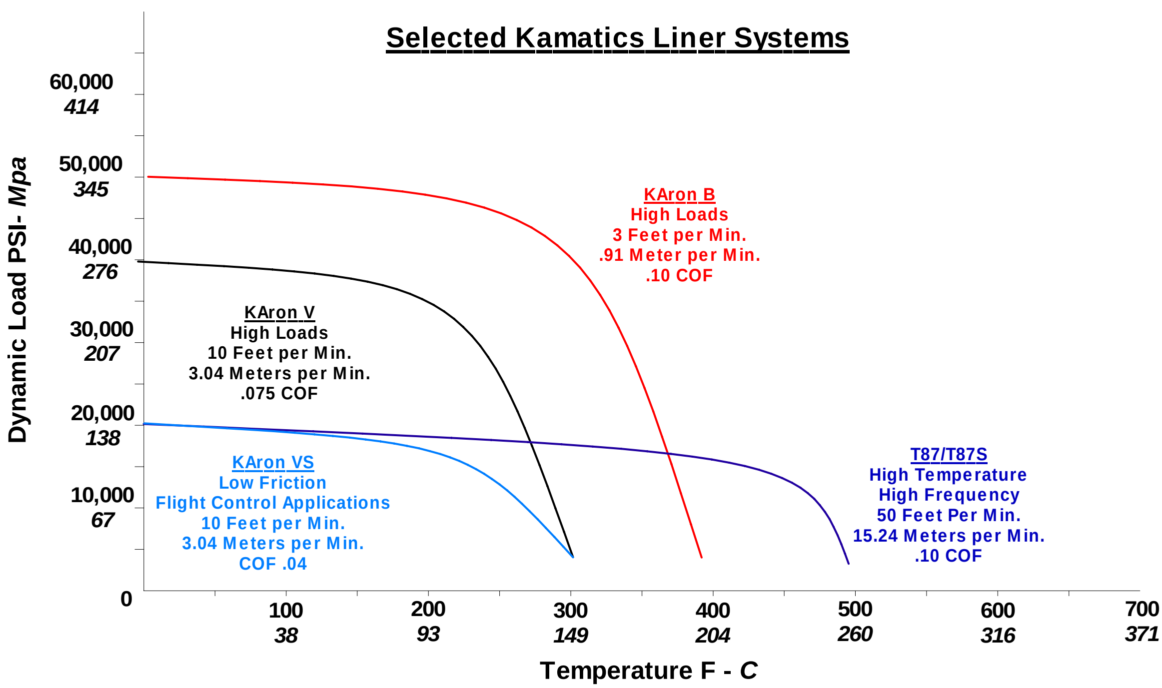
In the case of KAron lined bushings or anti-wear/fretting surfaces, the bearing supplier, in this case Kamatics, supplies one-half of the bearing system (the bearing) and the bearing user supplies the other half (the mating surface).

KAron wear rates are highly dependent on mating surface conditions and in general the harder the mating surface and the smoother the mating surface is the better the anticipated wear performance. Kamatics recommends that the mating surface be Rc 50 or harder and the mating surface finish is recommended to be Ra 8µin or smoother. One can review the table below to see the affect of hardness and surface finish as it relates to wear.

Mating Bearing Surface	
Surface Finish	
Roughness-µin.	*Life Factor*
8 (.0.2 µm)	*1.00*
16 (0.4 µm)	*.75*
32 (0.8 µm)	*.40*
Surface Hardness	
Hardness Rc	*Life Factor*
50+	*1.00*
40	*.60*
30	*.40*

Corrosion resistant hard surface finishes can also enhance performance depending on the application. Kamatics makes use of ceramic coatings (HVOF, Plasma) and chrome plate when added wear resistance is needed for demanding applications.

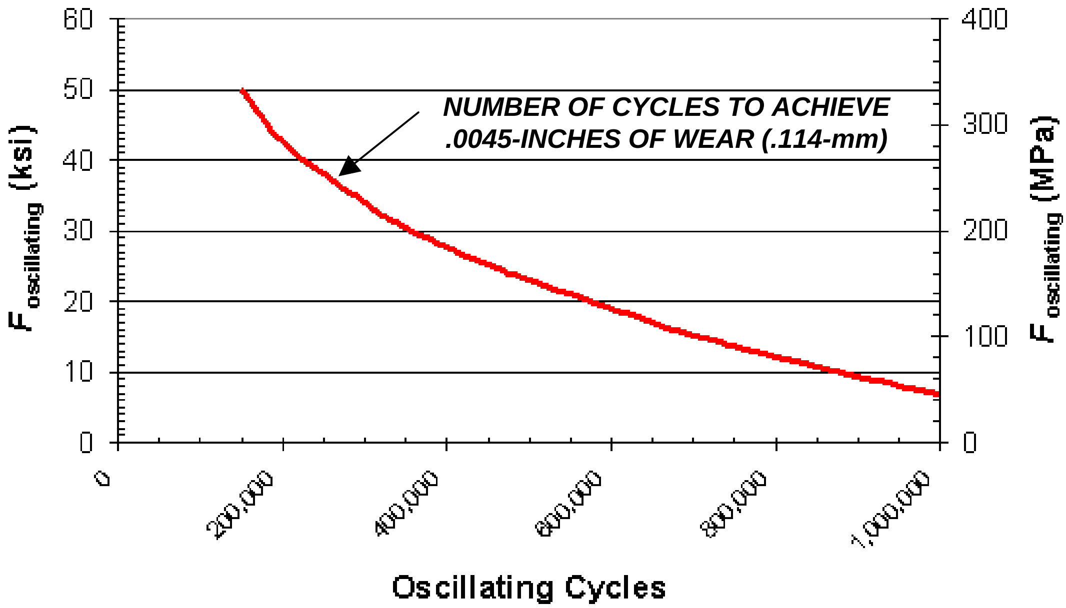
Approximate Load Capability verses Temperature for Selected KAron Liner Systems



The graphs shown indicate the pressure limits for the respective operating temperatures and are for reference purposes only. Contact Kamatics for assistance in determining the proper liner taking into consideration the pressure, temperature and duty cycle.

KAron B… High-Load, Self-Lubricating, Low Friction, Liner System

Wear Properties for Oscillating Conditions



Notes:

1. One Cycle is defined as a 1-inch (25.4-mm) bore bushing oscillating ±25° (100° total) or as a spherical bearing with a 1-inch (25.4-mm) ball OD oscillating ±25° (100° total)

2 *Although this graph depicts .0045-inches of liner wear (.114-mm), typical Kamatics' KAron bearings incorporate a liner thickness of .010/.015-inches (.254/.381-mm). Because KAron is a homogeneous mixture, consistent wear rates can be expected throughout its entire thickness.*

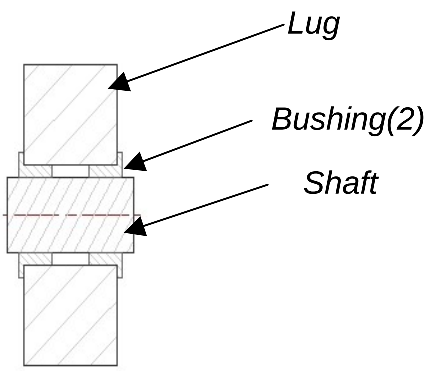
3. *Wear data was generated under a controlled laboratory test environment. The bearings were oscillating in a non-contaminated environment and at speeds under 5 ft/min (1.5m/min). All testing was done at room temperature. The mating shaft or ball was corrosion resistant steel with a minimum hardness of 50 RC and a surface finish of 8 Ra (.2 μm) or better.*

4. *This graph is to be used as a guide to calculate estimated bearing life. Actual wear rates may vary depending on the operational environment. Consult Kamatics Engineering for assistance.*

(Reference Kamatics Data Sheet 165)

Advantage of Machinable Liners
(Sheet 1 of 3)

Tolerance study of a typical lined bushing Installation (all dimensions in inches)

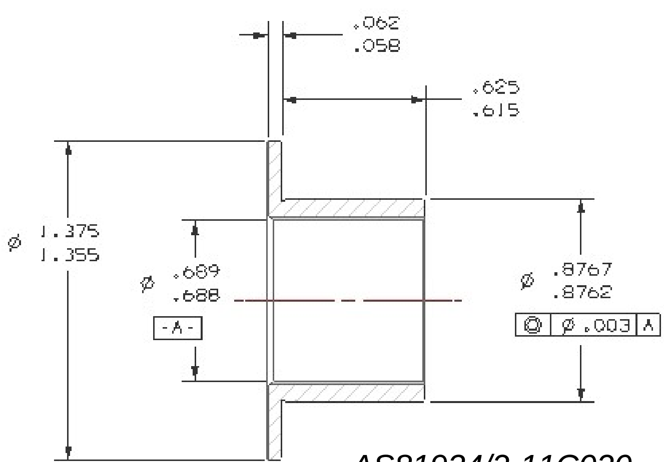


Design Considerations:

- *Lug - Bore Dia. & Tolerance*
- *Bushing / Lug Interference*
- *Bushing - OD & Tolerance*
- *Bushing - ID & Tolerance*
- *Bushing Concentricity - ID to OD*
- *Shaft / Bushing Running Clearance*
- *Shaft OD Tolerance*

Consider the Following Example:

- *AS81934/2-11C020 Bushing*
- *.8750-.8760 Dia. Lug Bore*
- *.6870-.6875 Preferred Shaft Dia.*
- *Preferred Running Clearance is .0005 - .002*
- *What Size Shaft Can Be Installed thru Fabric Lined, Back-to-Back Installed Bushings?*
- *What is the Running Clearance?*



AS81934/2-11C020

Advantage of Machinable Liners (Sheet 2 of 3)

<u>Interference Fit Effects on Bushing ID:</u>

Assume 75% of the interference between the bushing OD and housing bore is reflected in in the bushing's ID reduction.

<u>Max Interference</u>   .8767 max bush OD - .8750 min lug ID = .<u>0017</u>
75% of .0017 = .<u>0013</u> (ID reduction result of max press fit), therefore;
<u>Min Bushing ID After Installation</u> = (.688 -.0013)= <u>.6867</u>

<u>Similarly</u>;

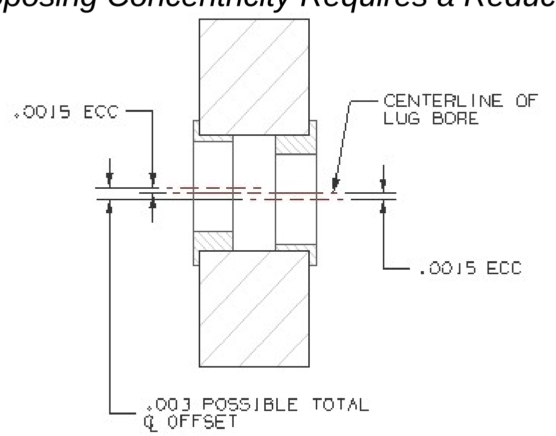
<u>Min Interference</u>   .8762 min bush OD - .8760 max lug ID = .<u>0002</u>
75% of .0002 = .00015 (ID reduction result of min press fit), therefore;
<u>Max Bushing ID After Installation</u> = (.689 -.00015)= .<u>68885</u>

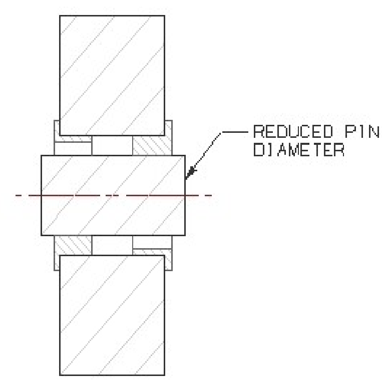
Therefore the Bushing ID range after installation equates to:

<u>.6867</u>(min bush ID) to <u>.68885</u> (max bushing ID)

<u>Effects of Back to Back Bushing Concentricity :</u>

Opposing Concentricity Requires a Reduction of the Shaft Diameter





.003 Concentricity Tolerance Requires a .003 Reduction in Shaft Dia.

Advantage of Machinable Liners (Sheet 3 of 3)

Combined Effects of Interference Fit and Bushing Concentricity

Recap…

- *Bushing ID after installation = .6867 - .68885*
- *.003 concentricity tolerance effectively reduces the bushing ID an additional .003*
- *Assume .0005 minimum clearance*

Therefore: Maximum Shaft Diameter=:

- *.6867 (min bushing installed ID) - .003 (concentricity reduction) - .0005 (min running clearance) = .6832*

And to determine the final shaft size:

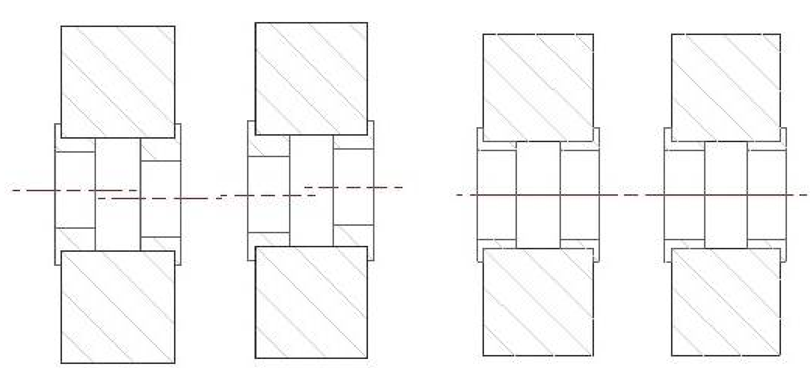
- *Assume .0005 tolerance on shaft OD*
- *Final shaft size =: .6832 (max shaft dia) -.0005 (shaft tolerance) = .6827*

Running clearance between the shaft and bushing installation = .0035 - .0062 in the example given.

Machinable Liner Advantage

1, KAron lined back-to-back bushing installations can be machined after assembly. (Fabric lined bushings should not be machined)

2, The Preferred Running Clearance of .0005 - .002 (reference sheet 1)is obtainable if the bushings are machined after assembly.



Before Machining ***After Machining***

Sizing Spherical Bearings for Aerospace Applications (Sheet 1 of 2)

Spherical Bearing Design:

Historically, aircraft manufactures have designed bearings with set dynamic load limits. Ever increasing demands to reduce weight and friction have driven aircraft manufactures to reevaluate the traditional load limits. The following information is intended to assist Design Engineers in selecting the correct Spherical bearing for their particular application. This paper is not intended to determine the design criteria of the aircraft manufacturer, but to assist in sizing the spherical bearings to a preset dynamic load limit while minimizing the bearing weight and subsequent supporting aircraft structure.

Calculating Spherical Bearing Pressure:

The "projected area" approach, also depicted in Kamatics' design catalog, is an effective, and industry accepted, method for calculating bearing pressures. See equation below.

Spherical Bearing Pressure Equation; S=P/A

Where:

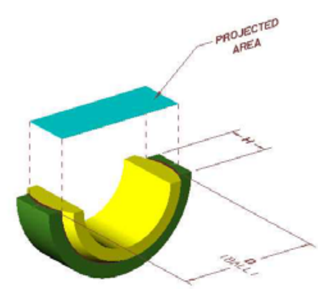
S = Pressure; P = Applied load (force); A = D(ball) x HEFF (projected area); D(ball) = Nominal ball OD; H = Nominal width of the outer race; HEFF = H minus "edge effects"

The "edge effects" are the possible non-load supporting liner setback allowances at each side face of the outer race. In the case of KAron lined spherical bearings, assume the setback at each side to be 0.025 inches (0.63mm) or 0.050 inches (1.27mm) total "edge effect".

Notes:

- *Liner wear rates are greatly dependant on bearing speed, frequency, and environment. Consult Kamatics Engineering for assistance in selecting a liner for any questionable application.*

- *Normal catalog weight calculations are made assuming the bearings are fabricated with a steel outer race and steel ball. If further weight savings is desired, Kamatics can offer dimensionally equivalent bearings with Titanium balls and/or Titanium outer races.*



Spherical Bearing Projected Area

Sizing Spherical Bearings for Aerospace Applications
(Sheet 2 of 2)

Some other important design considerations relative to the design of spherical bearings follow:

•It is imperative that the spherical surface of the ball be as hard, smooth and corrosion resistant as possible.

•There should be sufficient clamp-up torque applied to the ball faces to insure that motion takes place between the ball OD and outer race liner unless movement within the bore is anticipated.

•For applications where it is difficult to generate enough preload on the ball faces to prevent rotation between the bore and bolt/shaft, Kamatics can supply the bearing with a KAron liner in the bore and side faces. This will eliminate damage to mating surfaces in the event that motion takes place in the bore.

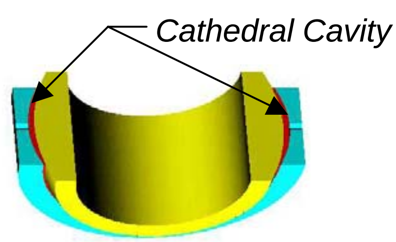
•Consideration should be given to the type of installation fit between the bearing OD and housing. A press fit will reduce the operating clearance between the ball and outer race and increase the break-away torque if there is initial torque. Either condition may be acceptable for the application. The designer is cautioned to consider the consequences of the fit.

•Similar consideration should be given to the fit between the ball bore and bolt as noted above. A designer is cautioned not to use an interference fit between the ball and bolt if the ball is hardened 440C stainless steel or other materials that may be prone to stress cracking when under tensile loads.

•For those applications where the user intends to use a thermal fit technique (shrink fit) to install a KAron spherical bearing, a solution of dry ice and solvent in which to immerse the bearing is recommended.

To assist in housing size selection, ***Tables 5 and 6 of the KAron Design Guide*** *offer typical housing dimensions for use with KAron lined spherical bearings.*

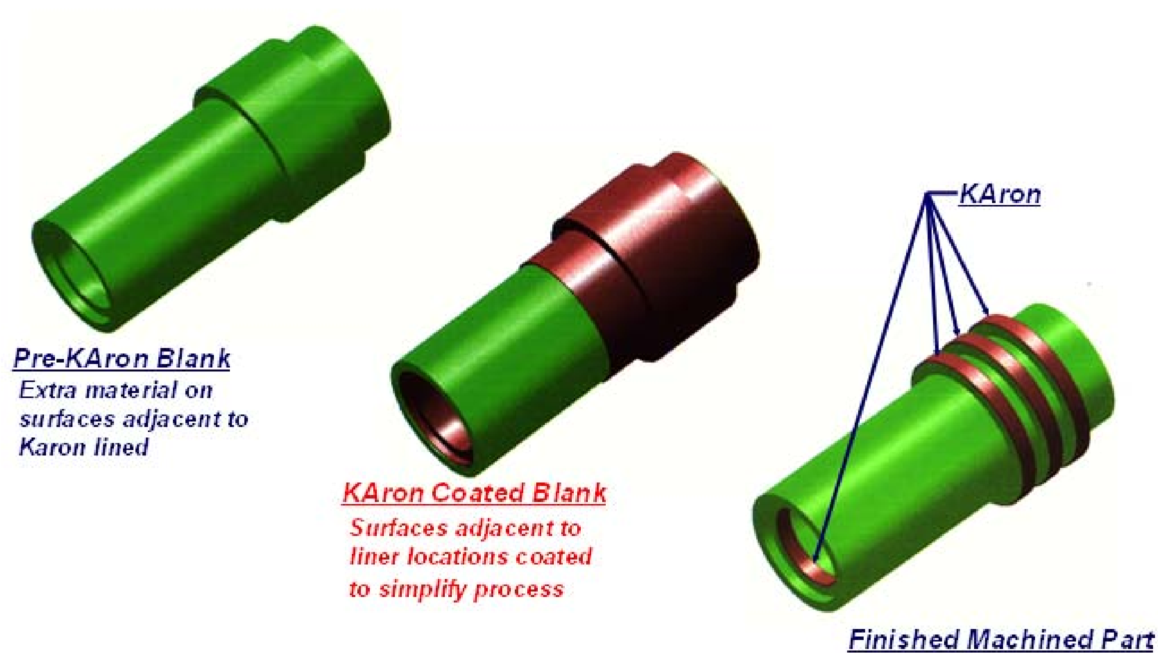
<u>Important Note</u>: Kamatics KAron lined spherical bearings incorporate a unique “cathedral” shaped cavity between the ball OD and outer race ID. This feature “locks” the liner within the bearing overcoming the familiar problem of liner loss suffered with many fabric lined bearings. ***Figure 1*** *shows the “cathedral” feature.*



<u>Figure 1</u>

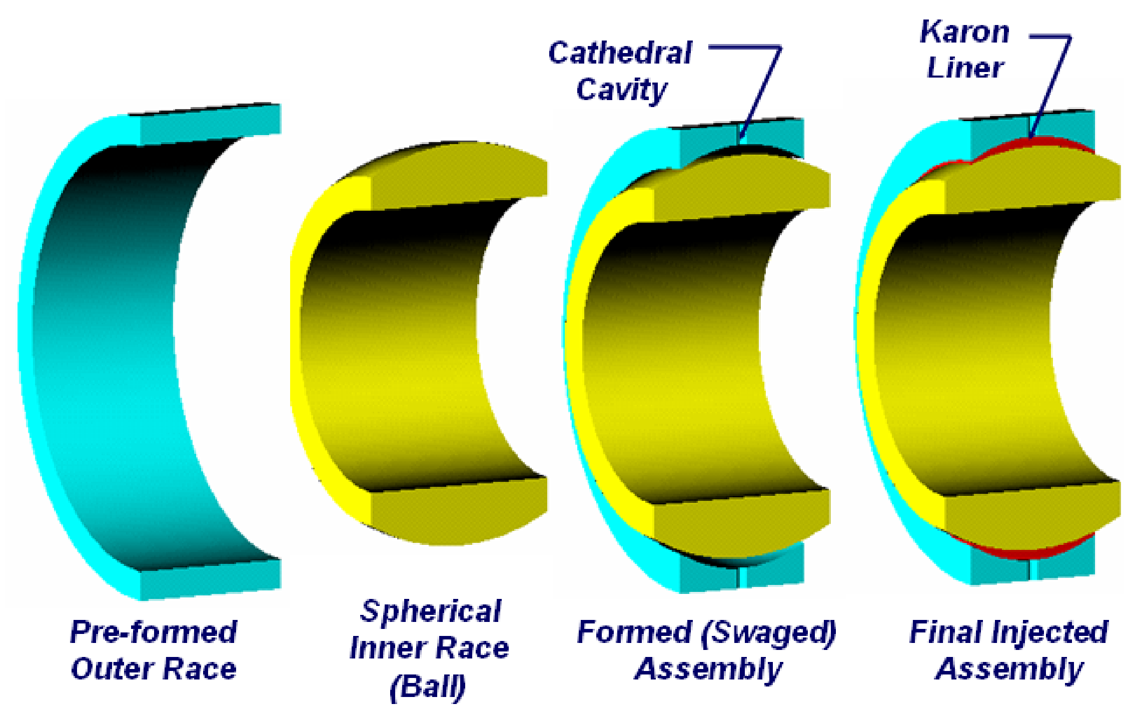
Example:

The evolution of a difficult-to-line landing gear bearing. Start with an oversize blank, apply KAron liner where needed, and final machine all-over to create the bearing surfaces where required. This results in a clean smooth accurate surface with smooth chamfered edges without fabric or fibers to interfere with the installation into it's housing.



KAron Spherical Bearing Construction

- *Outer Race machined to appropriate configuration*
- *Spherical Inner Race (ball) treated with a proprietary release agent*
- *Outer race formed over the inner race utilizing a unique forming technique to arrive at a "cathedral" cavity for the injected KAron liner material.*
- *Outer race accurately positioned with respect to the inner race and KAron liner injected between the two components creating a completely conforming liner-to-ball interface.*



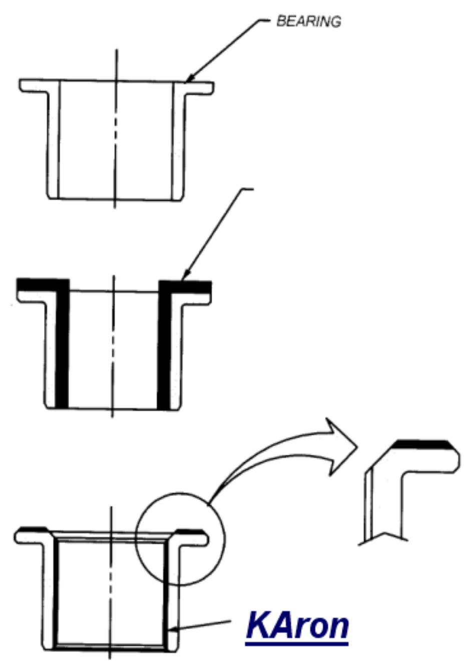
Karon Journal/sleeve Manufacturing Process

Oversize Blank,
Bearing Surfaces Roughened
and Cleaned

KAron Applied Oversized and Cured
100% Bond Achieved

Final Machining of KAron and Blank
Optional Final Machining by Customer

Oversize OD Available for Repairs



ROLL SWAGING TOOL

GENERAL:

THE INFORMATION GIVEN IN THIS DOCUMENT IS OFFERED AS A GUIDE WHEN DESIGNING A TOOL TO ROLL SWAGE A BEARING INTO A HOUSING. THE DATA PERTAINS TO THE MANUFACTURE OF A TOOL FOR ANY PARTICULAR BEARING SIZE. IT IS OBVIOUS THAT A "BASIC" TOOL COULD BE DESIGNED WITH INTERCHANGEABLE SPACERS,SLEEVES,AND ROLLERS THAT WOULD ACCOMMODATE A FAMILY OF BEARING SIZES. THE USER IS ENCOURAGED TO CONSIDER THIS OPTION WHEN DESIGNING TOOLING.

DIMENSIONS FOR ROLLER SUPPORT:

A DIA = AS REQ TO FIT DRILL OR MILL CHUCK (BEARING I.D. MIN)
B DIA = SLIP FIT IN BEARING I.D.(PRESS FIT ON SUPPORT)
C MIN = (BALL WIDTH - RACE WIDTH)/2 + MAX BRG GROOVE DEPTH +.020
C MAX = C MIN +.005
D DIA = B-.06 (PRESS FIT WITH SLEEVE I.D.)
E MIN = NOMINAL BOLT DIA
E MAX = E MIN + .010
F MIN = C MAX + E MAX }
F MAX = F MIN + .010 } (2 ROLLERS REQUIRED. O.D MUST BE WITHIN .001 OF EACH OTHER)
G MIN = MAX BRG GROOVE DIA + .005
G MAX = G MIN + .005
H DIA = SLIP FIT WITH BOLT DIA
L MIN = C + (1.5 x BRG BALL WIDTH)
L MAX = L MIN + .030
W MAX = G MIN - .06 (ALLOWS 2 .030 THICK SPACERS) SEE NOTE 3

DIMENSIONS FOR ROLLER BASE

J MIN = MAX BRG I.D.+ .005"
J MAX = J MIN + .005
K MIN = G MIN
K MAX = MIN BRG O.D.
M MIN = SUGGEST 1.00 MIN (TO SUIT USER EQUIPMENT)
N MIN = ((BRG BALL WIDTH - RACE WIDTH)/2) + .030
N MAX = N MIN + .030

$$P\ MIN = \left(2 \times \sqrt{(BRG\ BALL\ DIA/2)^2 - (RACE\ WIDTH/2)^2}\right) + .020$$

P MAX = P MIN + .010
R MIN = K MAX + .25 (MAX = TO SUIT CUSTOMERS EQUIPMENT)

NOTES:

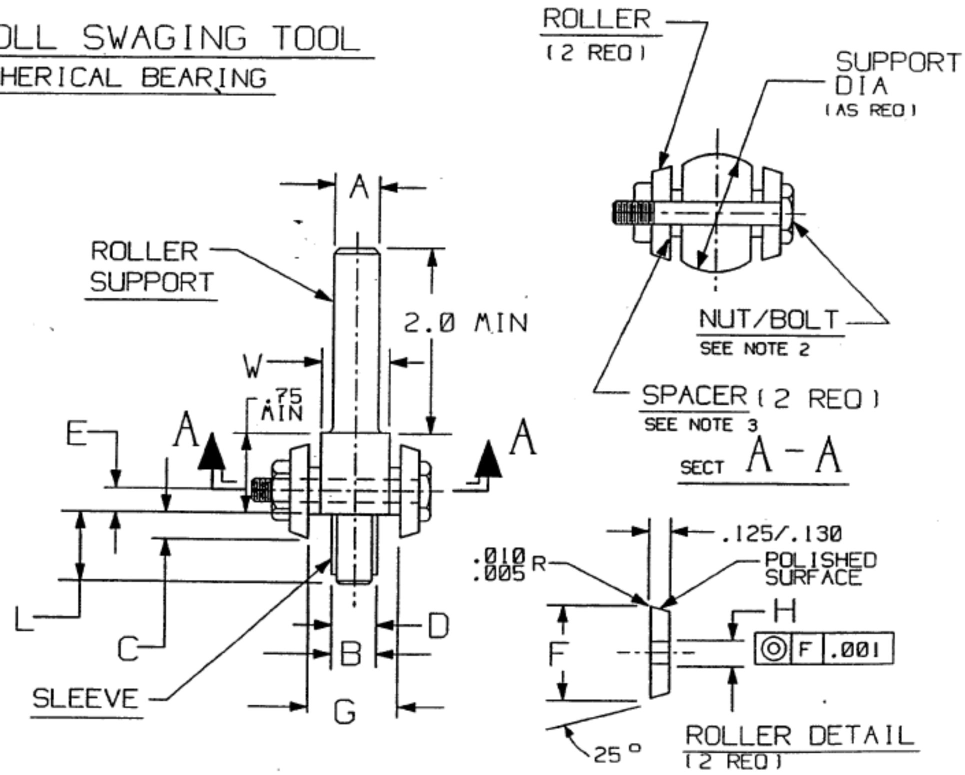
1. REFER TO MIL-STD-1599 REQUIREMENT 202, PARA.5 FOR INSTL AND SUBSEQUENT INSPECTION OF INSTALLED BEARINGS.

2. ASSEMBLE NUT AND BOLT AS SHOWN. TIGHTEN THE NUT SUCH THAT THERE IS APPROXIMATELY .005" LOOSENESS TO ALLOW THE ROLLERS TO ROTATE WITHOUT CATCH OR BINDING.

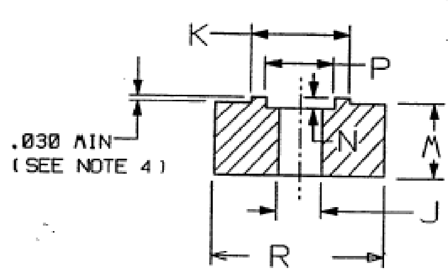
3. SPACER THICKNESS "AS REQUIRED" TO OBTAIN PROPER WIDTH TO MATCH DIM."G" (BEARING GROOVE DIAMETER). THE SUPPORT CAN BE MANUFACTURED WITHOUT THE NEED FOR SPACERS BUT THE TOOL IS THEN LIMITED TO THAT ONE SIZE UNLESS MODIFIED LATER.

4. THE UNDERCUT IS NOT MANDATORY BUT THE POTENTIAL FOR INTERFERENCE WITH MATING HOUSING WILL EXIST.

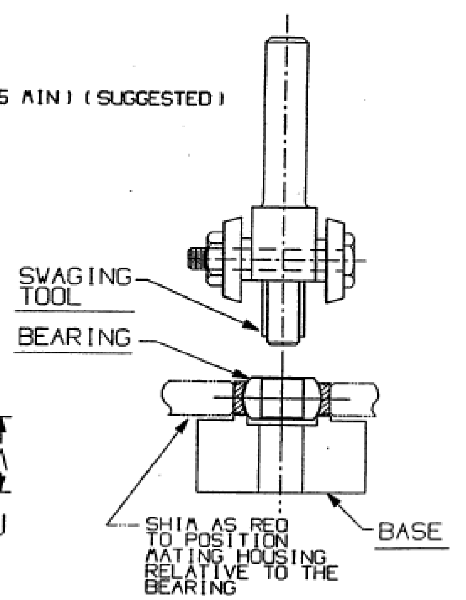
ROLL SWAGING TOOL
SPHERICAL BEARING



ROLLER SUPPORT- STEEL,Rc40 MIN
ROLLER (2)- TOOL STEEL,Rc55 MIN
SLEEVE- ACETAL RESIN, PTFE, NYLON, ETC
SPACER (2)- STEEL,Rc25 MIN
BOLT- .250 DIA.CLOSE TOLERANCE, HARDENED (Rc35 MIN) (SUGGESTED)
NUT- .250 THREAD (SELF-LOCKING SUGGESTED)
ROLLER BASE- STEEL,Rc40 MIN



ROLLER BASE

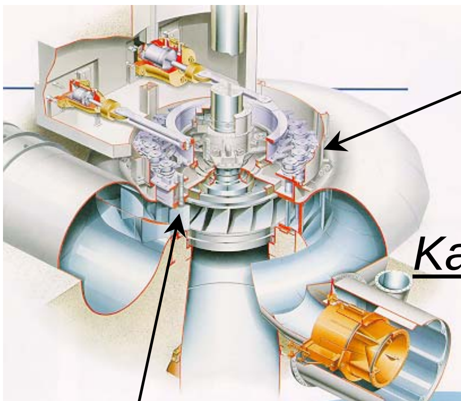


TYPICAL INSTALLATION SET-UP

Kamatics Hydropower Bearings

Page	Description
1	*Kamatics Hydropower Bearings Index Sheet*
2	*Hydropower Applications*
3	*Typical Kamatics Hydropower Wicket Gate Bearing Design*
4	*Submerged Hinge Sphericals*
5	*Spill Gate Submerged Hinge Bushings*
6	*Bushings for Wicket Gates*
7	*Sphericals for Kaplan Hub Turbine Control Linkages*
8	*KAron Lined Bearings for Francis Turbines*
9	*Track Rollers for Head Gate*
10	*Swing Bridge Hemispherical Pivot Bearing*
11	*Bonneville Dam Swing Bridge Self-Aligning Support Rollers*
12	*Little Goose Dam Lock Floating Mooring Bit Rollers*
13	*Miter Gate Pintle Bearing Application*
14	*KAron V Silty Water Test*
15	*KAron V, Fiberglass Backed Bushing Endurance Test (Clean Water) vs. 16 RMS Stainless Shaft*
16	*Hydroelectric Generator Turbine "Wicket Gate" Bearing Test*
17	*Pintle Bearing Testing – Miter Gate (PowerTech Labs)*
18	*Grand Coulee Francis Turbine Operating Ring Linkage Bushing Test*

Hydropower Applications



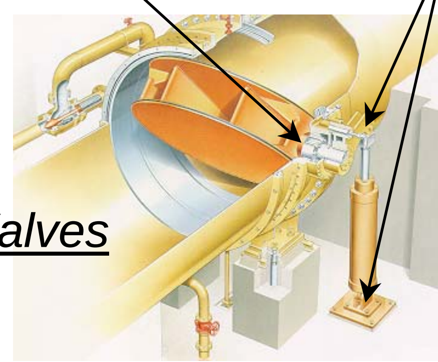
Linkage Bearings &
Regulating Rings

Kaplan Turbines

Wicket Gate
Bushings

Actuator Bearings

Trunnion Pivot
Bearings

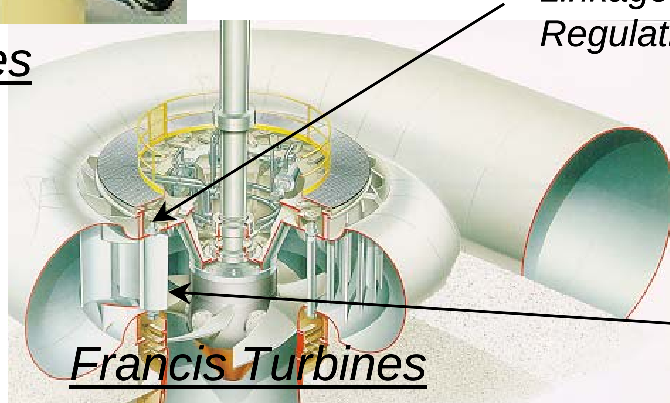


Valves

Gate Pivot Bearings

Gates

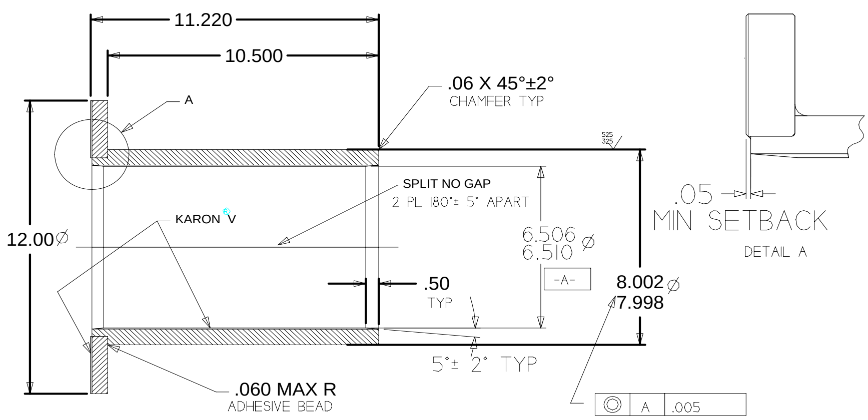
Linkage Bearings &
Regulating Rings



Wicket Gate
Bushings

Francis Turbines

Typical Kamatics Hydropower
Composite Backed Bushing Construction



Tolerances
- *ID= ± .002*
- *OD= ± .002*
- *Length= ± .01*
- *OD Finish= 325-525 RMS*
- *Concentricity=.005*

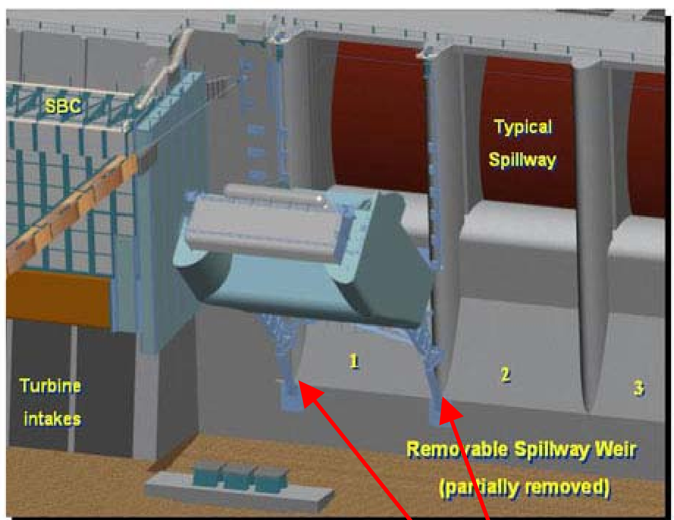
Installation& Fits
- *Press Fit=.001 min.*
- *Clearance Fit Bond Line=.005 min.*
- *Recommended Shaft Dia= .001 per inch of Shaft dia + Swell Allowance*
- *Swell Allowance = .2% OF Shaft Dia.*
- *Kamatics Installation Procedure= TN-11 & TN-16*

Physical Properties
- *Liner- KAron V .040 Thick*
- *Substrate- Fiberglass – Epoxy*
- *80,000 psi Ultimate Strength*
- *40,000 psi Static Limit Load Rating*
- *20,000 psi Dynamic Load Capability*

<u>Kamatics Hydro Power Applications</u>

Submerged Hinge Sphericals

RSW Gate

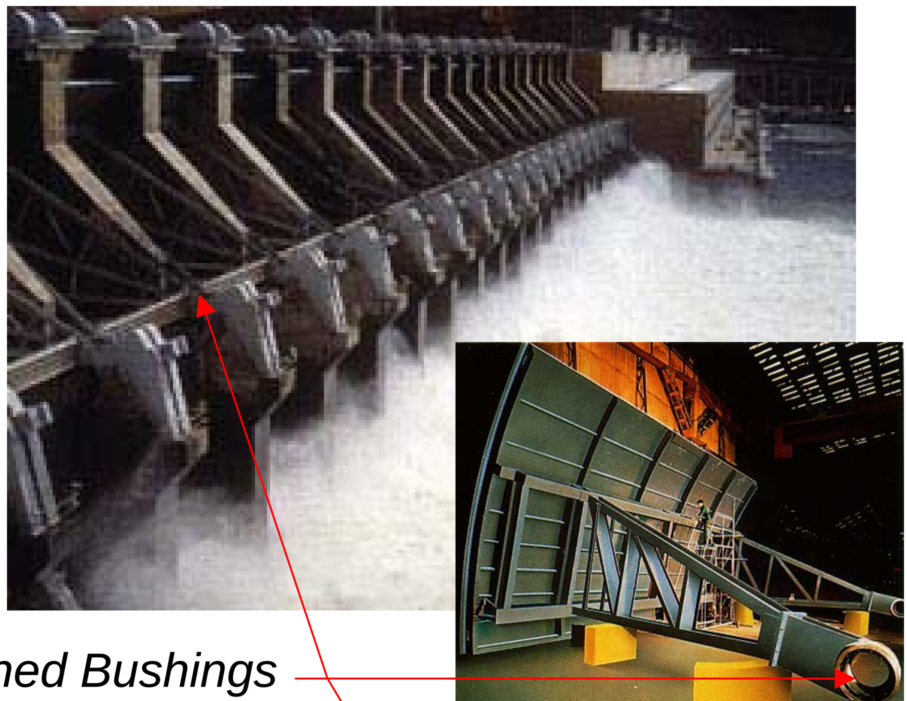


KAron Lined
Spherical Bearings

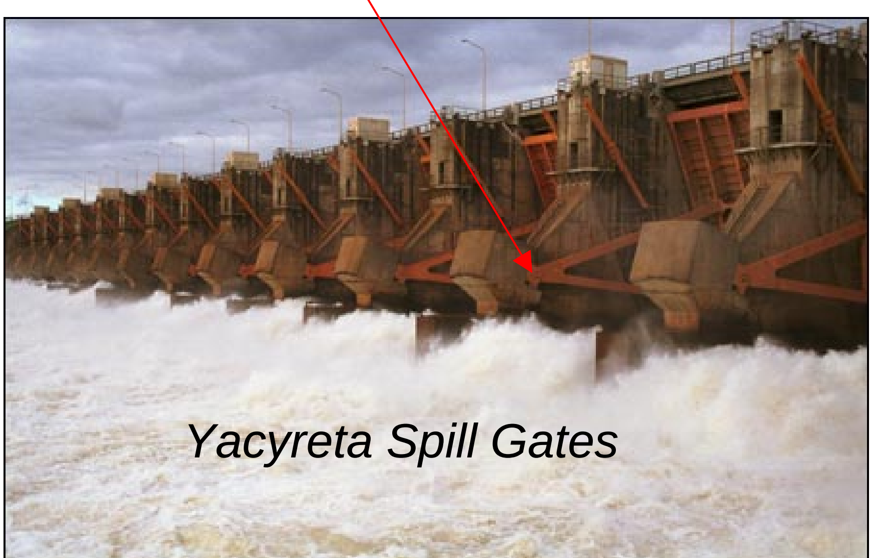
Kamatics Hydro Power Applications

Spill Gate Submerged Hinge Bushings

Lower Monument Dam Spill Gates



KAron Lined Bushings



Yacyreta Spill Gates

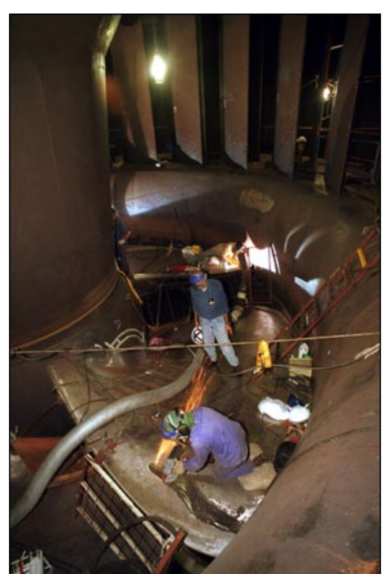
Kamatics Hydro Power Applications

Large Kamatics Bushings for Wicket Gates

Operate Submerged in River Water

Bonneville Wicket Gates

Yacyreta Wicket Gates



Kamatics Hydro Power Applications

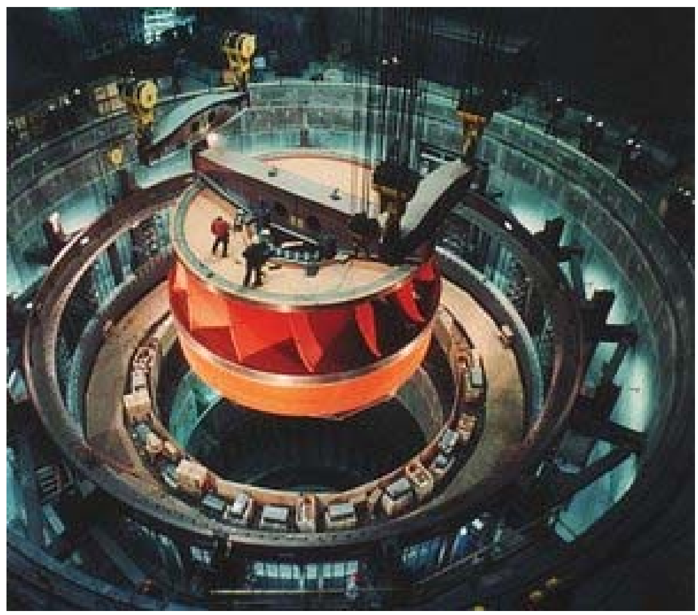
Large Kamatics Sphericals for Kaplan Hub Turbine Control Linkages

Yacyreta Turbines

Kamatics Hydro Power Applications

Large KAron Lined Bearings for Francis Turbines

Grand Coulee Turbines



Keenleyside Dam Turbines

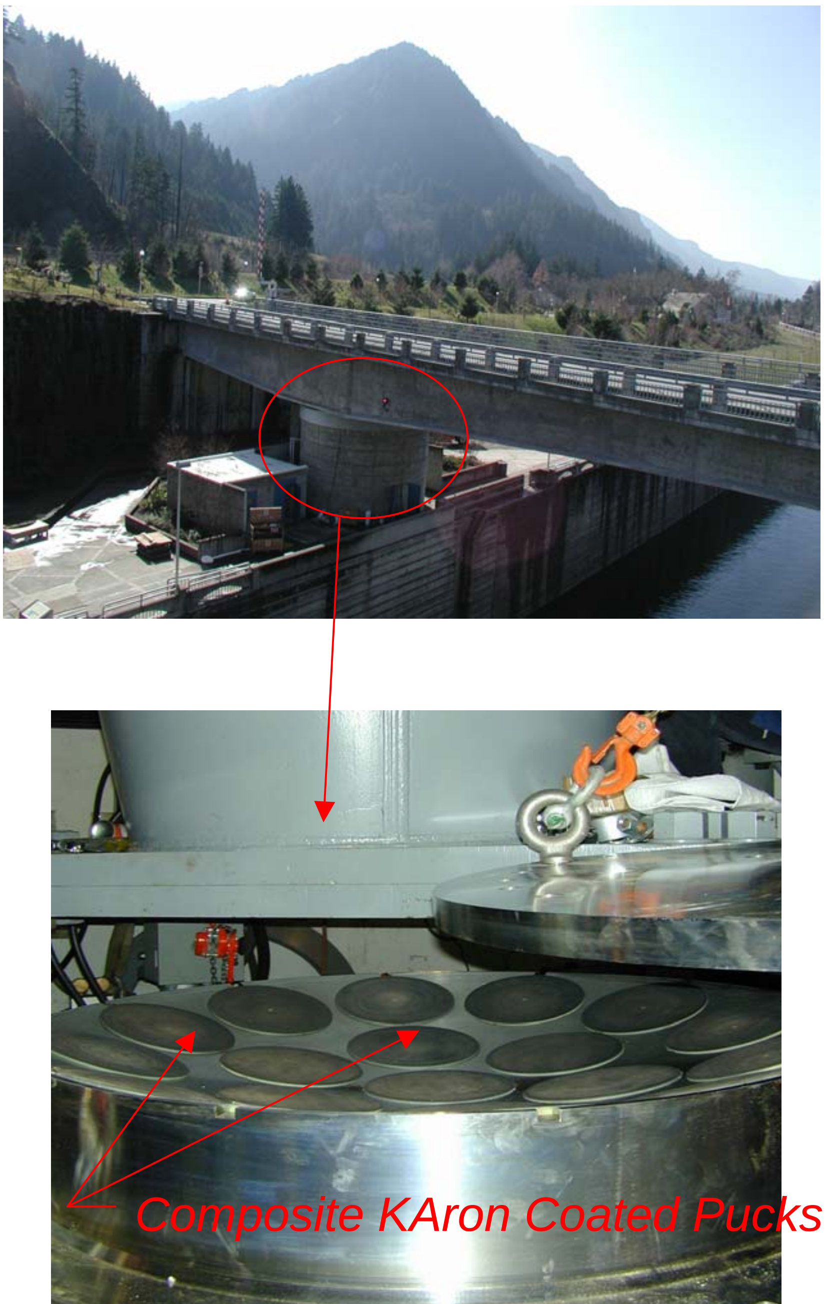
Kamatics Hydro Power Applications

Large Kamatics Track Rollers for Head Gate

Bonneville Dam Head Gates

Kamatics Hydro Power Applications

Swing Bridge Hemispherical Pivot Bearing



Kamatics Hydro Power Applications

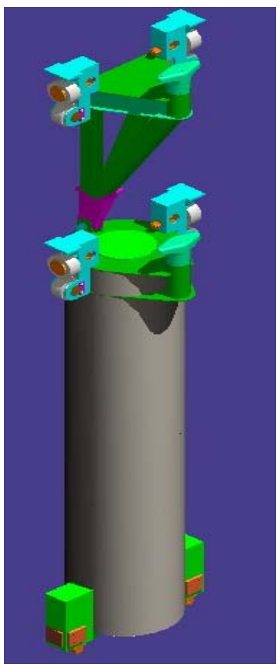
Bonneville Dam Swing Bridge
Self-Aligning Support Rollers

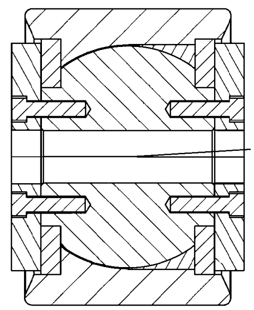
KAron Lined Self-Aligning Rollers

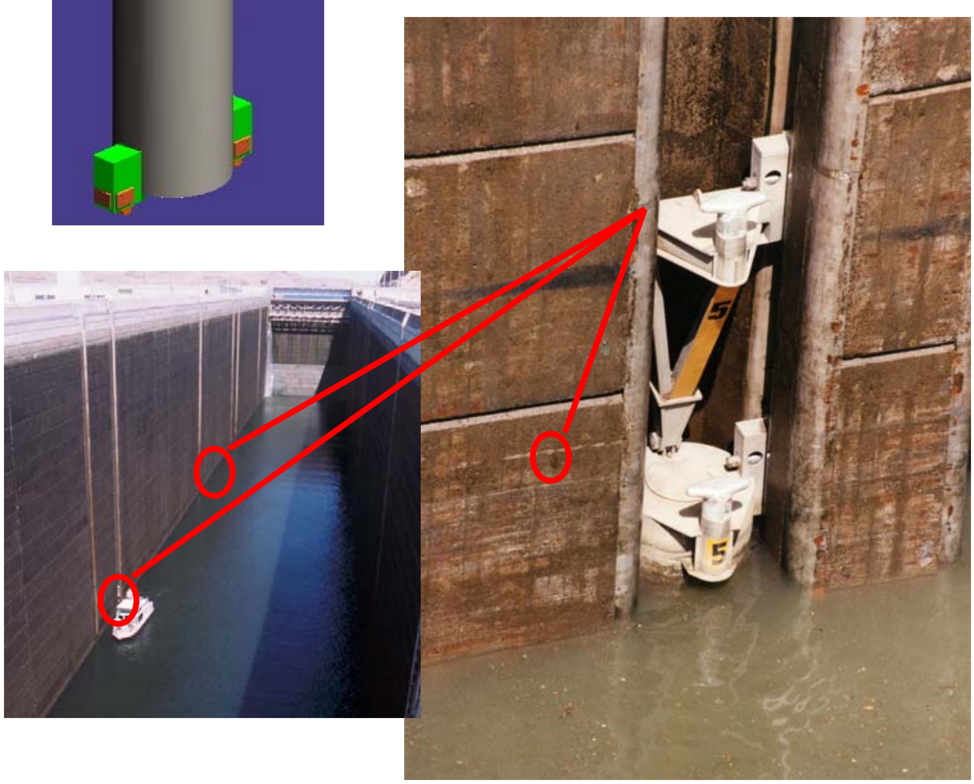
Kamatics Hydro Power Applications

Little Goose Dam
Lock Floating Mooring Bitt Rollers

- *KAron V lined Self-Aligning Rollers*
- *8 Years (4x life) and still operating perfectly*
- *Solved problems caused by uneven track guides*



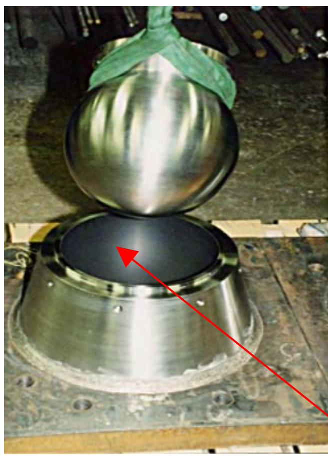




Kamatics Hydro Power Applications

Miter Gate Pintle Bearing Application

Santee Cooper Pinapolis Locks



KAron V Liner

Navigational Lock Pintles
COE & Panama Canal Authority

Powertech/Panama Canal Pintle Test
KAron Pucks and Low Friction KAron VS have excellent results
Minimal Wear with no damage to the pintle ball

Kamatics Hydro Power Testing

KAron V Bushing Silty Water Test

Application: Hydro Electric bearings operating in a silted water evironment againts a 125 microfinish

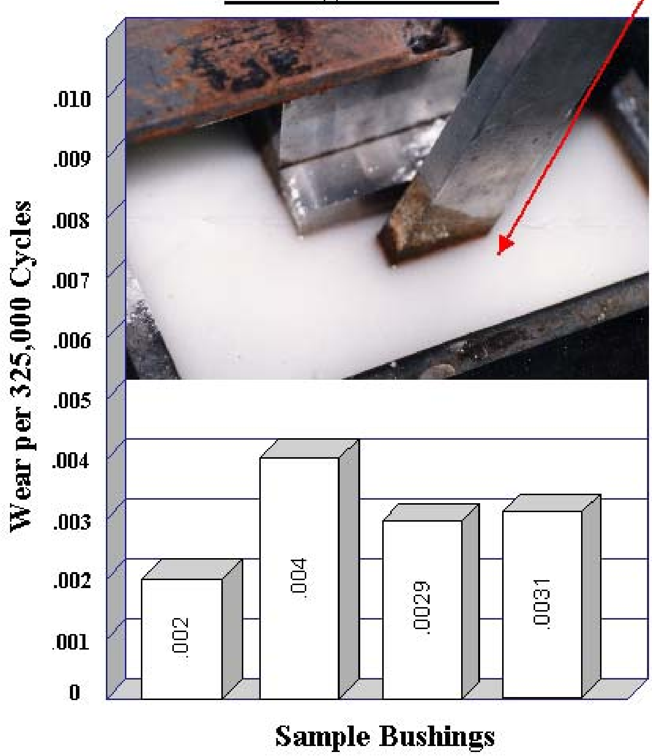
Problem: Excessive wear caused by harsh abbrasives entering the bearing wear zone compounded by a rough surface finish on the mating pin.

Test Plan: Evaluate 4 bushings immersed in silty water operating againts a 125 microfinish for 325,000 cycles (22 cycles per day for 40 years).

Test Conditions
325,000 Cycles
3000 PSI
+/-10° (40° Total)
19 CPM
Immersed in silty water per Mil-Std 810
(100% / 100 mesh, 75% / 325 mesh)
Shaft 17-4 with 125microinch turned finish

Test Specimans:
2.0 ID
2.375 OD
.75 L
.012 KAron V
Fiberglass Substrate

Test Rig and Results



Conclusion: KAron can operate successfully in silty water againts a 125 microinch finish

KAron V, Fiberglass Backed Bushing Endurance Test (Clean Water) vs. 16 RMS Stainless Shaft

APPLICATION:
Hydro-Electric Wicket Gate Bearing.

PURPOSE OF TESTING:
To demonstrate the performance of KAron V liner material when oscillated through small angles at high cycle rates, submerged in clean water.

TEST SPECIMENS:
Fiberglass backed, KAron V lined, straight bushings, 1.0" I.D. x .5" long.

TEST CONDITIONS:
Load - 1000 lbs. (2000 psi)
Oscillation - ± 8° (32° total per cycle)
Speed - 285 cpm (4.75 Hz)
Temperature - Ambient
Media - Clean water
Shaft - 17-4PH cres with a 16 RMS turned finish

TEST SETUP:
The shaft was inserted through the test bushing, supported on each end by rig support bearings, and oscillated through an angle of ± 8° (32° total sweep angle per oscillation) while the load was applied to the test bushing and the bushing and shaft were submerged in clean water.

TEST RESULTS:
Following 7,000,000 cycles, the bearings liner exhibited 0.001" wear and the finish of the shaft was unchanged.

CONCLUSION:
Operation of KAron V bearings in water through small angles at high cycle rates does not significantly wear the bearing or the shaft.

Hydroelectric Generator Turbine "Wicket Gate" Bearing

PURPOSE OF TESTING:
To demonstrate the performance of KAron V bearing liner material when run against a stainless steel shaft with a 63 micro-inch turned finish.

TEST SPECIMENS:
Stainless backed journal bearing; .015" thick KAron V lined bore, 1.0" I.D. X .5" wide.

TEST CONDITIONS:
Load - 500 lbs (1000 psi) and 1000 lbs (2000 psi)
Oscillation - ± 25° (100° total per cycle)
Speed - 20 cpm
Temperature – Room Temperature
Environment - Dry
Shaft - 17-4PH CRES with a 63 micro-inch turned finish

TEST SETUP:
The shaft was inserted through the test bushing, supported on each end by rig bearings, oscillated through an angle of ± 25° (100° total per oscillation) while loaded as noted above.

TEST RESULTS:
After 230,000 oscillatory cycles at 1000 psi, the bushing exhibited 0.001" wear and the finish of the shaft was essentially unchanged. Following an additional 230,000 cycles at 2000 psi, the bushing exhibited <.001" additional wear and the finish of the shaft was not changed. (230,000 cycles is equivalent to 15 cycles per day for 40 years and is typical for this type of application.)

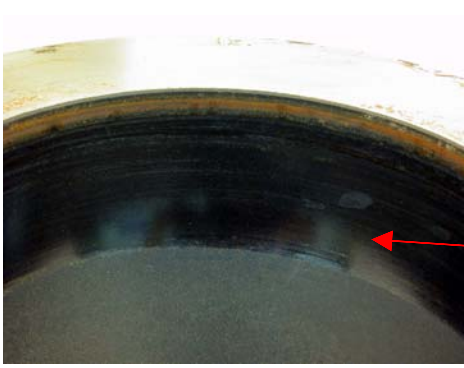
CONCLUSION:
KAron V bearings performed successfully against a relatively rough (63 rms) stainless steel shaft at pressures up to 2000 psi and had little, if any, effect on either the liner or shaft.

Kamatics Hydro Power Testing

Pintle Bearing Testing – Miter Gate (PowerTech Labs)

50,000 Cycle Test Program

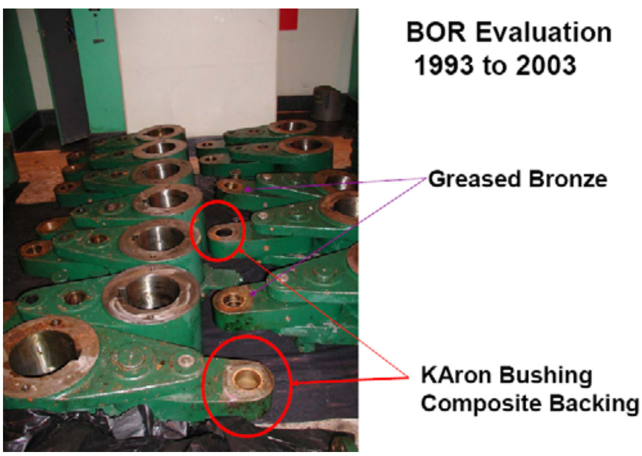
Liner looks like new



Less than .003 wear on KAron V liner after 50,000 Cycles

Grand Coulee Francis Turbine Operating Ring Linkage Bushing Test Summery

KAron Bushings Installed 1993
- *Turbine disassembled 2003*
- *KAron Bushings Less than .001 Wear*
- *Lubricated Bronze Bushings Scored*



KAron Linkage Bushing After 10 years of Service

Linkage Pins

Greased Bronze Bushing After 10 years of Service

KAtherm Systems

Page	Description
1	*KAtherm Systems Index Sheet*
2, 3	*General Characteristics of KAtherm*
4	*KAtherm F-76 Material Properties Data Sheet*
5	*KAtherm G-17 Material Properties Data Sheet*
6	*KAtherm G-22 Material Properties Data Sheet*
7	*KAtherm G-53 Material Properties Data Sheet*
8	*KAtherm G-57 Material Properties Data Sheet*
9	*KAtherm T-10 Material Properties Data Sheet*
10	*KAtherm T-87 Material Properties Data Sheet*
11	*KAtherm T-87S Material Properties Data Sheet*
12	*KAtherm T-88 Material Properties Data Sheet*

General Characteristics of KAtherm

KAtherm ® High Temperature Self-lubricating Liner Materials

These specially formulated advanced materials consist of high strength, high temperature polymers interspersed with PTFE and other lubricating fillers. Their unique compositions impart self-lubricating properties in elevated temperature applications that require extreme bearing pressures and/or speeds. The materials are applied as thin, tight tolerance coatings onto a variety of metallic and non-metallic substrates in typical bearing designs such as bushings, self-aligning bearings, track rollers, cam followers, and thrust washers.

KAtherm	*Service Temp*	*Physical and mechanical properties*	*Typical Applications*
T10	*-65°F to 600°F (-53°C to 315°C)*	*Nominal Thickness: 0.010" (.25 mm)* *Static Limit Bearing Load: 40,000 psi (276 MPa)* *Dynamic Max Temp Limit Bearing Load: 20,000 psi (138 MPa)* *Coefficient of Friction: 0.04 to 0.1* *Surface Velocity: Up to 30 ft/min (9 m/min)*	*Gas turbine engine variable stator vane bushings; self-aligning engine control bearings; high temperature track rollers, bleed valves.*
T88	*-65°F to 600°F (-53°C to 315°C)*	*Thickness: .010" - .020" (.25mm - .50mm)* *Static Limit Bearing Load: 30,000 psi (207 MPa)* *Dynamic Max Temp Limit Bearing Load: 10,000 psi (69 MPa)* *Coefficient of Friction: 0.04 to 0.1* *Surface Velocity: Up to 10 ft/min (3 m/min)*	*Engine control bearings; thrust reverser bearings; engine linkages*
T87	*-65°F to 500°F (-53°C to 260°C)*	*Thickness: .010" - .020" (.25mm - .50mm)* *Static Limit Bearing Load: 30,000 psi (207 MPa)* *Dynamic Max Temp Limit Bearing Load: 20,000 psi (138 MPa)* *Coefficient of Friction: 0.04 to 0.1* *Surface Velocity: Up to 30 ft/min (9 m/min)*	*Engine control bearings, track rollers, and cam followers; thrust reverser bearings; engine linkages, helicopter pitch link/change bearings.*
T87S	*-65°F to 500°F (-53°C to 260°C)*	*Thickness: .010" - .020" (.25mm - .50mm)* *Static Limit Bearing Load: 22,000 psi (152 MPa)* *Dynamic Max Temp Limit Bearing Load: 15,000 psi (103 MPa)* *Coefficient of Friction: 0.02 to 0.08* *Surface Velocity: up to 50 ft/min (15 m/min)*	*Helicopter pitch link/change bearings; high speed track rollers; industrial pulleys*

(Reference Kamatics Data Sheet 158)

General Characteristics of KAtherm (Continued)

KAtherm ® High Temperature/Wear Resistant Composite Materials

Kamatics offers a family of fiber reinforced composite materials that integrate unparalleled strength-to-weight ratios with extreme high temperature service capabilities and wear resistant properties. These products are designed with reinforcing fibers that are braided, woven, filament wound, or randomly oriented. The fibers are combined with advanced polymer matrix materials that are custom formulated to provide exceptional wear resistance and high temperature capability. The finished products are fabricated using proprietary processes to custom specifications and tolerances.

KAtherm	Service Temp	Fiber construction and general description	Typical Applications
G53	-65°F to 650°F (-53°C to 343°C)	Braided carbon fibers provide superior strength and wear properties. Can be molded into straight and flanged bushing shapes, or pressed into flat strips.	Engine sync ring wear pads; engine cowl wear pads; compressor stator vane bushings.
G63	-65°F to 650°F (-53°C to 343°C)	Random oriented chopped carbon fibers provide excellent strength and wear properties. Can be molded into various custom shapes.	Compressor stator vane bushings; bumper pads; wear pads
G22	-65°F to 650°F (-53°C to 343°C)	Random oriented milled carbon fibers provide good wear resistance with moderate strength. Can be molded into various custom shapes and easily machined.	Compressor stator vane bushings; thrust washers; seals; industrial bushings
T22	-65°F to 600°F (-53°C to 315°C)	Random oriented milled PTFE fibers provide exceptional lubricating and wear properties. Can be molded into various custom shapes and easily machined.	Engine control bushings; seals
G17	-65°F to 500°F (-53°C to 260°C)	Woven carbon fibers provide superior strength and wear properties. Can be molded into flat panels.	Wear plates; seals; bumper pads
G57	-65°F to 500°F (-53°C to 260°C)	Braided carbon fibers provide superior strength and wear properties. Can be molded into straight and flanged bushing shapes, or pressed into flat strips.	Engine cowl wear pads; thrust reverser wear pads
F76	-65°F to 400°F (-53°C to 200°C)	Filament wound glass fibers provide superior strength properties. Can be molded into round tubes and flanged bushing shapes.	Non-metallic substrate for KAtherm® and KAron® self-lubricating bearing systems.
G65	-65°F to 300°F (-53°C to 150°C)	Random oriented chopped carbon fibers provide excellent strength and wear properties. Can be molded into various custom shapes.	Bumper pads, wear pads, Non-metallic substrate for KAron® self-lubricating bearing systems.

KAtherm F-76
Material Properties Data Sheet

Description:

Kamatics KAtherm® F-76 is a composite material consisting of high strength glass fibers and an advanced thermoset polymer matrix. The material is fabricated in a filament wound construction into bushings, flat disks, washers, and other various sizes and shapes.

KAtherm® F-76 is a suitable substrate for Kamatics KAron® B and KAtherm® self-lubricating bearing materials in non-metallic applications that require service temperatures up to 350°F (175°C). When applied onto a KAtherm® F-76 substrate, the performance of these self-lubricating bearing materials are specific to each individual application. Consult with Kamatics Engineering for bearing performance specifications.

Characteristics:

Operating Temperature Range:	*-65°F to 350°F (-51°C to 175°C)*
Maximum Short Term Excursion:	*450°F (230°C)*
Maximum Filament Wound OD:	*32 inches (80 cm)*
Maximum Filament Wound Length:	*40 inches (100 cm)*

Physical Properties:

Density:	*0.067 lb/in3 [1.85 gm/cc]*
Hardness:	*Rockwell M 90/100*

Through Thickness Compressive Properties:

Yield Strength:	*40,000 psi (246 MPa)*
Ultimate Strength:	*60,000 psi (414 MPa)*
Modulus:	*600,000 psi (4138 MPa)*

Fluid Compatibility

KAtherm F76 is compatible with the following fluids:

JP4 Jet Fuel, MIL-L-7808 lubricating oil, MIL-H-5606 hydraulic oil, MIL-A-8243 anti-icing fluid, MIL-H-83282 hydraulic fluid, Skydrol, Distilled water, Seawater

For other specific fluid compatibility requirements please contact Kamatics Engineering

KAtherm G-17
Material Properties Data Sheet

Description:
Kamatics KAtherm® G-17 is a high temperature wear resistant composite material consisting of carbon graphite fibers with a high temperature toughened polyester thermosetting resin system. The material is fabricated in a laminate construction into flat panels, washers, and seals of various sizes and shapes.

Characteristics:

Thickness:	*0.025” to 0.300”*
Operating Temperature Range:	*-65F to 525F*
Coefficient of Friction:	*0.2 to 0.3*
Surface Rubbing Speeds:	*Up to 50 ft/min*

Physical Properties:

Specific Gravity:	*1.526*
Density:	*0.056 lb/in3 [1.53 gm/cc]*
Hardness:	*Rockwell M 110/120*
Compression Modulus:	*643,000 psi*
Thermal Conductivity (@450°F):	*6.93 BTU•in/(hr•ft^2•°F) [.737 W/(m•K)]*

Load Carrying Capabilities:

Ultimate Stress to Failure:	*101,500 psi (compression)*
Elastic Limit:	*92,000 psi (compression)*
Wear (@ 500F ± 25F):	*0.004” at 18 psi, 1750 cpm, 0.100” stroke, after 10x106 cycles*

KAtherm G-22
Material Properties Data Sheet

Description:

Kamatics KAtherm® G-22 self lubricating bearing system is a homogeneous matrix consisting of a high performance thermoset polymer reinforced with carbon fibers. The material provides the following attributes:

- *High temperature capability*
- *Machinable*
- *Low friction*
- *Chemical resistance*

Physical Characteristics:

Max Continuous Operating Temperature:	*600°F (315°C)*
Max Temperature Excursion:	*650°F (343°C)*
Density:	*1.49 g/cc*
Compressive Strength:	*23,000 psi (158.6 MPa)*
Compressive Modulus:	*600,000 psi (4.1 GPa)*
Coefficient of thermal expansion:	*18 x 10-6 in/in·°F (32.4 x 10-6 mm/mm·°C)*
Coefficient of Friction:	*0.1 - 0.2*

Bearing Properties:

KAtherm G22 provides its best performance sliding against smooth (16 RMS or better), hardened surfaces. Examples include:

- *Anodized Aluminum*
- *Ceramic Coated Components*
- *Hard Coated Aluminum*
- *Coated Titanium*
- *Stainless Steel - Rc 28 and up*

Wear for KAtherm® G22 was measured after 25,000 cycles at 550°F in a journal bearing configuration against Rc 42 stainless steel, 8 RMS (± 25° oscillation, 20 cycles per minute):

At a 3000 psi load: measured wear < .003 inches (0.075mm)

(Ref Data Sheet 133)

KAtherm G-53 High Temperature Wear Pad Material Data Sheet

Description:

Kamatics KAtherm® G-53 wear pad material is a composite material consisting of a unique semi-crystalline organic thermoset polymer with high thermal stability and oxidation resistance reinforced with braided high strength carbon fibers. The material is designed for high temperature aerospace applications that require linear fretting or abrasion wear resistance.

Characteristics:

Wear Pad Thickness:	*0.050” to 0.200”*
Standard Operating Temperature:	*-65°F to 650°F*
Maximum Short Term Exposure Limit:	*750°F*
Weight Loss at 650°F (100 hours):	*15%*
Surface Rubbing Friction:	*0.2 to 0.3*
Surface Rubbing Speeds:	*Up to 30 ft/min*

Physical Properties:

Density:	*0.056 lb/in3 [1.55 gm/cc]*
Hardness:	*Rockwell M 110/120*
Compressive Strength:	*100,000 psi*
Compressive Modulus:	*300,000 psi*
Thermal Conductivity (@450°F)	*5 BTU•in/(hr•ft²•°F) [.72 W/(m•K)]*

Wear Characteristics:

50 psi pressure tested against Inconel 718 (16 rms), +/- .050" linear travel, 1750 cycles per minute, for 100 hours (10,500,000 cycles)

Temperature (°F)	Wear (inch)
300	.0010
500	.0015
600	.0020
650	.0030
700	.0045
750	.0070

(Reference Kamatics Data Sheet 154)

KAtherm G-57 High Temp Wear Pad Material Properties Data Sheet

Description:

Kamatics KAtherm® G-57 wear pad material is a braided carbon graphite fiber with a high temperature toughened polyester thermosetting resin system.

Characteristics:

Wear Pad Thickness:	0.050” to 0.300”
Operating Temperature Range:	-65°F to 525°F
Coefficient of Friction:	0.2 to 0.3
Surface Rubbing Speeds:	Up to 50 ft/min

Physical Properties:

Specific Gravity:	1.526
Density:	0.056 lb/in3 [1.53 gm/cc]
Hardness:	Rockwell M 110/120
Compression Modulus:	643,000 psi
Thermal Conductivity (@450°F):	6.93 BTU•in/(hr•ft²•°F) [.737 W/(m•K)]

Load Carrying Capabilities:

Ultimate Stress to Failure:	101,500 psi (compression)
Elastic Limit:	92,000 psi (compression)
Wear (@ 500F ± 25F):	0.004” at 18 psi, 1750 cpm, 0.100” stroke, after 10x106 cycles

KAtherm T-10 Self-Lubricating Bearing Material Data Sheet

Description:

Kamatics KAtherm T-10 is a self-lubricating bearing material consisting of a high temperature thermosetting polymer which is reinforced by a woven fabric of high strength glass fibers and self-lubricating TFE fibers. This unique combination of advanced materials provides for an optimized combination of high compressive strength, low wear, low friction, and thermal distortion stability. The material is applied as a thin self-lubricating liner onto metallic and non-metallic substrate materials in a variety of components: bushings, thrust washers, wear pads, link arms, self-aligning bearings, track rollers, and cam followers.

Characteristics:

Nominal Thickness:	*0.010" (.25 mm)*
Standard Operating Temperature:	*-65°F to 600°F (-53°C to 315°C)*
Maximum Short Term Excursion:	*675°F (350°C)*
Coefficient of Friction:	*0.04 to 0.1 depending upon temperature, pressure, and speed*
Surface Velocity:	*Up to 30 ft/min (9 m/min)*

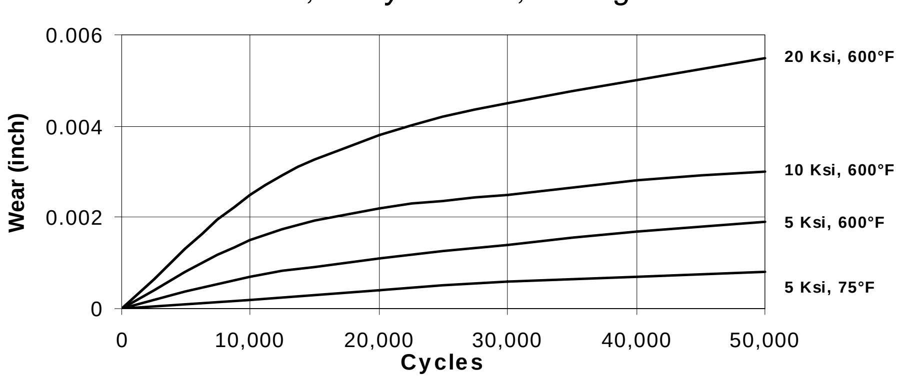
Physical Properties:

*Static Ultimate Bearing Load:**	*60,000 psi (414 MPa)*
*Static Limit Bearing Load:***	*40,000 psi (276 MPa)*
Permanent Set at Static Limit Load:	*.002" (.025 mm)*
*Maximum Dynamic Bearing Load:****	*20,000 psi (138 MPa) @ 600°F (315°C)*

Notes:
** Equivalent to 1.5 times the static limit load, local liner distress may occur. Typical liner thickness 0.012 in. (0.3 mm).*
*** Maximum load that will result in a permanent set in the liner no greater than .004 (0.10mm) inches after the load is applied for 3 minutes.*
*** .006 inches (0.152 mm) maximum permitted wear at 600°F (350°C) after 10,000 cycles, at 20Ksi, ± 25o at 10 cpm.*

Wear Data:

Measured at +/- 20° oscillation, 20 cycles/min, mating surface 17-4 PH H900



(Reference Kamatics Data Sheet 157)

KAtherm T-87
Material Properties Data Sheet

Characteristics:

Description: KAtherm T-87 is a non-peelable, non-fabric, machinable homogeneous mixture of PTFE fibers and a high temperature toughened polyester resin system that enable very low friction levels including at low temperatures.

- *Nominal liner thickness: .010 to .020 in. (.25 to .51 mm), Max .060 in. (1.52 mm)*
- *Operating temperature range: -100° F to +450°F (-73°C to +232°C)*
- *Coefficient of friction range: .02 to .08, depending upon temperature, pressure, and velocity.*
- *Compatible backing substrate materials: stainless steel, carbon steel, titanium, aluminum, nickel alloys, and composites.*
- *Surface speeds to 50 fpm (15.0 m/min)*

Physical Properties:

- *Density* — *1.39 gm/cc*
- *Hardness* — *Rockwell 15X 88*
- *Compression Modulus* — *3.1 x 105 psi (2,137 MPa)*

Typical Load Carrying Capabilities:

- *Static Ultimate* — *35,000 psi (241 MPa)*
- *Static Limit* — *22,000 psi (152 MPa)*
- *Dynamic (max.)* — *15,000 psi (103 MPa)*
- *Dynamic (continuous)* — *10,000 psi (69 MPa)*

Fluid Compatibility:

Compatible with aircraft hydraulic fluids, lubricating oils, jet fuels, de-icing fluids, cleaning fluids, and water.

Typical Applications:

For bearing applications requiring an extremely low friction level, especially at ambient and low temperatures, for high speed oscillatory operation such as Helicopter applications: main and tail rotor pitch change and pitch link bearings, main rotor scissors link bearings. Aircraft applications: high speed aircraft universal joints.

KAtherm T-87S
Material Properties Data Sheet

Characteristics:

Description: KAtherm T-87S is a non-peelable, non-fabric, machinable homogeneous mixture of PTFE fibers and a high temperature toughened polyester resin system that enable very low friction levels including at low temperatures.

- Nominal liner thickness: .010 to .020 in. (.25 to .51 mm), Max .060 in. (1.52 mm)
- Operating temperature range: -100° F to +500°F (-73°C to+260°C)
- Coefficient of friction range: .02 to .08, depending upon temperature, pressure, and velocity.
- Compatible backing substrate materials: stainless steel, carbon steel, titanium, aluminum, nickel alloys, and composites.
- Surface speeds to 50 fpm (15.0 m/min)

Physical Properties:

• Density	1.39 gm/cc
• Hardness	Rockwell 15X 88
• Compression Modulus	3.1 x 105 psi (2,137 MPa)

Typical Load Carrying Capabilities:

• Static Ultimate	35,000 psi (241 MPa)
• Static Limit	22,000 psi (152 MPa)
• Dynamic (max.)	15,000 psi (103 MPa)
• Dynamic (continuous)	10,000 psi (69 MPa)

Fluid Compatibility:

Compatible with aircraft hydraulic fluids, lubricating oils, jet fuels, de-icing fluids, cleaning fluids, and water.

Typical Applications:

For bearing applications requiring an extremely low friction level, especially at ambient and low temperatures, for high speed oscillatory operation such as Helicopter applications: main and tail rotor pitch change and pitch link bearings, main rotor scissors link bearings. Aircraft applications: high speed aircraft universal joints.

KAtherm T-88
Material Properties Data Sheet

Description: KAtherm T-88 is a self-lubricating liner material consisting of a high temperature multifunctional aromatic polyester with Teflon and other fillers. It is designed to be applied as a .005" - .010" (.127mm - .254mm) thick liner in high temperature bearing applications up to 600°F (315°C). Compatible backing substrates include stainless steels, carbon steels, and high nickel alloys.

<u>Physical Properties</u>:

•Specific Gravity=	*1.3 g/cc*
•Hardness=	*Rockwell M 80 – 90*
•Operating Temperature=	*-65°F to 600°F (-50°C - 315°C)*

<u>Bearing Properties (up to 600°F):</u>

•Static Limit=	*20,000 psi (138 MPa)*
•Dynamic Limit=	*10,000 psi (69 MPa)*
•Wear Rate at Dynamic Limit=	*< .005" (.13 mm) wear **
•Coefficient of friction range:=	*.05 to .11, depending on load and speed*
•Surface speed range=	*Up to 30 fpm (9 m/min)*

<u>Fluid Compatibility:</u>

KAtherm T-88 does not degrade under long term exposure to the following aerospace grade fluids:

Skydrol 500B hydraulic fluid
JP4 or JP5 jet fuel
MIL-L-7808 lubricating oil
MIL-H-5606 hydraulic oil
MIL-A-8243 anti-icing fluid
MIL-H-83282 hydraulic fluid
Distilled water

** Test sample: 1" (25.4mm) ID bushing, .5" (12.7mm) width, 17-4 PH H1150 substrate. Test conditions: 5,000 lb. (22,200 N) load, 25,000 cycles, ±25°, 20 cpm, 600°F (315°C). Mating shaft: 17-4 PH H900, 8 rms (.2 µm) surface finish.*

Miscellaneous KAtherm Testing

Page	Description
1	*Miscellaneous KAtherm Testing Index Sheet*
2	*High Temperature G-47 Wear Pad Test for B767/CF6-80C2 Exhaust Nozzle*
3	*KAtherm T-87 Endurance Test (475° F Temperature*
4	*KAtherm T-87 High Temperature Endurance Testing – Various Temperatures* *KAtherm T-87 Fluid Compatibility Testing* ►*KAtherm T-87 verses Skydrol Hydraulic Fluid* ►*KAtherm T-87 verses JP-4 Jet Fuel*
5	*.MIL-B-81819 Contamination Testing -Steady Load, KAtherm T-87 Liner (Helicopter Environment)*

High Temperature G-47 Wear Pad Test for B767/CF6-80C2 Exhaust Nozzle

Purpose of Test:
The purpose of this test was to evaluate the performance of a Kamatics high temperature G-47 composite wear pad against the original equipment wear pad currently in service. The original equipment wear pad product in service is being removed prematurely due to wear.

Test Specimens:
Two (2) Kamatics G-47 composite wear pads (ref. p/n KWS800001).
One (1) graphite polyimide type wear pad that is currently being used on the Boeing 767/CF6-80C2 exhaust nozzle installation.

Test Conditions:
The test was performed at a constant 500°F temperature by use of heating rods in an Inconel 718 block that was ground to a 16 rms surface finish. The Inconel 718 block was cycled through 0.100" linear travel, rubbing against the wear pads at a rate of 1750 cycles per minute. A test load of 50 lbs was applied to represent actual operating loads.

Test Results:

Sample	Run Time (Hours)	Total Cycles	Total Wear (in)	Wear Rate (microns/ft)
Original Equipment Graphite Polyimide	87	9,156,000	0.0050	.0335
Kamatics G-47	101	10,605,000	0.0040	.0231
Kamatics G-47	101	10,605,000	0.0020	.0116

Conclusions
The Kamatics high temperature G-47 composite wear pads showed a significant improvement in wear characteristics relative to the original equipment graphite polyimide wear pad that is currently in service.

(Reference Kamatics Data Sheet 128)

KAtherm T-87 Endurance Test 475° F Temperature

Purpose of Test:
To evaluate the performance of KAtherm T-87 at 475° F for an extended duration.

Test Specimens:
Six (6) journal (sleeve) bearings, 1.19" OD x 1.00" ID x .50" long. Journal substrate material was 17-4 PH stainless steel; the KAtherm T 87 liner was .012" nominal thickness.

Test Setup:
Three (3) journal bearings were tested at the same time in a lug/clevis configuration with two clevis bearings each reacting one half the load of the center lug. The shaft through the bearing bores was fitted with a heater and thermocouple the provide the temperature required.

Test Condition :
Two test rigs were run at the same time, both configured as noted above.
- *Load = 2600 pounds:*
- *Bearing Pressure = 5200 psi on center lug bearing; 2600 psi on each clevis bearing.*
- *Temperature = 475° F.*
- *Oscillation Angle = ±35° (140° total).*
- *Oscillation Rate = 49 cpm (5 foot per minute rubbing velocity).*
- *Shaft = 17-4PH, Condition H900, 8 RMS finish.*

Test Results:

Test Rig #	Bearing Location	Bearing Pressure	No. Cycles	Liner Wear
1	Clevis Center Lug Clevis	2600 psi 5200 psi 2600 psi	138800 138800 138800	.0025" .004" .003"
2	Clevis Center Lug Clevis	2600 psi "" 5200 psi "" 2600 Psi ""	93480 230672 93480 230672 93480 230672	.002' .004" .004" .010" .0025" .004"

(Reference Kamatics Data Sheet 130)

KAtherm T-87 High Temperature Endurance Testing

Specimens:
KRJ16-ST87-016 (1.00 in. bore x 0.50 in. long journal) (25.4mm x 12.7mm)

Pressure	Temperature	Cycles (±25°)	Wear
5ksi (34mPa)	70°F (21°C)	100,000	~ 0.001 (0.025mm)
10ksi (68mPa)	70°F (21°C)	100,000	~0.0015 (0.038mm)
5ksi (34mPa)	300°F (149°C)	100,000	~0.0015 (0.038mm)
10ksi (68mPa)	300°F (149°C)	100,000	~0.002 (0.05mm)
10ksi (68mPa)	400°F (204°C)	111,325	~0.002 (0.05mm)
5ksi (34mPa)	500°F (260°C)	100,000	~0.003 (0.075mm)
10ksi (68mPa)	500°F (260°C)	100,000	~0.004 (0.10mm)

Reference STRR 3466

KAtherm T-87 Fluid Compatibility Testing

KAtherm T-87 verses Skydrol Hydraulic Fluid:

- Specimen size 1 in. x 1 in. x .125 in. thick (25.4mm x 25.4mm x 3.17mm).
- Specimens soaked in Skydrol @ 160°F (71°C) for 72 h ours.
- Negligible change in dimension, hardness, or weight.

KAtherm T-87 verses JP-4 Jet Fuel:

- Specimen size 1.10 in. x 1.85 in. x .150 in. thick (27.9mm x 47.0mm x 3.81mm).
- Specimens soaked in JP-4 Jet Fuel @ 110°F (43.3°C) for 72 hours.
- Negligible change in dimension, hardness, or weight.

MIL-B-81819 Contamination Testing - Steady Load KAtherm T-87 Liner (Helicopter Environment)

Test Samples (2):

Spherical bearing = M81819/1-2,
- OD = 1.75 in. (44.5 mm),
- Bore = 1.0 in. (25.4 mm), ball diameter = 1.5 in. (38.1 mm)
- Liner = KAtherm T-87

Test Conditions:

- Immersed in fluid for 24 hours prior to test at 160ºF (71ºC), except for JP-4 at 110ºF (43ºC)
- 1,925 psi (13.3 N/mm2) steady load, 300 cpm, ±10º for 200 hours

	Measured Wear – inches (mm)	
Type of Fluid	Sample 1	Sample 2
MIL-A-8243 De-Ice	0.0005 (.013)	0.0005 (.013)
MIL-H-83282 Hyd Fluid.	0.0 (0.0)	0.001 (.025)
JP-4 Jet Fuel	0.001 (.025)	0.001 (.025)
MIL-H-5606 Hyd. Fluid	0.0 (0.0)	0.0 (0.0)
Lubricating Oil	0.001 (.025)	0.0 (0.0)

Unique KAtherm Applications

Page	Description
1	*Unique KAtherm Applications Index Sheet*
2	*High Temperature Wear Pads*
3	*High Temperature Applications and Bearing Configurations*
4	*Various Engine KAtherm Applications*
5	*Nacelles / Thrust Reversers*

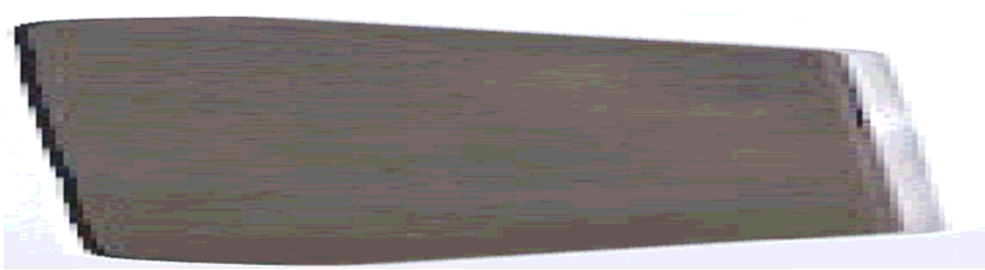
HIGH TEMPERATURE WEAR PADS

APPLICATIONS:

- Exhaust Nozzle Wear Pads for Boeing 747,767/GE CF6-80C2
- Aft Fairing Wear Pads for Boeing 767

FEATURES:

- For use up to 500°F continuously, to 525°F for short term
- Can be fabricated as an all composite pad (G47,G57) or self lube liner (T87)
- can be applied to metal backings
- Prevents wear/fretting between contacting surfaces



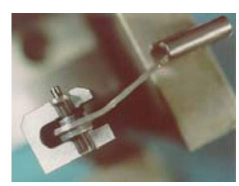
High Temperature Applications

- *VG Vane System Journals, Sleeves & Thrust Washers.*
- *Torque Tube / Pillow Block Journals & Spherical Bearings*
- *Bleed Valve Cam Followers, Journals & Spherical Bearings*
- *Hi Temperature Wear Pads / Fretting Barriers*
- *Thrust Reverser Linkage / Pivot Bearings*

Bearing Configurations

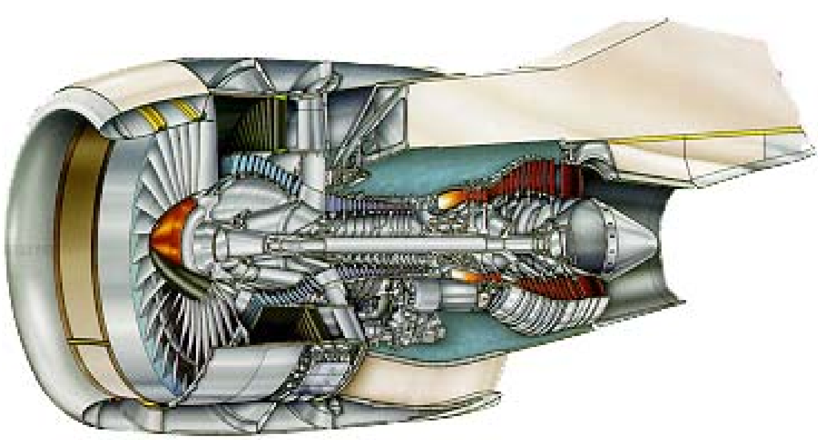
- *Flanged /Unflanged Journal Bearings:*
  Braided, Filament Wound, Composite, Compact Carbon
- *Spherical Bearings :*
  Injected Composite, Compact Carbon
- *"KRP" Type Torque Tube / Airframe Bearings:*
  Injected Composite, Compact Carbon
- *Wear Pads / Fretting Barriers:*
  Braided, Laminate, Composite

Various Engine KAtherm Applications



Nacelles / Thrust Reversers

- ***Wear Strips***
- ***Wear Pads***
- ***Thrust Reverser Slide Tubes / Blocks***
- ***Composite Backed Bearings***
- ***High Temperature Bearings***



Kamatics KAflex and Tufflex Couplings and Driveshafts

Page	*Description*
1	*KAflex and Tufflex Couplings and Driveshafts Index Sheet*
2	*Kamatics KAflex and Tufflex Couplings and Driveshafts*
3	*KAflex Coupling and Driveshaft Design*
4	*KAflex Driveshaft Design Features*
5	*KAflex Driveshaft Design Features (Continued)*
6	*KAflex Coupling and Driveshaft Applications*
7	*KAflex Coupling and Driveshaft Testing*
8	*KAflex Coupling and Driveshaft Testing - One Million Cycle Reverse Torque Test*
9	*KAflex Driveshaft –Fail-Safe Feature*
10	*KAflex Driveshaft –Fail-Safe Feature (Continued)*
11	*Tufflex Coupling and Driveshaft Design*

Kamatics KAflex and Tufflex Couplings and Driveshafts

KAflex Coupling and Driveshaft Design

General:
The KAflex design has accumulated over 25 years of exceptional service.
Over 20,000 KAflex driveshafts and couplings are in operation worldwide.
KAflex driveshafts and couplings have accumulated over 20 Million flight hours.

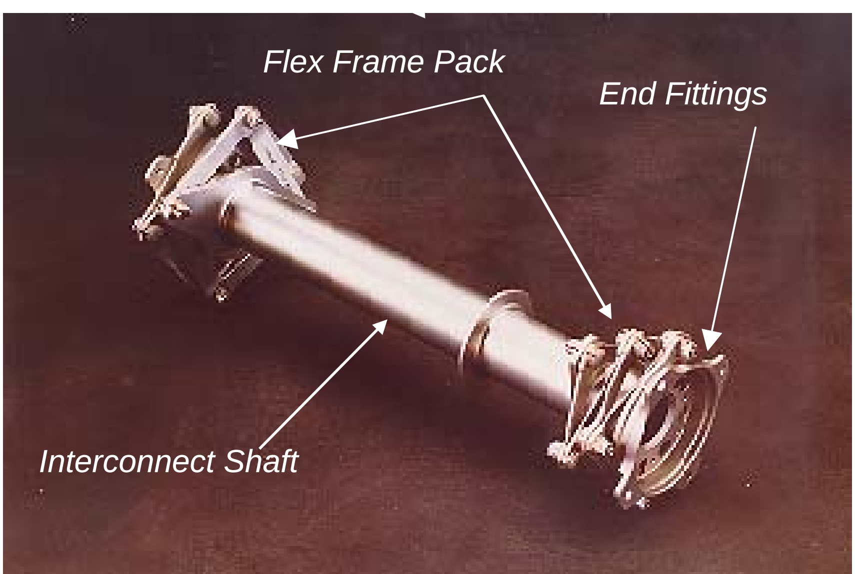
Flexible driveshafts and couplings are required for Helicopter main and tail rotor shafts and other similar applications, to provide torque transmission along with angular and axial misalignment. Misalignment is generally caused by relative motion of the engine, gearbox, transmission, rotor system, flight loads and thermal growth.

KAflex design features include the following features:

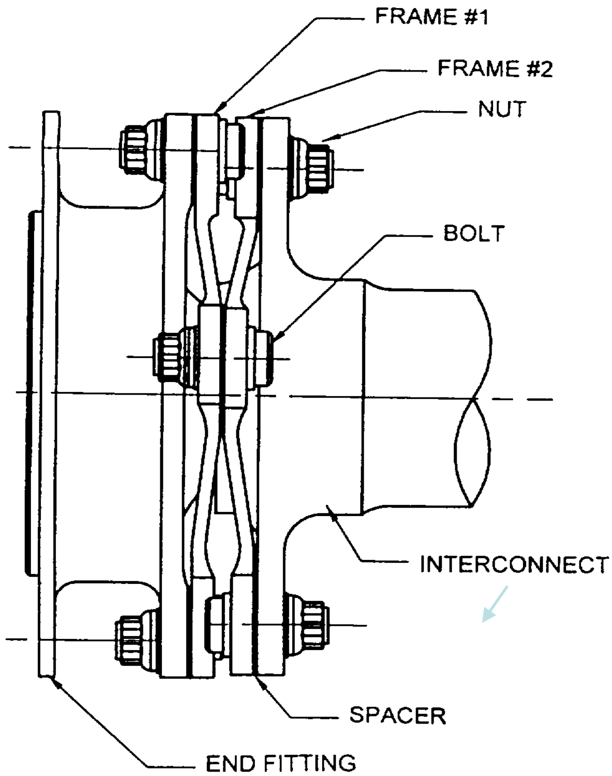
Lubrication is not required, a superior misalignment capability, a built-in fail-safe, high torque transmission capacity, zero backlash, ease of inspection, a damage tolerant design, extended life, and repairable if necessary.

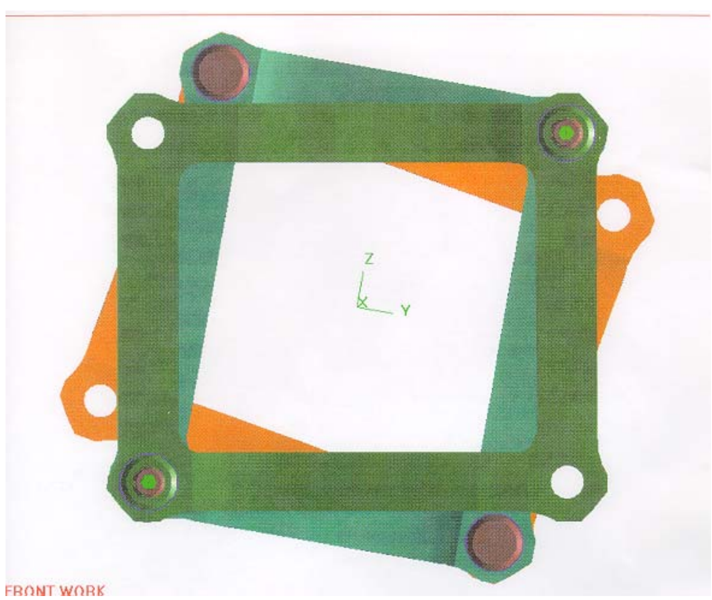
KAflex Design Major Components

- *End Fittings… connection to drive shaft*
- *Flex Frames… torque carrying and misalignment capability*
- *Interconnect …connects flex frame packs*



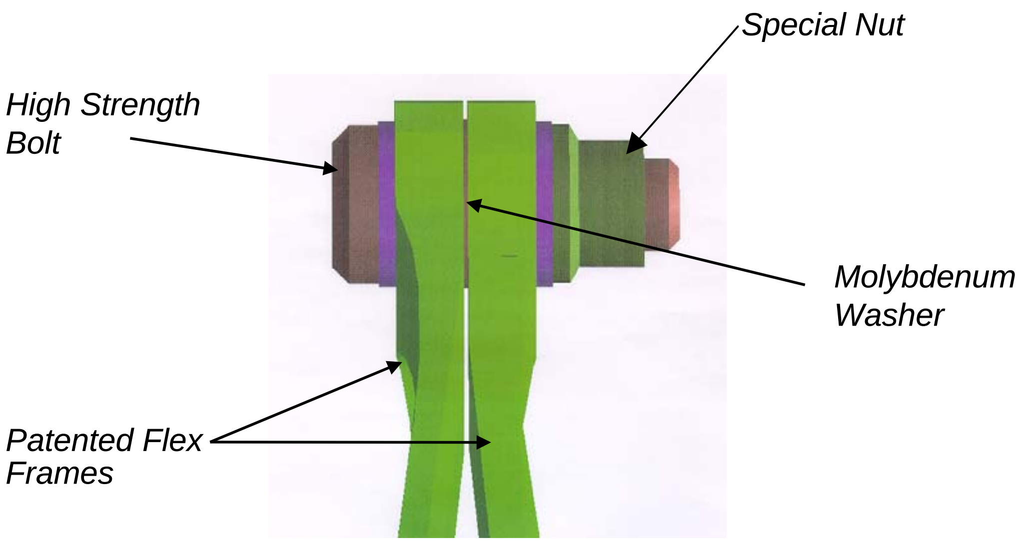
KAflex Driveshaft Design Features





View showing typical multiple Flex frame stack-up

KAflex Driveshaft Design Features



The KAflex bolted joint is uniquely designed to inhibit metal fretting at connection points.

- *Rigid Flex Frame corners force bending motion away from bolted connection.*
- *High clamping forces and high strength bolts used to clamp Flex Frame stack and eliminate motion at joint.*
- *Nitrided Flex Frame surface layer resists fretting (R_c65 hardness).*
- *Corrosion/Fretting Protection…Flex frames are coated with a ceramic bonded aluminum (MIL-C-81751) to inhibit fretting and provide corrosion protection.*
- *Molybdenum washers are used between the flex frames and mating surfaces to inhibit fretting.*

KAflex Coupling and Driveshaft Applications

- The KAflex driveshaft began service in U.S. Army UH-1 helicopters in January 1976, followed by a fleet retrofit.
- German, Australian, and New Zealand UH-1 fleet retrofits - June 1980.
- Total number of KAflex Driveshafts delivered for UH-1 fleet is 6500 units worldwide.
- Total number of hours on UH-1 fleet in excess of 14,000,000 flight hours.
- UH-1 KAflex lead-the-fleet-aircraft approaching 15,000 flight hours.
- No reported accidents due to KAflex UH-1 Driveshafts in 20 years of operation

COMMERCIAL

BELL 205
BELL 206B
BELL 206LT
BELL 206 L1
BELL 206 L3
BELL 206 L4
BELL 407
BELL 427
AGUSTA EH 101
AGUSTA NH 90
MBB B0105
MD500
MD520N (NOTAR)
MD600N
SCHWEIZER 330
KAMAN K-MAX

MILITARY

UH-1H
AH-1S
UH-1N
OH-58C
OH-58D
OH-6
SH-2F
SH-2G

KAflex Coupling and Driveshaft Testing

Kamatics KAflex endurance test rig showing the high misalignment capability of the KAflex design.

KAflex Coupling and Driveshaft Testing

One Million Cycle Reverse Torque Test (Customer Requirement)

•Customer Test Requirement - 50,000 reverse torque cycles at 100% max. torque

•KAflex driveshaft demonstrated 1,000,000 reverse torque cycles without fretting.

Actual test parameters run by Kamatics

NO CYCLES	IN-LB REVERSING TORQUE	% OF MAXIMUM TORQUE
100,000	± 8350	100%
400,000	± 6262	75%
500,000	±4175	50%
1,000,000	Total Accumulated Cycles	

Reversing torque Test and the Tested Coupling

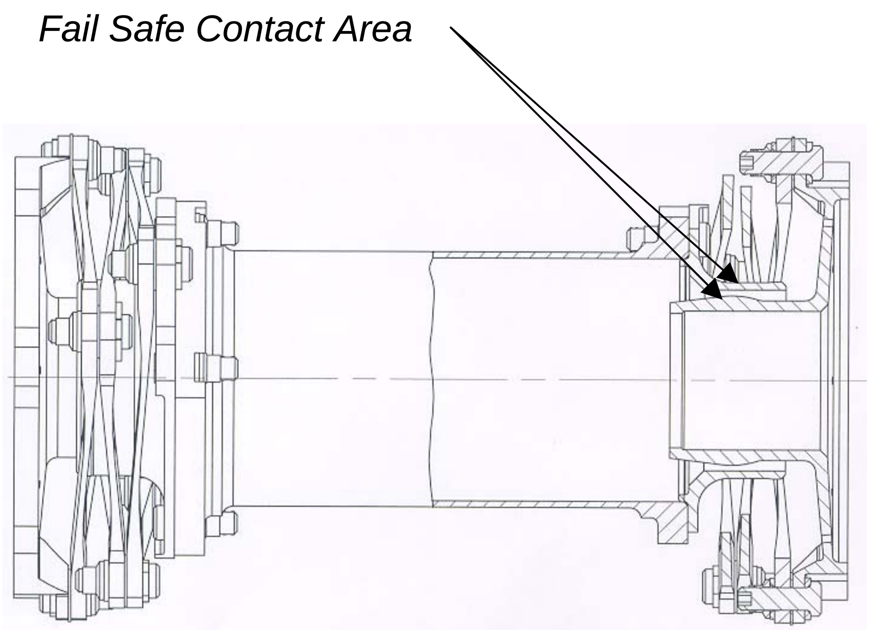
Other demanding Qualification Test Conditions successfully completed by KAflex

Application	Torque (In-Lb)	Angle (Degrees)	Axial ± (Inches)
BHTI 407	7178	5.85°	0.291
BHTI 206 A/B	5429	6.0°	0.250
BHTI UH-1N	15,280	5.6 / 6.1°	0.679 / 0.721
BHTI 205	15,400	5.9°	0.625
AGUSTA NH-90 (Single Frame)	16,310	3.0°	0.020
Kaman SH-2G	27,750	2.875°	0.230

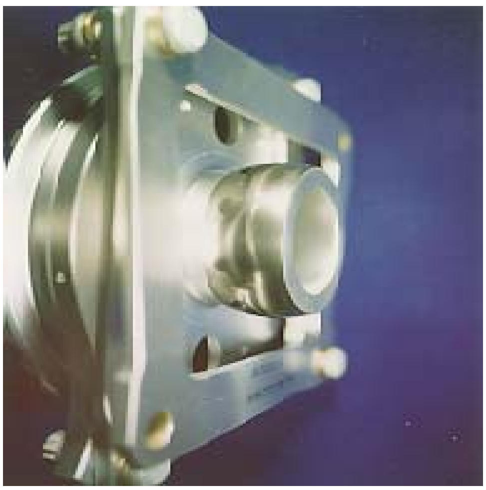
KAflex Driveshaft –Fail-Safe Feature

A designed-in Fail-Safe feature enables the driveshaft to continue to operate in the unlikely event of a failure in a primary load carrying member.

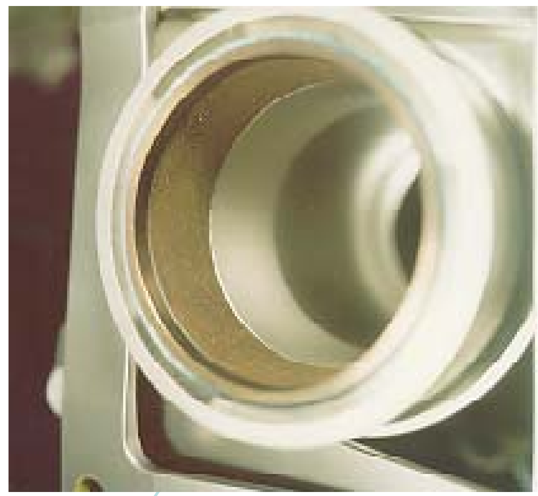
- *Successful Fail Safe Design - High temperature bearing system provides continuing torque carrying capability.*
- *Redundant Load Path -Contact of Fail Safe hubs establishes new load path to carry torque in unlikely event of a broken frame leg or bolt.*
- *Pilot Notification -Contact of fail safe hubs results in a noticeable unbalance alerting the pilot of a problem thereby allowing a controlled flight to a safe landing area.*



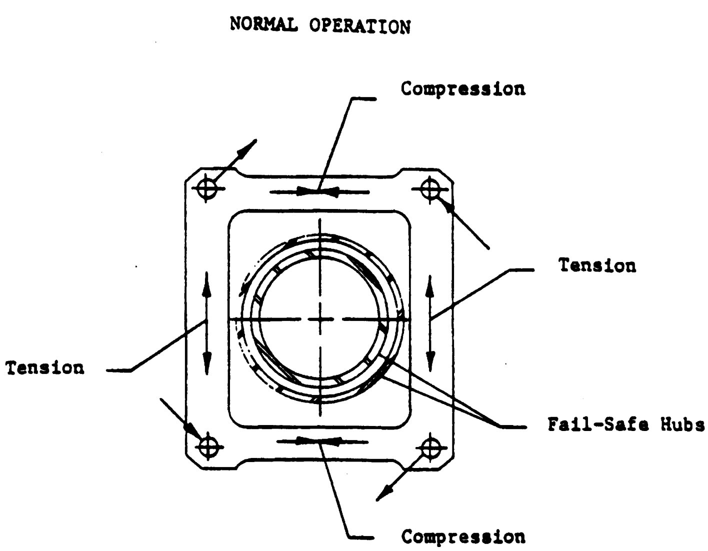
KAflex Driveshaft –Fail-Safe Feature

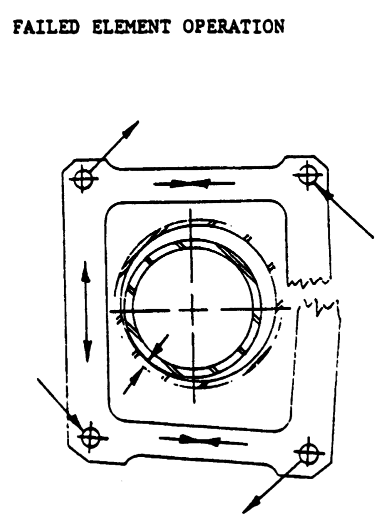


Fail-Safe (male)



Fail-Safe (female)





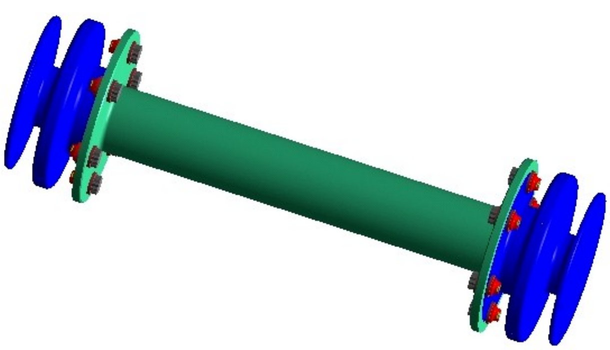
Fail safe design provides continuing torque carrying capability.

Tufflex Coupling and Driveshaft Design

The Tufflex coupling design is a concept created by Kamatics engineers. It eliminates the bolted joints highly successfully used in the original KAflex design, thereby providing higher speed operation while maintaining the ability to transmit high operating forces (torque) at substantial misalignment angles.

It's major components are similar to the KAflex design except there are no bolts used to connect the basic flexible feature.

The unique design has generated considerable interest in the aerospace community because of its relatively small "package" size and high torque and misalignment capabilities.



Kamatics Composite Systems

Page	Description
1	Kamatics Composite Systems Index Sheet
2	Typical Kamatics Composite System Components
3	Fiberlon Self-Lubricating Fiber Reinforced Composite Bearings
4	Fiberlon Materials and Construction
5	Fiberlon Bearing Uses
6	Fiberlon Also Applied to Spherical Bearings
7	Kamatics P-54 Wear Pad Material Properties Data Sheet
8	Kamatics Wear Resistant Strips, Pads and Custom/Special shapes
9	KAron Lined Wear Strips
10	Self-Lubricated Structural Components
11	Composite Backed Bearings & High Temperature Wear Pads
12	KAtherm G-47 Wear Pad – 767 CF6-80C2 Exhaust Nozzle
13	Power Plant Cowling Rub Strip Installation
14	Wire Winding Equipment - High Speed Standard Flyer Bows
15	High Speed Standard Flyer Bows (Continued)
16	High Speed Unique Flyer Bows
17	High Speed Unique Flyer Bows (Continued)
18	High Speed Flyer Bow Line Card
19	High Speed Flyer Bow Line Card (Continued)

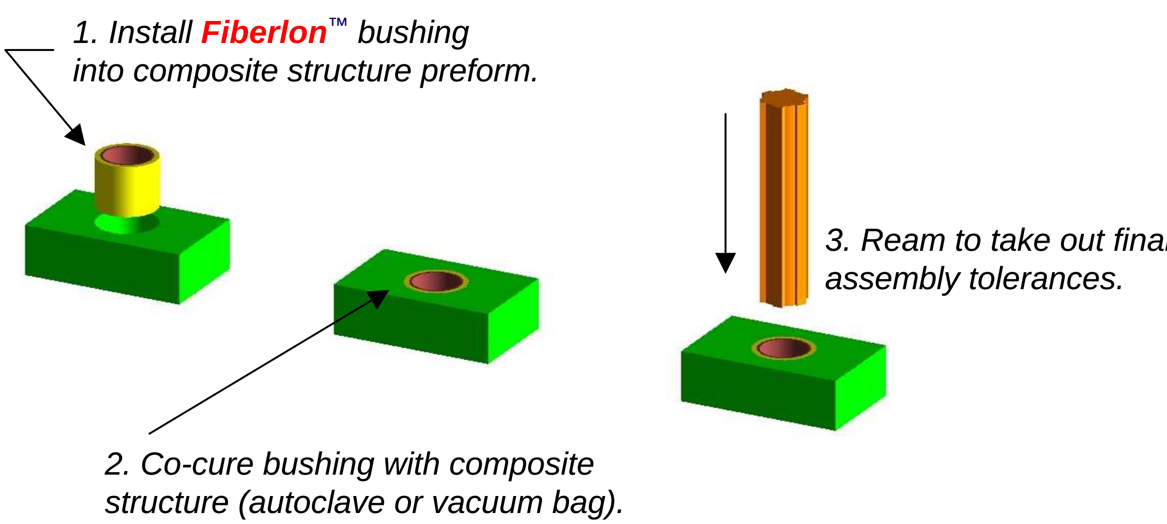
Typical Kamatics Composite System Components

Fiberlon™ Bearings

Self-Lubricating Fiber Reinforced Composite Bearings

Bonded-In Bearing Surfaces

Use **Fiberlon** ™ bearings integrated directly into composite structures



Fiberlon™ Bearings

Fiberlon Materials and Construction

Substrate: Fiberglass/Epoxy

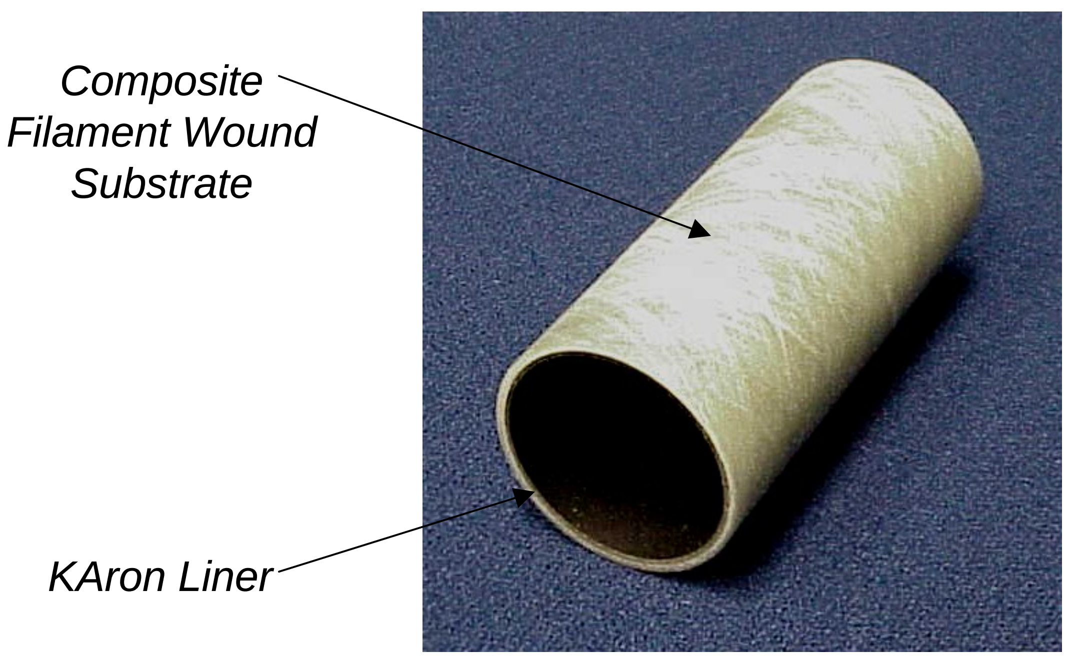
Fibers are filament wound using a precision computer controlled geometry to maximize strength and consistency.

Advanced thermoset polymer chemistry is used to insure corrosion resistance and maximum temperature capabilities.

Liner: KAron® V

Proprietary self-lubricating polymer consisting of PTFE and other fillers in a thermoset resin matrix.

Over 25 years of proven self-lubricating performance in the most demanding aviation and marine applications

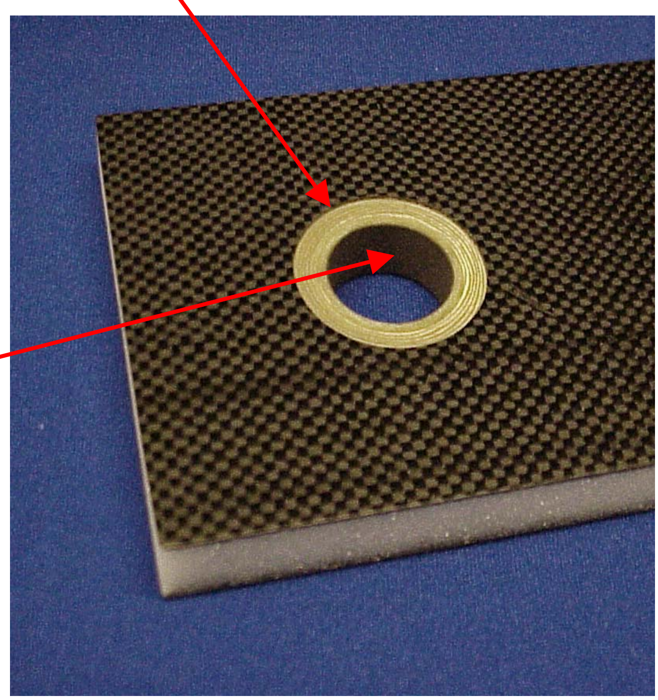


Fiberlon™ Bearings

Fiberlon Bearing Uses

- *Light weight KAron lined composite backed bearing*
- *Can be co-cured or potted into composite structures*
- *Eliminates need for heavy metallic housing*
- *Higher strength and lighter weight – no cutting of composite matrix to insert metallic housing and fasteners*
- *Bearing can be replaced if required by reaming out old bearing and bonding in new bearing*
- *Use of composite bushing to protect composite structure*

Composite Protection Bushing

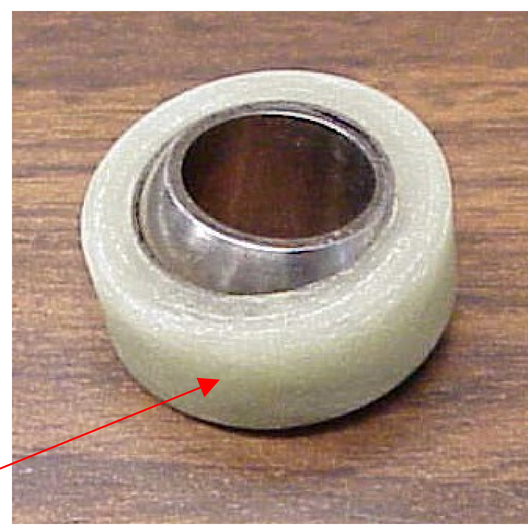


KAron Lined Composite Backed Bushing

Fiberlon™ Bearings

Fiberlon Also Applied to Spherical Bearings

- *Composite outer race reduces weight over all steel bearings*
- *Can be integrated into composite structures*



Filament wound outer race incorporating KAron self-lubricating liner material. Wound over metallic spherical inner race (ball).

Kamatics P-54 Wear Pad
Material Properties Data Sheet

Description:

Kamatics P-54 Wear Pad is an engineered composite material comprised of a resilient thermoset resin matrix with synthetic fibers in a laminate construction for strength and durability. The material can be bonded or mechanically fastened in place for industrial, marine, and aerospace applications.

Typical Applications:

P54 Wear Pad is designed for applications where standard off-the-shelf wear resistant plastics fall short in performance. It can eliminate metal-to-metal wear and fretting damage on surfaces exposed to excessive rubbing or scuffing. Use the material where impact resistance is required, under edge loading, in heavy abrasion applications, and where gross amounts of contaminants can be expected.

Dimensional Constraints:

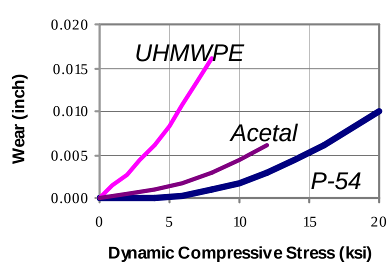
Our standard processes accommodate the manufacture of P-54 Wear Pad in flat sizes up to 12" x 48". Standard thickness range is .020" - .125". P54 Wear Pad can be bonded onto standard fiberglass laminates for thicker parts. For special shapes and dimensions outside of this envelope, please check with Kamatics.

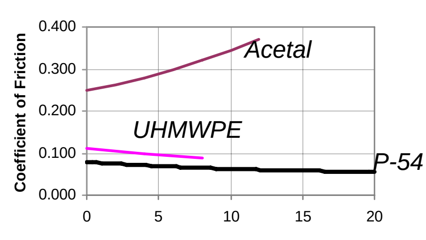
Physical Properties:

Operating Temperature Range:	-65oF to 250oF
Density:	.0466 lb/in3 (1.29 g/cc)
Hardness:	80 Shore D
Maximum Dynamic Compressive Load	20,000 psi
Maximum Static Compressive Load	50,000 psi
Compressive Modulus	150,000 psi
Linear Coefficient of Thermal Expansion:	44.2(10-6)°F-1 [79.7(10-6)°C-1] flatwise
	37.7(10-6)°F-1 [67.9(10-6)°C-1] edgewise

Wear Properties:

A smooth stainless steel button, 1/2" diameter, was rubbed back and forth over a .200" long path against a sample of P-54 Wear Pad. Travel speed was 8"/min for 180,000 cycles. Wear and friction were measured at various loads. Test values for UHMWPE and unfilled acetal are shown for comparison.

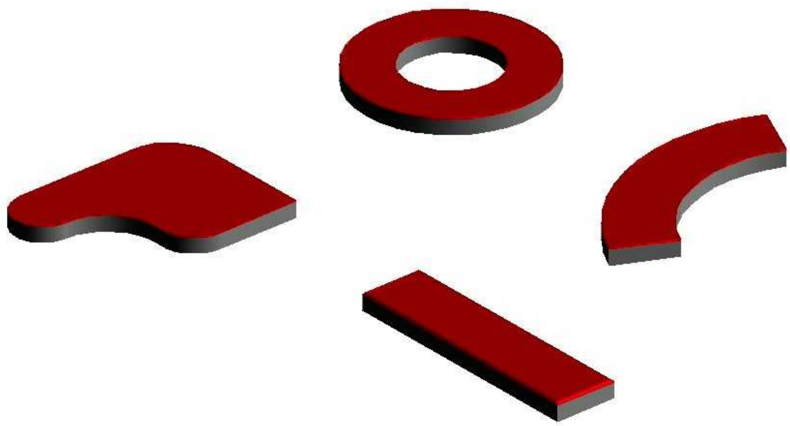




Chemical Resistance:

Kamatics P-54 Wear Pad is not affected by the following chemicals: Phosphate Ester Hydraulic Fluid (Skydrol), MIL-T-5624 Turbine Fuel Grade JP-4, MIL-L-7808 Lubricating Oil, MIL-H-5606 Hydraulic Oil, MIL-A-8243 Anti-icing Fluid, MIL-H-83282 Hydraulic Fluid, Fresh Water, Salt Water.

Kamatics Wear Resistant Strips, Pads and Custom/Special shapes



Custom Wear Pads

Wear Pads are Designed for Specific Application Needs

Applications:

- A330/340 Flap Side Pads
- F100 Nozzle Wear Pads
- Miscellaneous Applications

Features:

- Can be integrated into design structure
- Tailored design to solve bearing, wear or fretting issues

KAron Wear Strips

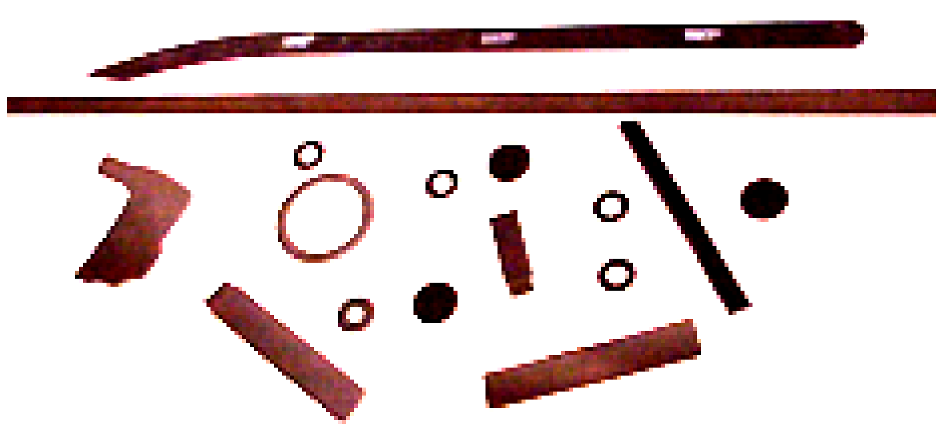
Utilizes KAron Self-Lubricating Liner System on a Composite Backing Material for Custom, Flexible Applications

<u>Applications</u>

- *Fan Cowl Wear Strips for 737/CFM56, numerous locations to prevent fretting between two interfacing surfaces.*
- *Gulfstream V, A330/340, others, - Cut-to-size wear strips.*
- *C-17 horizontal stabilizer formed wear strips.*
- *American Airlines, others – Sheet size material applied to tracks used with a track roller, cam follower or as a bearing "bumper" protection.*

<u>Features</u>

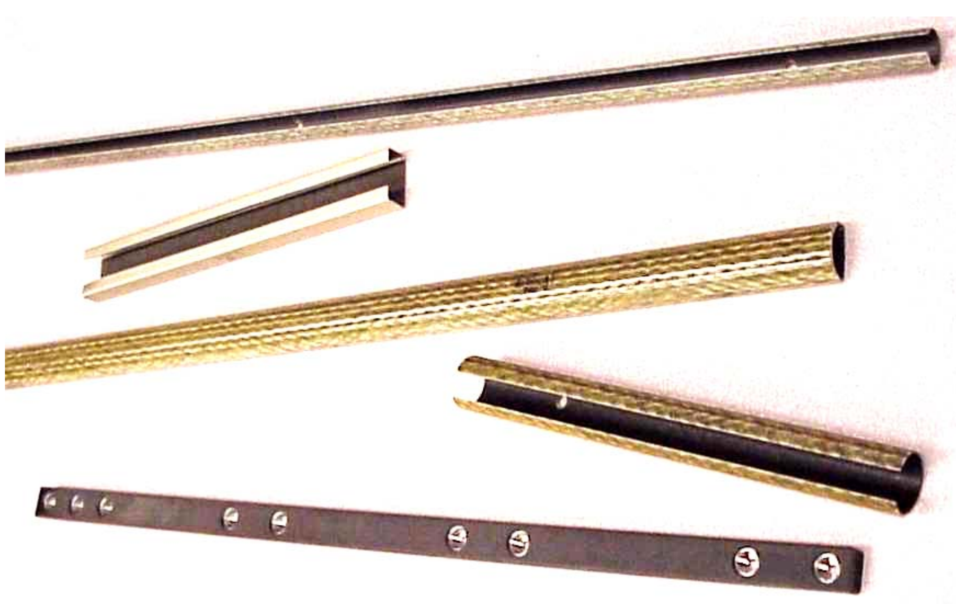
- *Can be fabricated in customer specified shapes or standard strip widths.*
  - *Standard strip size .75 inch and 1.0 inch wide with or without break- away tabs .*
- *Can be cut into custom size/shapes using scissors.*
  - *12 inch x 48 inch standard production sheets.*
- *Operating temperature -100°F to 250°F (-73°C to 121°C).*
- *Flexible and can be used on curved or flat surfaces.*
- *Uses a "peel-ply" backing to keep bonding surfaces clean prior to application.*
- *Wear strips can be easily applied using a structural adhesive.*
- *Prevents wear/fretting between contacting surfaces.*
- *Protects expensive components.*



Self-Lubricating Structural Bearing Components

Applications
- Composite thrust reverser slide blocks for Bombardier (Canadair) Challenger regional jet.
- Composite thrust reverser slide tubes for Rolls Royce-Rohr 757 nacelle.

Features
- Self-lubricating structural bearing components offer reduced weight when compared with metal components.
- Self-lubricating structural bearing components do not require periodic lubrication therefore lowers maintenance costs.
- Self-lubricating structural bearing components can be utilized in difficult to access or inaccessible maintenance areas.



Composite Backed Bearings

Composite Aircraft and Engine Structures integration

- Construction – KAron ID lined with fiberglass epoxy design.
- Can be co-cured into composite structure during initial fabrication.
- Unique "machine-at-assembly" capability.
- Thick KAron machinable liner minimizes composite assembly tolerances.
- Changing from metallic housing to a composite housing takes full advantage of weight savings for a Kamatics design.

KAron

Fiberglass Epoxy Backing

High Temperature Wear Pads

Applications

- Exhaust nozzle wear pads for 747, 767 CF6-80C2 engines.
- Aft Fairing wear pads for 767 aircraft.

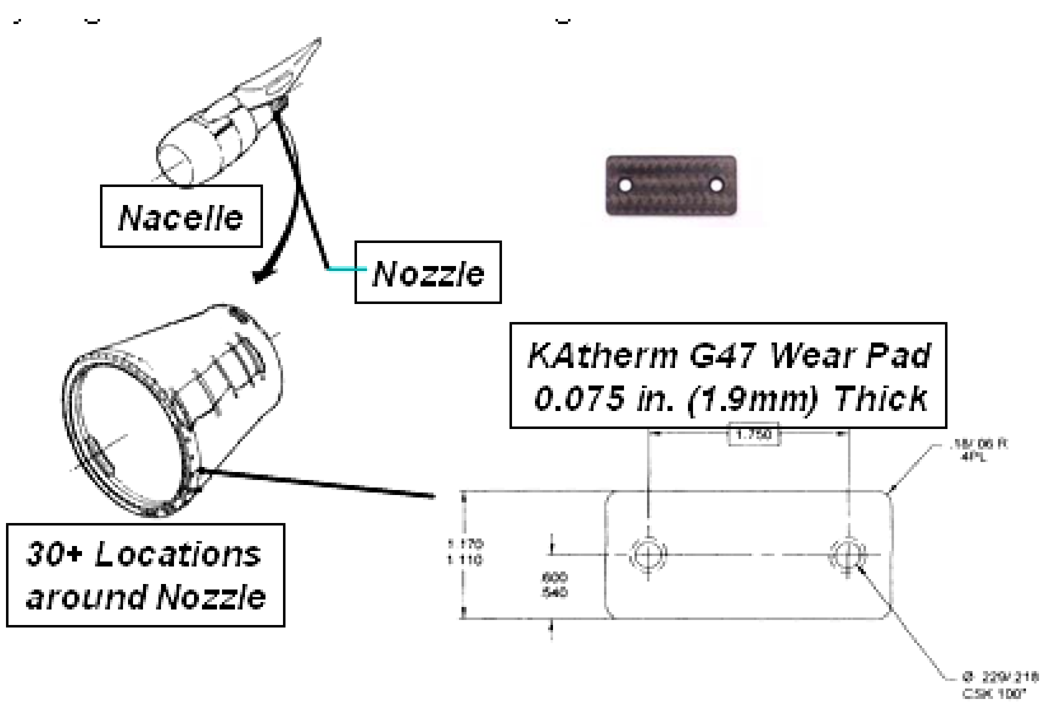
Features

- Allows use up to 500°F (260°C) continuously or 525°F (274°) for short term use.
- Can be fabricated as an all composite pad (G-47 or G-57) or self lube liner (T-87) can be applied to a metallic backing.
- KAtherm G-53 composite pads allow use up to 675°F (357°) for short term use.
- High temperature wear pads minimizes wear and fretting between contacting surfaces

KAtherm G-47 Wear Pad
B767 / CF6-80C2 Exhaust Nozzle

G-47 carbon fiber braided construction replaced the existing molded configuration. Comparison testing at Kamatics indicated KAtherm G-47 material exhibited a significant improvement in wear resistance relative to the original equipment molded component.

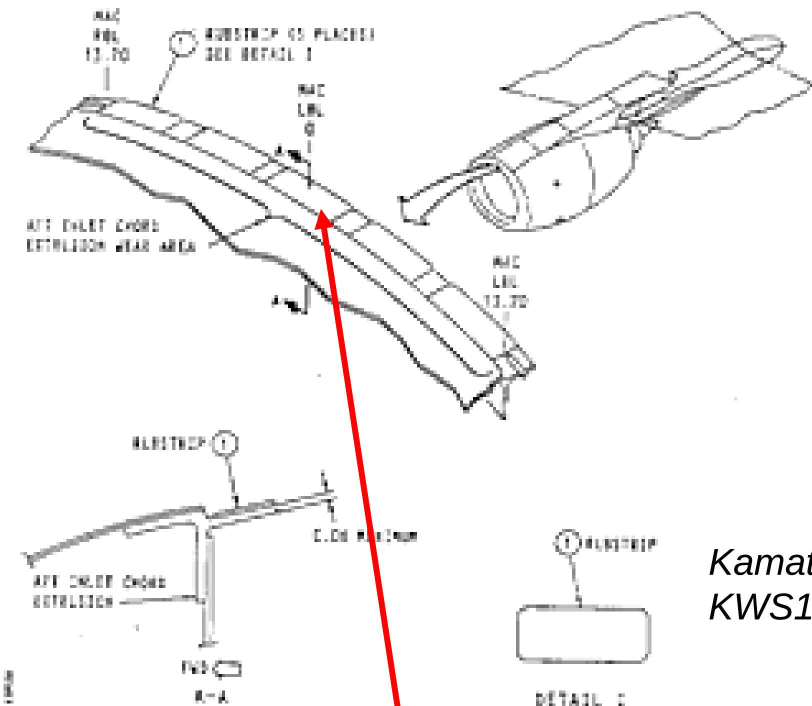
The molded graphite polyimide exhibited wear and breakage during operation due to thermal cycling and was the reason for the change to KAtherm G-57



Boeing Service Bulletin 737-71-1336

Power Plant Cowling Rub Strip Installation

Fan Cowl Support Beam/Engine Inlet Cowl Interface



Kamatics P/N KWS100011

Wire Winding Equipment

High Speed Standard Flyer Bows

Page 1 of 2

KAMATICS - Composite Flyer Bows

In 1990, a new and unique high-performance flyer bow was introduced to the wire industry. By combining aerospace-proven composite materials technology with a revolutionary triaxial braiding process, a quantum advancement in strength and durability was achieved.

The superior performance and quality of these bows were immediately recognized and, in less than three years, they became the volume leader in the replacement market worldwide.

Kamatics Corporation designs and manufactures a wide variety of patented, high-performance products used in thousands of critical applications in jet aircraft, helicopters, space vehicles, ships, and submarines.

Applying advanced aerospace analytical and fabrication techniques, Kamatics evolved a broad range of significantly improved flyer bow products. This is an ongoing effort directed at providing even greater toughness to withstand wire hits and improved aerodynamics, allowing higher wire line speeds while reducing bearing loads and machine noise.

Features

- Triaxially braided construction
- Aerodynamic design
- Toughened epoxy matrix
- Lighter weight
- Adjustable tensile, flexural & torsional properties

Benefits

- Higher operating speeds
- Increased survival rates
- Less machine downtime
- Reduced bearing loads and noise

Composite Flyer Bows
A product of **Kamatics Corporation**

High Speed Standard Flyer Bows

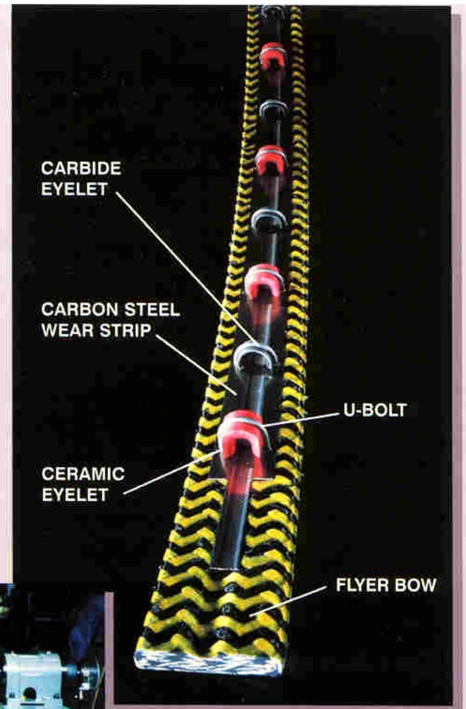
Page 2 of 2

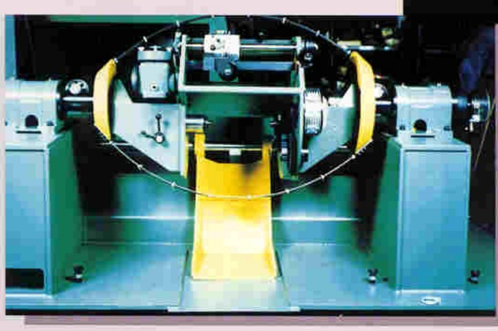
A Different Approach

Custom Engineered
To meet your individual requirements.

New Materials
Special toughened epoxy with carbon, glass, and Kevlar fibers.

Unique Construction
Triaxial braided fibers, oriented to optimize flexure and strength.





Address Inquiries to:

Kamatics Corporation
P.O. Box 3
Bloomfield, CT 06002-0003
(800) 529-6906
Fax: (203) 243-7993

KAMAN

High Speed Unique Flyer Bows

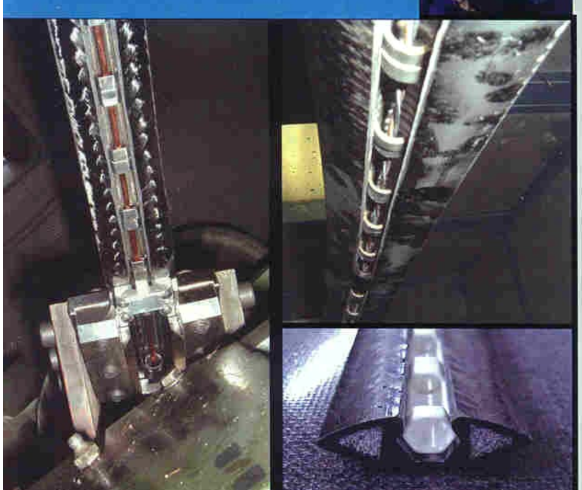
Page 1 of 2

KAMATICS - BackBone™ Flyer Bow

In 1990 Kamatics introduced a unique high-performance composite flyer bow by combining aerospace proven technology and a revolutionary tri-axial braiding process.

Now in 2005 we are offering a new innovative solution for wire processing called the Back*Bone Bow.*

The Back*Bone Bow* is designed to incorporate all the positive features of an Enclosed Bow without any of the negatives associated with operating a Tube or totally Enclosed Flyer Bow. The Semi-Enclosed Back*Bone Bow* gives the customer increased reliability and performance needed in today's competitive environment.



Features:

- Improved Bow Strength (No Holes)
- I-Beam Construction for Significantly Improved Bow Stiffness
- Wire is Out of the Air Stream
- Bow Shaped like a Wing for Improved Aerodynamics and Low Cw Factor
- Wear Strip eliminated and replaced by Wear Bushings with Windows for easy Inspection and Dust Clearing
- Wear Bushings can be Changed while Bow is Mounted on the Rotor
- Wear Bushings can be Ceramic, Steel (43-58Rc) and other Materials or Coatings
- Wear Bushings Improve Support of Difficult to Make Products
- No Wire Pinching between Guide and Wear Strip

Benefits:

- Higher TPM - Maintaining Wire Quality
- Reduced Elongation @ higher TPM
- Reduced Bow Breakage
- Lower Power (AMPS) Consumption
- Increased Life on Wear Surfaces Reducing Downtime and Maintenance
- Easy Assembly and Change Out of Wear Bushings
- Wire Breaks are Contained Within The Bow – Extending Bow Life

US Patent **#6,233,513** and Others Pending

Kamatics Corporation

Direct: 800-529-6906

Fax: 860-769-7702

Email: FB-Kamatics@Kaman.com

www.Kamatics.com

KAMAN

High Speed Unique Flyer Bows

Page 2 of 2

KAMATICS - Back*Bone*™ Wear Bushings

Our Wear Bushing can be made of different material types for Bare Copper, Aluminum, Steel, Plated and Insulated Wire processing. This unique Hex Design opens up the problem solving options not available with the standard Wear Strip and Ceramic or Carbide guide combination.

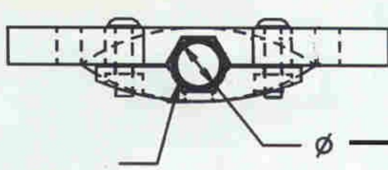
Material Options.

- (S) Hardened Steel (43-59 Rc Polished 16 Micro)
- (K) Hardened Steel (Chrome Plate)
- (C) Ceramic 99% (Polished to 10-16 Micro)
- (B) Silicon Carbide (Polished to 10-16 Micro)
- (P) KAlube Coated Dimpled (Insulated Wire)
- (G) Garolite for Aluminum Wire (No Scratches)
- (E) Special P54 with Teflon® (Insulated & Plated Wire)
- (U) UHMW,HDPE, for Special Applications.
- Other Coatings

US Patent **#6,233,513** and Others Pending

Sizes [mm]

.165 [4.2]	- Ceramic
.188 [4.7]	- Steel
.275 [7.0]	- Ceramic
.297 [7.5]	- Steel
.450 [11.4]	- Dimpled
.530 [13.5]	- Steel
1.05 [26.7]	- Dimpled
1.12 [28.5]	- Steel



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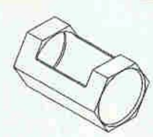
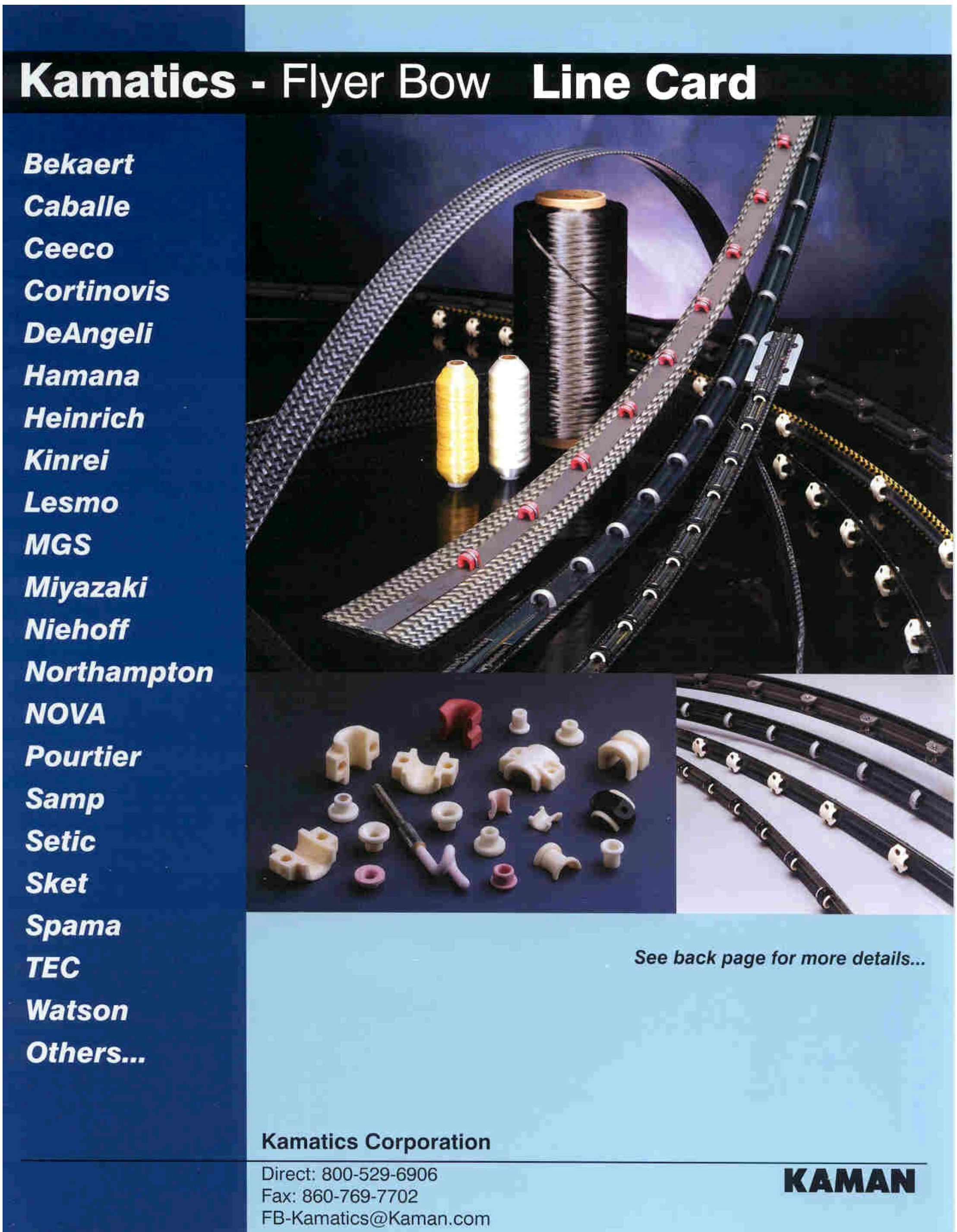
HEX GUIDE



Dimpled Wear Surface for Reduced Friction

High Speed Flyer Bow Line Card

Page 1 of 2



High Speed Flyer Bow Line Card

Page 2 of 2

Bekaert 250
Bekaert 450
Bekaert 630
Bekaert 800
Bema Strander
BSH 400
BSH 630
BSH 640

Caballe 1000
Caballe 1250
Caballe 630
Caballe 800
Caballe HMB500
Caballe PDT 500
Caballe Twinner
Cabel 1000
Ceeco 1600
Ceeco 1800
Ceeco 24
Ceeco 26
Ceeco 52
Ceeco 53
Ceeco 53 Twinner
Ceeco 530
Ceeco 530 Group Twinner
Ceeco 531 Group Twinner
Ceeco 532
Ceeco 540
Ceeco 630
Ceeco Single Twinner
Cortinovis 1600
Cortinovis 450
Cortinovis 500
Cortinovis 630
Cortinovis GT500

DeAngeli 400
DeAngeli 630
DeAngeli 760
DeAngeli 800
DeAngeli TB125
DeAngeli TR800
Digeb 630
Digeb DS025

Eastern Twinner
Edmands 36
Edmands 48
Edmands 560
Edmands NY 24s
Edmands Hmb
Edmunds Twinner
En-Shiang 760

Enthwistle
Entwhistle 4WDT
ES 350
ES 500
ES 650

FME 1250
FME 630
FME group twinner
Foresmac 630
Frigerio Strander
Furesmac 630

GCR 630
GCR 800
GCR TDT630
Godderidge 800
Godderidge M259DTC
Godderidge M400DTC
Goldstar KM

Hamana HPT 630
Hamana 1000
Hamana 500
Hamana 610
Hamana 630
Hamana BM024
Hamana GH 22
Hamana GH24
Hamana HIBM 800
Hamana HIPT 1250
Hamana HMKPT 610
Hamana HMPT (F)-630
Hamana HMPT AR 6001
Hamana HPT 630
Hamana HPT-F- 630
Hamana HPT-I-630
Hamana HYPT 610
Heinrich 630
Heinrich 631
Heinrich 800
HMB
HMB CFL 2

Kinrei 300
Kinrei 450
Kinrei 500
Kinrei 560
Kinrei 630
Kinrei 630/760
Kinrei 760
Kinrei Backtwister
Kinrei MB 500
Kinrei NB 630

Laribee 24
Laribee 800
Laribee DTB 30
Lesmo 1000
Lesmo 1250
Lesmo 1600
Lesmo 1800
Lesmo 450
Lesmo 500
Lesmo 560
Lesmo 630
Lesmo 760
Lesmo 800
Lesmo 800 (high arc)
Lesmo 800 New Long
LG 800
LG Data 800 Buncher

Magnum
Magnum Twister
Malifer
MGS 1500
MGS 20
MGS 2000
MGS 30
MGS 30 high speed
MGS 30 SSB
MGS 48"
MGS DTB 30
MGS DTB48
MGS HSB
Miyazaki 600
Miyazaki 630
Miyazaki bsh 400
Miyazaki BSH 610
Miyazaki S 3185
Miyazaki SPB A450
Miyazaki SPB A500
Miyazaki SPB A610

Niehoff 400
Niehoff 560
Niehoff 561
Niehoff 630
Niehoff 800
Niehoff D 630 GL
Niehoff D800
Northampton SLB 630
Northampton 1000
Northampton 1250
Northampton 450
Northampton 560
Northampton 630
Northampton 630 (B)
Northampton 800
Northampton Din 630 SLB
Northampton DT1250
Northampton SLB
Northampton SLB 630
Northampton SLB MX III
Northampton SLU630
Northampton SLB 630
NOVA 327/23.3

Ozmak 630

Pourtier 800
Pourtier BMT 630
Pourtier BMT500
Pourtier DTT500
Pourtier Gauder 590
Pourtier GTC 501
Pourtier GTC-500
Pourtier GTM 800
Pourtier GTM-560
Pourtier GTM-600
Pourtier QHT600
Pourtier QTT-500
Pourtier QTT600
Pourtier Quadder
Pourtier THL-600

Rabak 630
Rabak RB-1
Redaelli

Samp 1250
Samp 560
Samp 630
Samp 760
Samp 800
Samp BH 630
Samp BM900
Selecta 1250
Selecta 400
Selecta 500
Selecta 630
Setic 1600
Setic 1085
Setic 1250
Setic 1285
Setic 484
Setic 630
Setic 630K
Setic 681
Setic 799
Setic 800
Setic DVD-560
Setic Pa 630
Setic Pa 800
Setic Pai 800
Setic T 484
Setic T-1285
Setic T-75
Setic T-785
Setic T-80
Setic T-81
Setic TA 630
Setic TA 800
Setic TAC800
Sket Strander
Sket Group Twinner
SMD B-800
SMD 500
SMD 560
SMD 760
SMD 800
SMD 800
SMD B-760
Spama 400
Spama 550
Spama 630
Spama 760
SWB 760
SWB-800

TEC 20
TEC 24
TEC 24 BIG H
TEC 24 DTC
TEC 24 SMALL H
TEC 30
TEC 36
Tecalsa 800
Theseus 630
TMC Buncher
TMC CDO500-IV-D
Trafalger 1000
Trafalger 630

Watson 630
Watson NY 24

Yoshida 500
Yoshida Group
Yoshida YBH 500