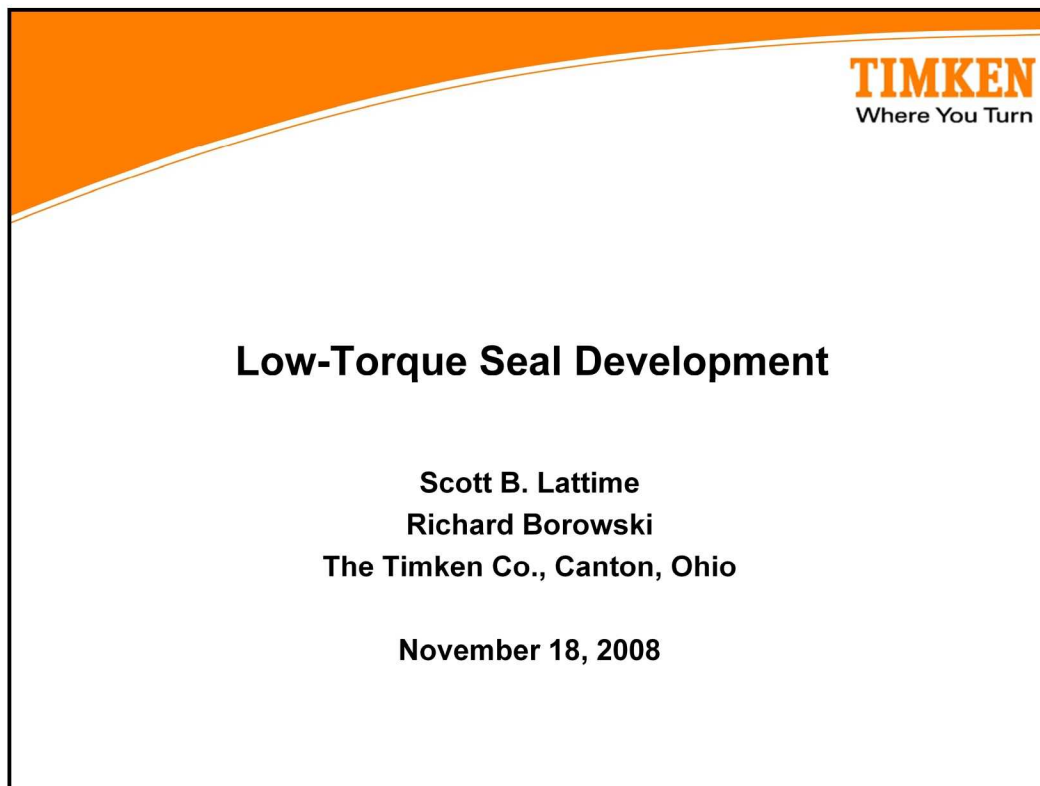


LOW-TORQUE SEAL DEVELOPMENT

Scott Lattime and Richard Borowski
The Timken Co.
Canton, Ohio

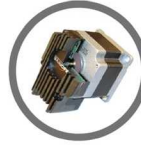


Overview

- Due to increasing energy costs, many industries are paying more and more attention to the energy required to keep their equipment moving. The torque required to overcome the drag produced by contacting lip seals that are found in a variety of rotating equipment can significantly add to the total operating costs of that equipment.
- The Timken Co. is constantly working on innovations that manage friction via development in the areas of bearings, seals, coatings, and lubricants.
- Two examples of such work are presented in the area of seal development where Timken has been working on
 - 1) Engineered surfaces for enhanced performance of contacting lip seals
 - 2) The development of a non-contacting seal for rail applications.

Company Overview

The Timken Company is a leading global provider of highly engineered bearings, power transmission solutions and high-quality alloy steels. We serve a wide range of industries through our **Bearings and Power Transmission Group** business segments – Aerospace and Defense, Process Industries and Mobile Industries – and our **Steel Group**.



Bearing Friction Management

Power Transmission
& Electronic Controls



Services



Precision Steel
Components

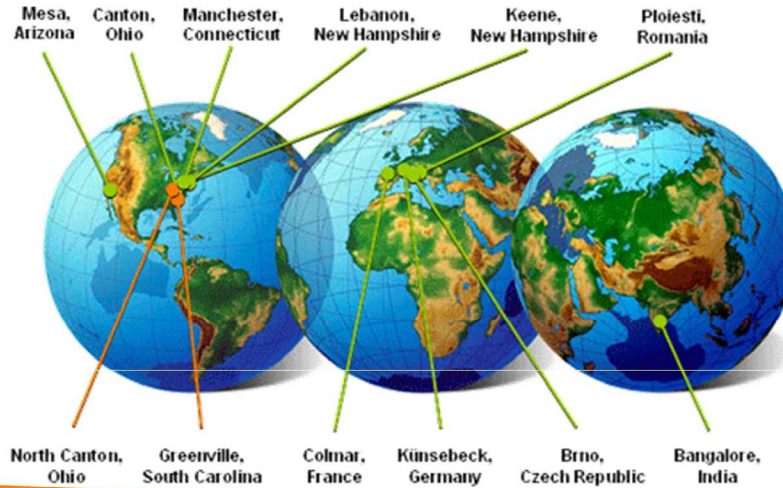


Steel

3

Major products and services include: Friction Management Bearings, surface engineering, lubricant and seal development; Power Transmission and Electronic Controls – innovative gear assemblies (flex-pin), electric drive motors, sensor products; Steel - specialty steels and precision steel components, Aerospace components and services (brgs, helicopter transmissions and rotorhead assemblies; Bearing maintenance tools, Condition monitoring systems and services, Engineering and technical services, Repair and refurbishing services

- Established in 1899
- Total number of associates worldwide: 25,000
- 62 plants and 104 sales offices, 12 technology centers
- Listed on the New York Stock Exchange since 1922



Motivation: Torque Reduction = Energy Savings

Process Industries (electric motors, pumps, gearboxes, windmills)

- Small bore lip seals (< 3") can account for 4 in-lb of torque.

➡ 4 in-lb = 170 W (3600 rpm) = 496 kW/yr (8 hr/day)

- Large bore lip seals (>62") can account for torque > 400 ft-lb

➡ 400 ft-lb = 1 kW (20 rpm) = 2900 kW/yr (8hr/day)

Automotive Industries (wheel end applications)

➡ ~0.01% mpg = 1 in-lb (per wheel)

Rail Industries (major car owners)

➡ ~0.1% fuel savings = 1 in-lb (per wheel)

The Effects of Deterministic Micro-Features on Radial Lip Seal Performance

6

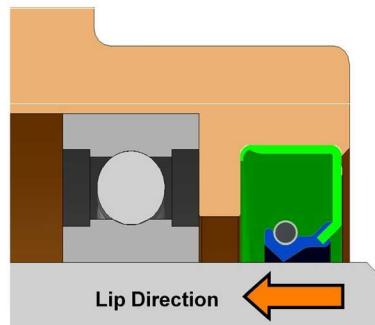
Background

- **Elastomer lip seals have been in use since the 1930's. They offer low-cost sealing solutions to power, process, transportation industries.**
- **Properly designed elastomer lip seals operate under full fluid film lubrication due mainly to the hydrodynamic action micro-asperities which are formed on the elastomer surface during break-in (Jagger '57, Jagger & Walker '66).**
- **Surface micro-features have been developed to enhance bearing and seal performance (Otto '74, McNickle & Etsion '01, Yu et al. '02, Stephens '04, Lou '04) .**

Seal Function

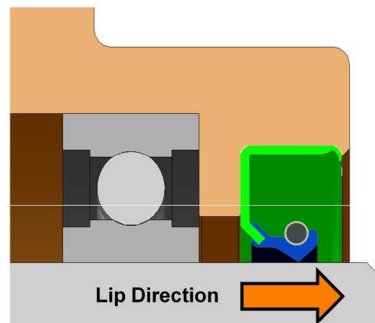
Retention

- The primary purpose is to retain lubricant in the assembly (prevents lubricant leakage)
- The sealing lip should be positioned toward the lubricant



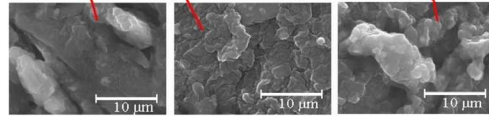
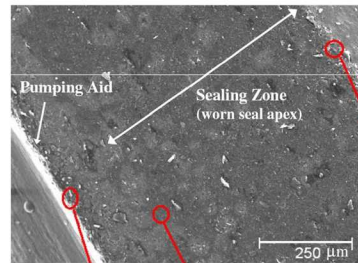
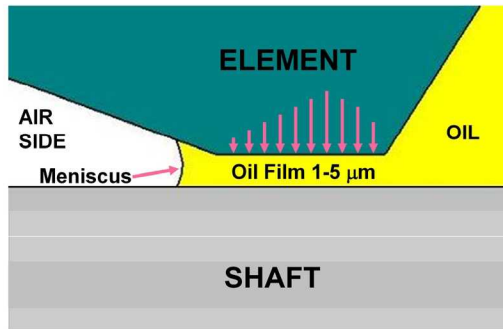
Exclusion

- The primary purpose is to exclude contamination (prevents contaminant ingress)
- The sealing lip should be facing the contamination



Sealing Mechanism

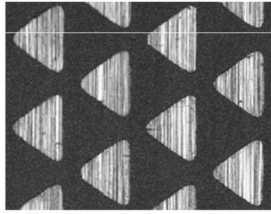
- Micro-asperities in the elastomer surface retain fluid and deform under shear stress functioning like tiny viscous pumps
- The generated pressure distribution across sealing zone provides load support as well as reverse pumping



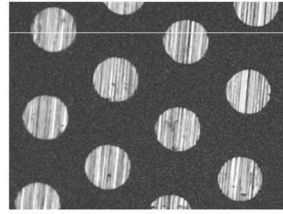
Paige '05

Surface Texture Geometries

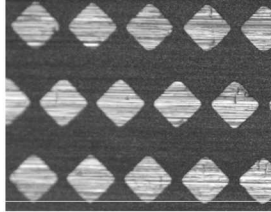
- Cavity geometries chosen due to ease of manufacturing and wear considerations
- Manufacturing Processes
UV-photolithography
Roll-forming
- Over 20 different texture sizes/orientations have been tested



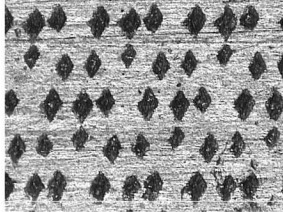
Triangular



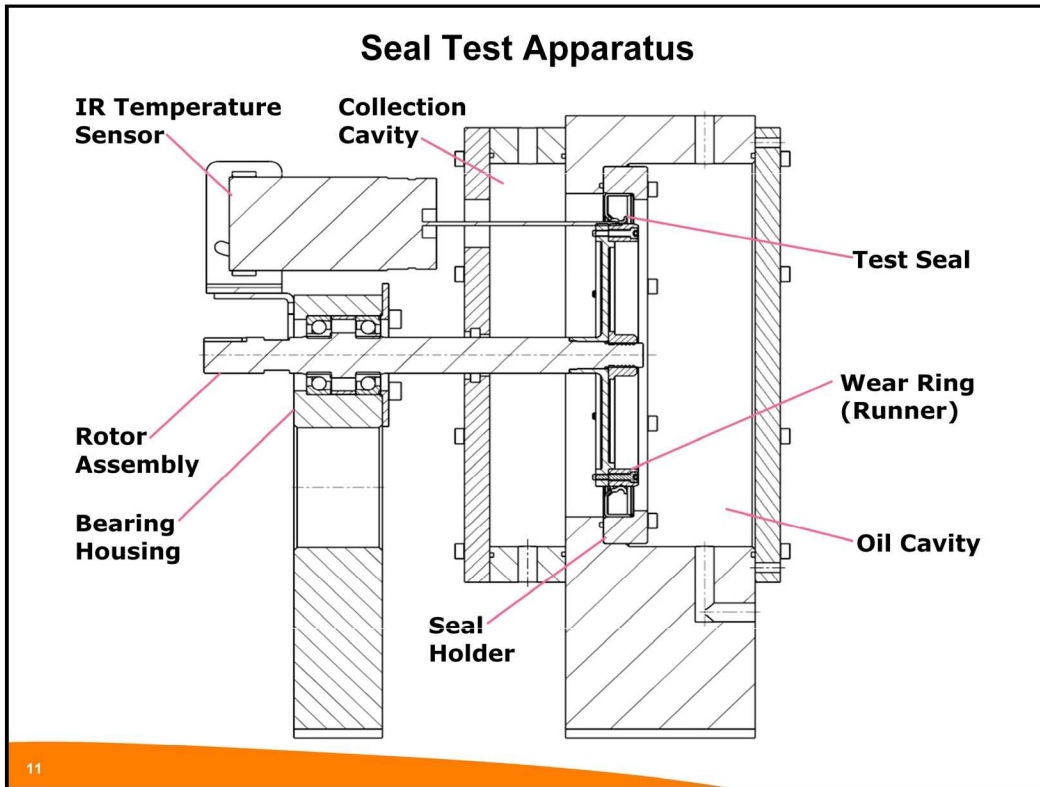
Circular



Diamond



Pyramidal

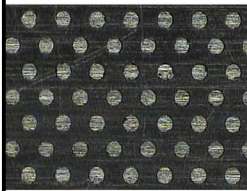


Test were performed with 20W-50 oil at 750 rpm over 24 hr.

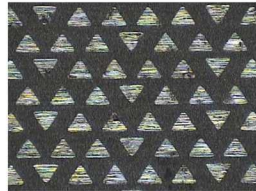
Results: Torque as Compared to Baseline (Non-Textured Runner)

← direction of rotation →

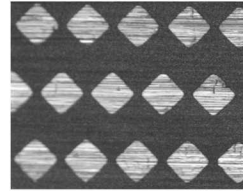
oil side



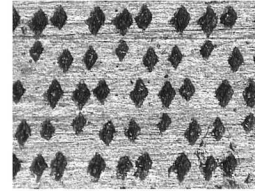
Circle



Triangle

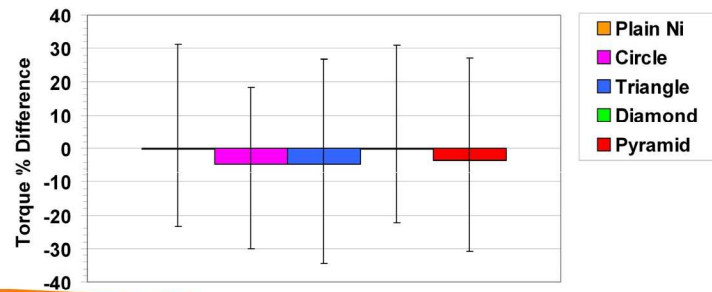


Diamond

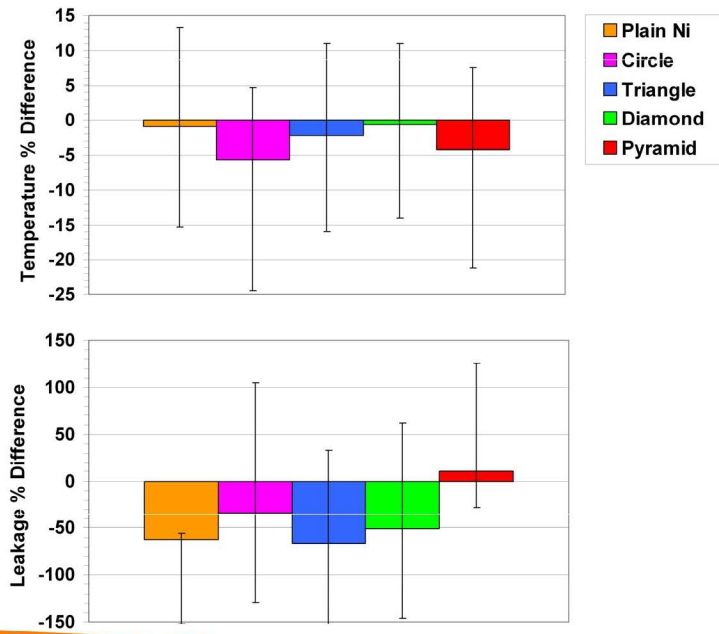


Pyramid

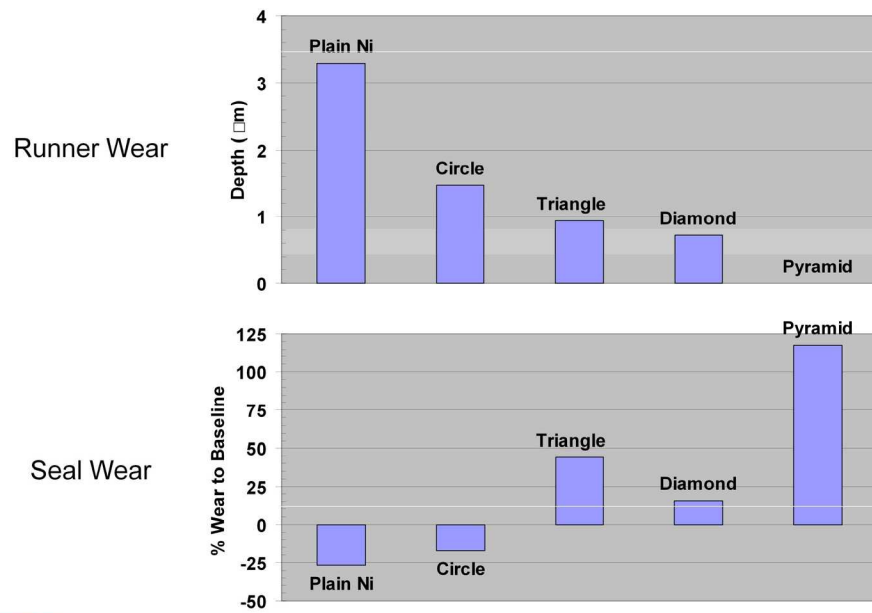
air side



Results: Temperature & Leakage as Compared to Baseline (Non-Textured Runner)



Results: Runner & Seal Wear as Compared to Baseline (Non-Textured Runner)



Conclusions

- Feasibility of enhancing lip seal performance due to the application of manufactured micro-features on the running surface was experimentally proven.
- Although there was a large amount of scatter to the data, the trends show the textured running surfaces exhibited a reduction in operating torque and temperature of up to 5% and over 50% reduction in leakage as compared to non-textured surfaces.
- Wear of the cavity-textured running surfaces was less than 25% of the cavity depth and seems unlikely to have a large influence on the performance results.
- The circular cavities exhibited the best overall performance on lowering seal torque and temperature with the least amount of seal wear. However it is unclear at this point what effect the Ni plating itself has on the performance (e.g. solid lubricant).

Future Work

- The effects of the Ni plating must be ruled out by manufacturing texture geometries on the native metal (e.g., laser machining).
- Due to the variability of the results, larger sample sizes should be used to gain statistical confidence.
- Development and evaluation of textured elastomer on plain running surface (textured molds) should be investigated as a lower cost alternative.
- Characterize the long-term effects of micro-features on seal life with much longer test runs (100's of hours) as well as on the elastomer micro-asperities.

**EcoTurn Seal:
Development of a Non-contacting
Seal for Rail Applications**

17

Timken History of Railroad Innovation

- 1923 FIRST RAILROAD APPLICATION
- 1930 TIMKEN FOUR ACES LOCOMOTIVE
- 1954 TIMKEN “AP” BEARING
- 1968 FIRST FITTED BACKING RING
- 1972 NFL BEARING CONCEPT INTRODUCED
- 1988 TIMKEN HDL™ SEAL
- 1994 TIMKEN “AP-2” BEARING
- 2008 TIMKEN ECOTURN™ SEAL

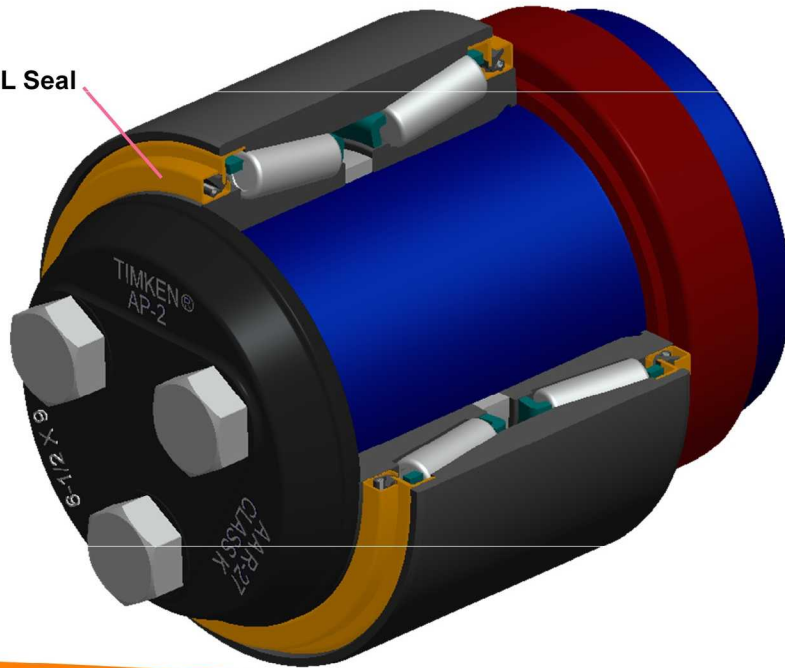
Class K AP-2 Wheel Sets & Bearings



19

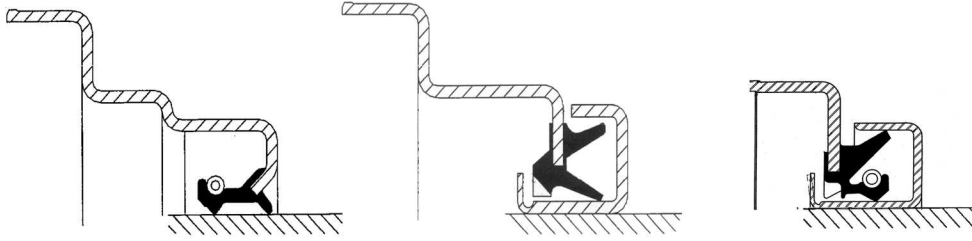
AP-2 Rail Bearing Assembly

HDL Seal



20

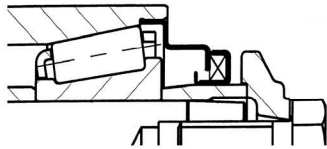
Timken Rail Seal Progression



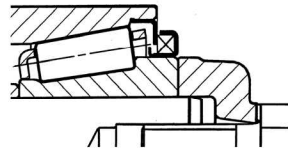
NT AP Seal

HDL AP Seal

HDL AP-2 Seal



AP Seal Position



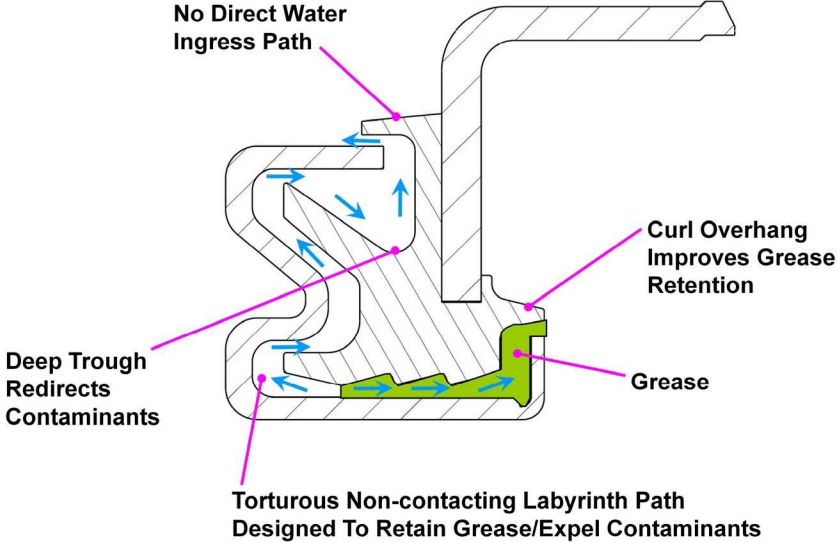
AP-2 Seal Position

Design Criteria

“THE SEAL PERFORMANCE MUST EXCEED THAT OF THE CURRENT HDL SEAL DESIGN”

- **REDUCED GREASE WEEPAGE**
- **“ZERO” TORQUE**
- **IMPROVED WATER/CONTAMINANT EXCLUSION**
- **INCREASED ROBUSTNESS**
- **COST**
- **IP RETENTION**
- **FIT BOTH “AP” AND “AP-2”**

EcoTurn Seal Design – Features



Seal Laboratory – Test Capabilities



- PERFORMANCE
- TORQUE
- VIBRATION
- SLURRY INGRESS
- DUST INGRESS
- WATER SPRAY
- WATER SUBMERSION
- HIGH/LOW TEMPERATURE
- LIFE

AAR Qualification Testing Summary

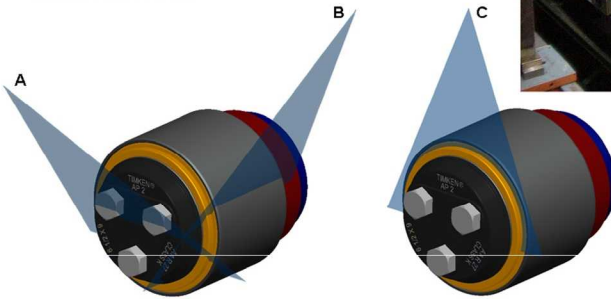
M-959 Sec.	Test	M-959 Limits		Results			Status
		Grease Purge	Contaminate Ingress	Grease Purge	Contaminate Ingress	Pass/ Fail	
● 4.3.1	Elevated Temperature	10g Per seal	N/A	0g	N/A	Pass	Complete
4.3.2	Low Temperature	No damage or excessive wear		No damage or wear observed		Pass	Complete
4.3.3	Dust Ingress	N/A	1%	N/A	0.1%	Pass	Complete
● 4.3.4	Water Spray	N/A	0.5% free water	N/A	0% free water	Pass	Complete
● 4.3.5	Vibration	10%	N/A	0%	N/A	Pass	Complete
4.3.6	Accelerated Life	10%	N/A	1.1%	N/A	Pass	1 of 2 sets complete
4.1.4	Seal Torque	34 in-lbf		1.25 in-lbf		Pass	Complete

25

Accelerated Life test: 34,400 lb, 60 mph, 250,000 mi

Water Spray Test

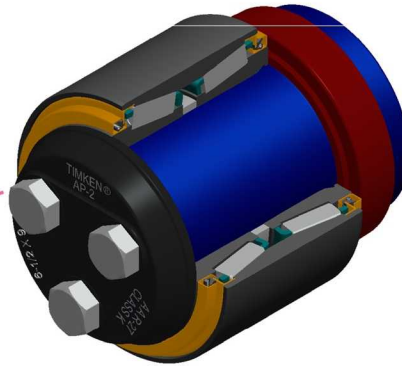
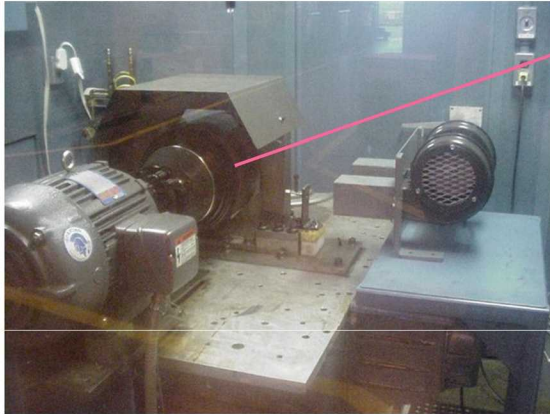
Nozzles: 1/8" NPT, 808 Flat Fan Spray
Flow Rate: 48 gpm
Speed: 60 mph
Duration: 21 hr



Locations "A" and "B" are consistent with AAR Spec M-959-2007
Location "C" is most torturous

Vibration Test

Displacement: 1/16" peak to peak in the vertical plane through axle
Frequency: 38 Hz
Cycle: 21 hr running, 3 hr down
Speed: 60 mph
Duration: 4 Days



Dust Test

Closely Fitted Canister (0.5" Radial Clearance)

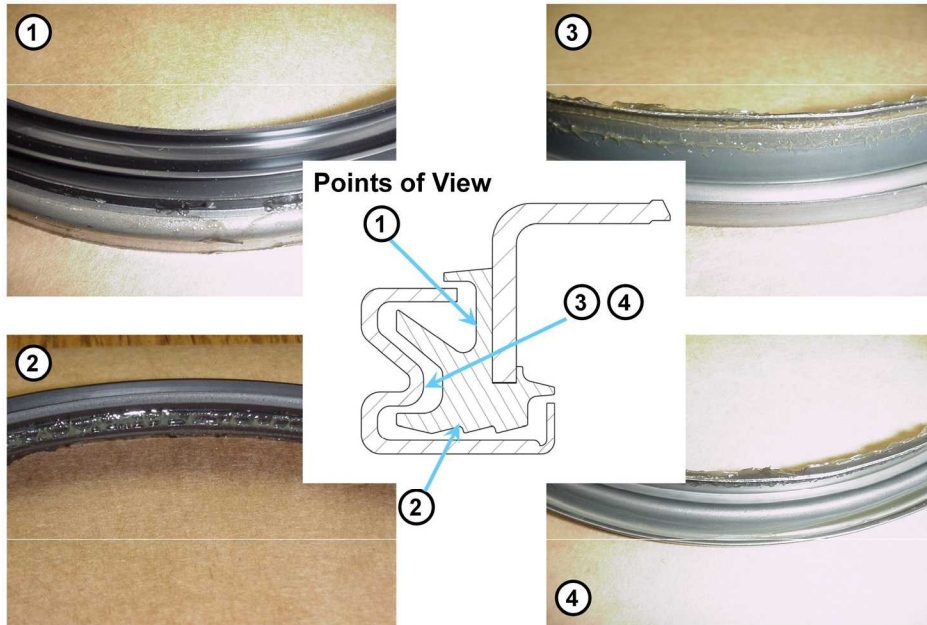
Dust Fill: 15%

Speed: 500 rpm

Duration: 100 hr

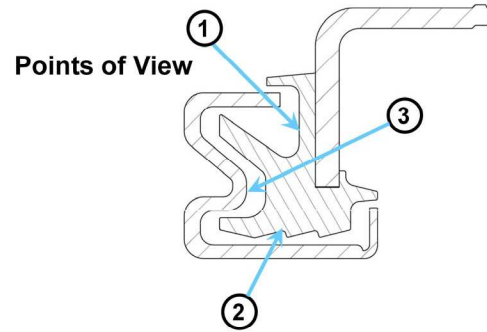


Elevated Temperature Test: Post Test Inspection

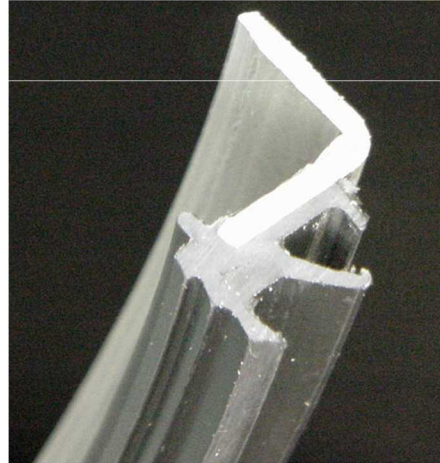


NO GREASE PURGE PAST SEAL BORE

Dust Test: Post Test Inspection



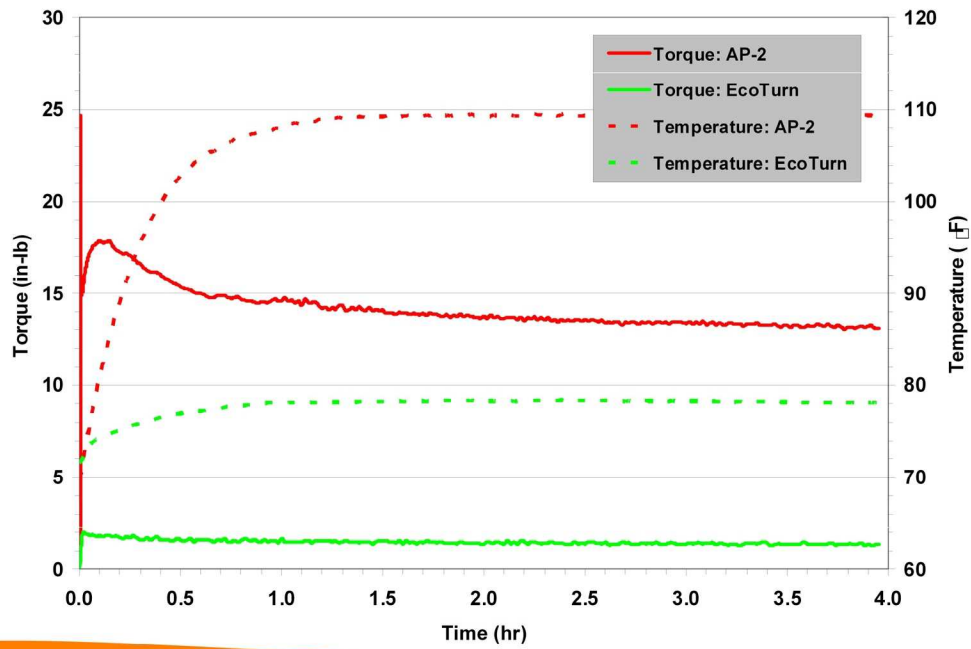
Vibration: Post Test Inspection



NO GREASE PURGE THROUGH SEAL

NO WEAR OF SEAL LIP

Torque & Temperature: EcoTurn vs HDL @ 500 rpm



32

Field Testing

- Currently have 80 seals on a captured line since July of '08
- Bearings have been visually inspected twice (most recent 09/04/08) showing no signs of seepage.



33

Conclusions

- The EcoTurn Class K production prototypes have passed all AAR qualification tests and received conditional approval.
- The accelerated life test on the second set of seals is in progress. Due to the performance of the first set, no problems are expected.
- The seal has demonstrated superior performance over the HDL seal in the test lab with virtually zero torque and excellent contaminant exclusion and grease retention.