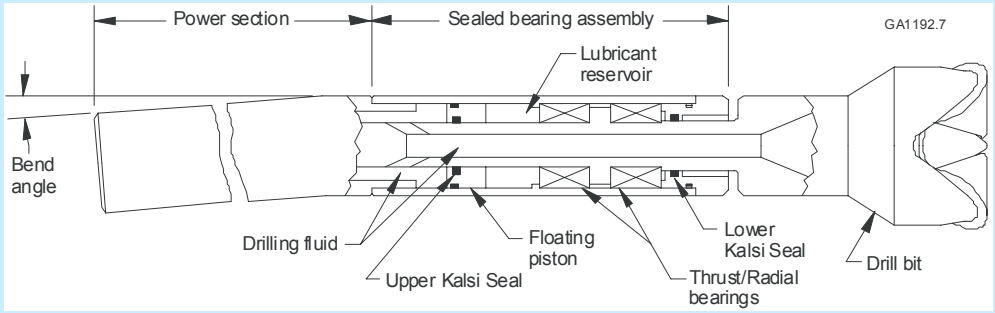
Kalsi Seals

Advanced Sealed Bearing Assembly for Positive Displacement Motors Used in Microhole Drilling



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PTTC: Microhole Integration Meeting, 11/16/2005
Houston, Texas

Introduction

- **The DOE "Roadmap" Report for Microhole identified the development of PDM with:**
  - higher pressure drop capability
  - sealed bearing assemblies

  as a critical technology area.
- **Sealed bearing assembly; as compared to a mud lubricated bearing assembly that bypasses the flow through the bit enables:**
  - maximum ΔP across the bit nozzles
  - more energy for available drilling, hole cleaning, or combinations to optimize ROP

Kalsi Engineering proposal selected in July 2004 and awarded a DOE/SBIR Phase I Project under their subtopic – *Small Bore "Microhole" Drilling*

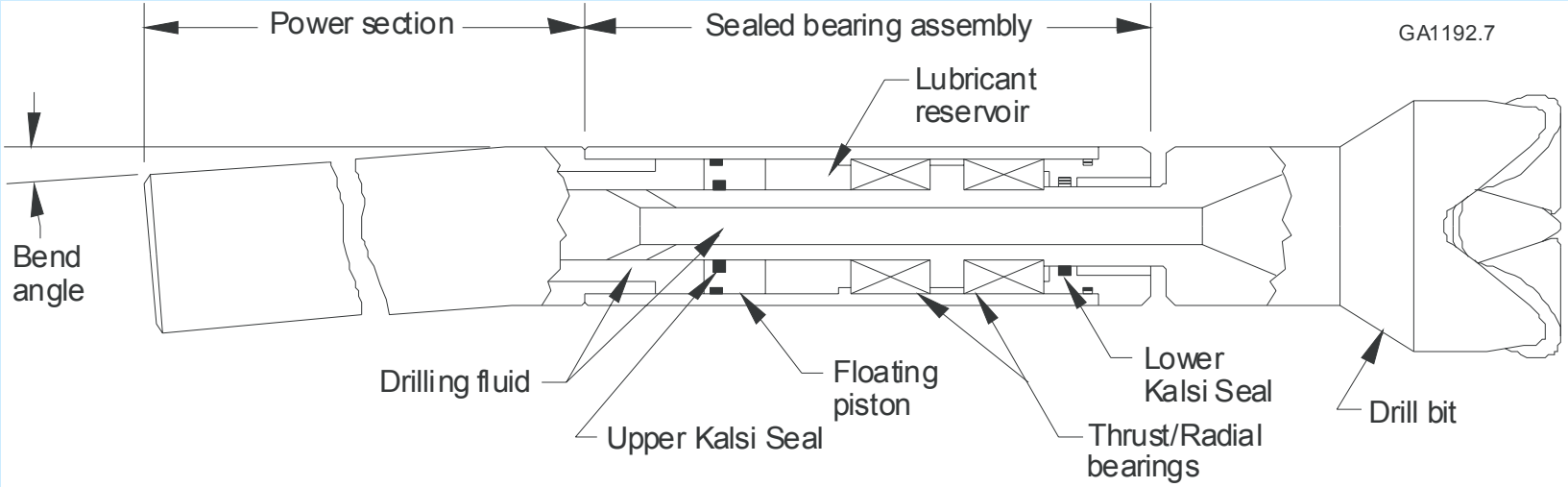
OBJECTIVE

Develop a highly durable, long-life (1000 hours), low cost sealed bearing system for microhole PDMs used in coiled tubing

Key Technical Areas:

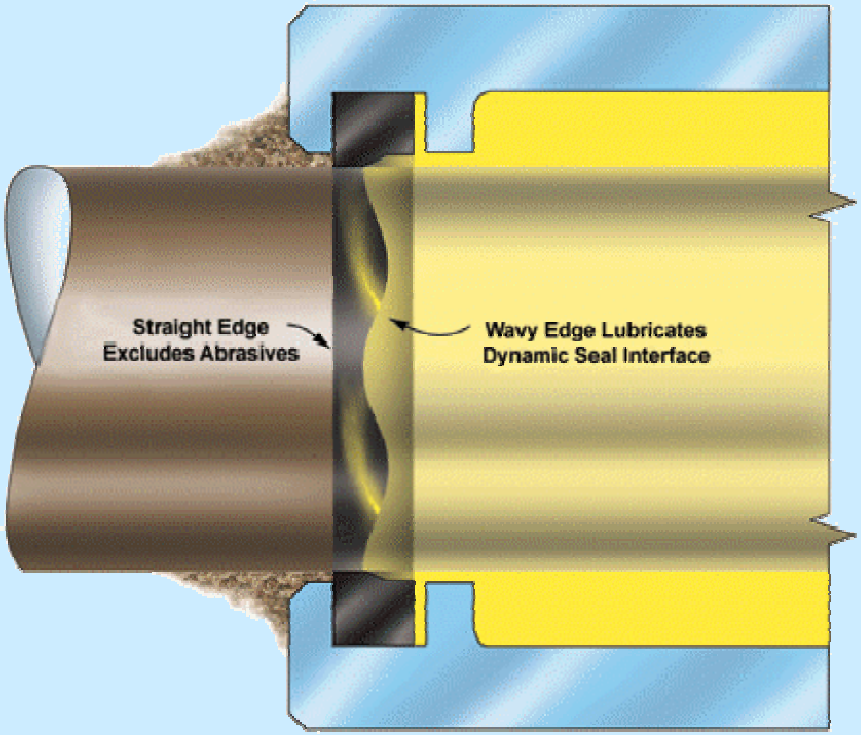
- **Advanced Hydrodynamic Rotary Seals**
  - smaller radial cross-sections
  - higher pressures, higher speeds, longer life
- **Load Responsive Hydrodynamic Thrust Bearings**
  - overcome rolling element bearing limitations
- **Structural capabilities and fatigue life >1000 hours under harsh vibration environment in coiled tubing**

Applications



Schematic of a Typical Oilfield Downhole Drilling Mud Motor

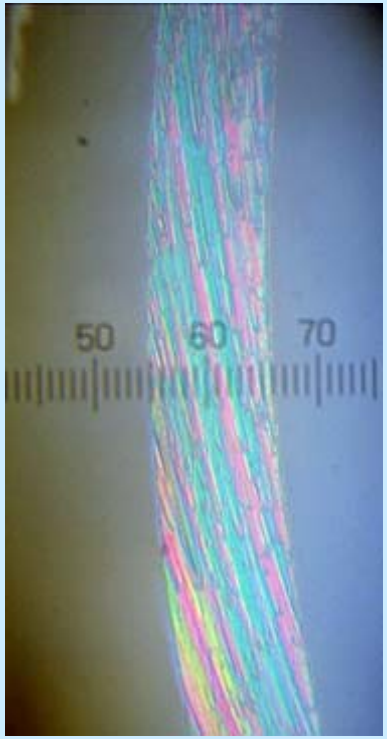
Kalsi Seals Principle of Operation



Kalsi Seal (Standard Design)

- Unique geometry: hydrodynamic lubrication and abrasive exclusion
- Lowers friction, reduces wear, provides long life
- Simple one-piece construction

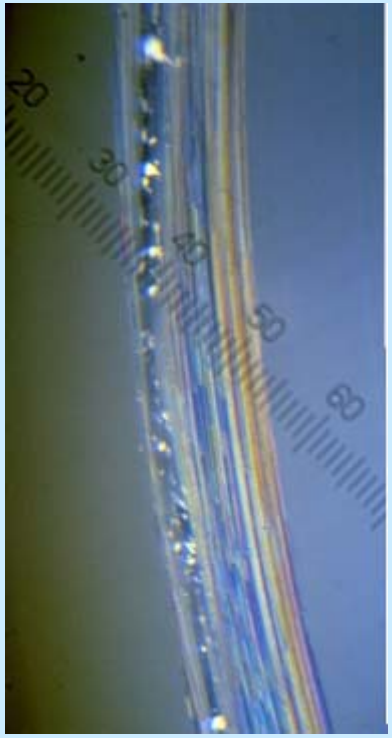
Optical Studies



Hydrodynamic Seal

Eliminates direct rubbing/wear, lowers friction

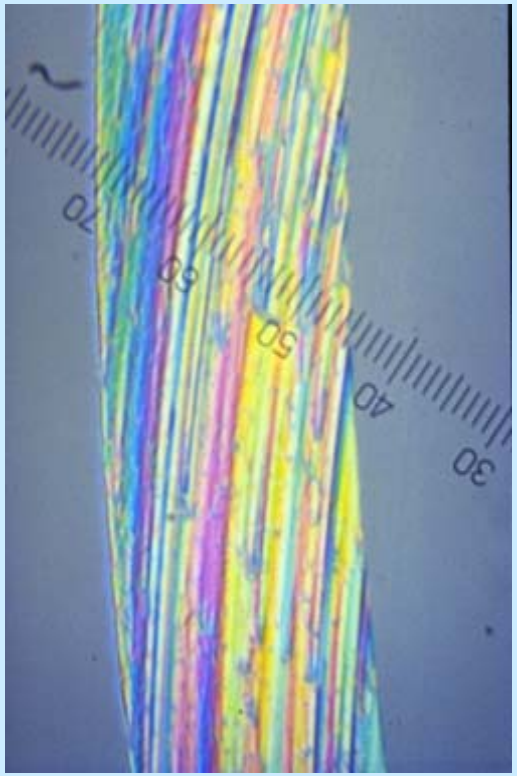
Low ΔP Operation



Conventional Seal

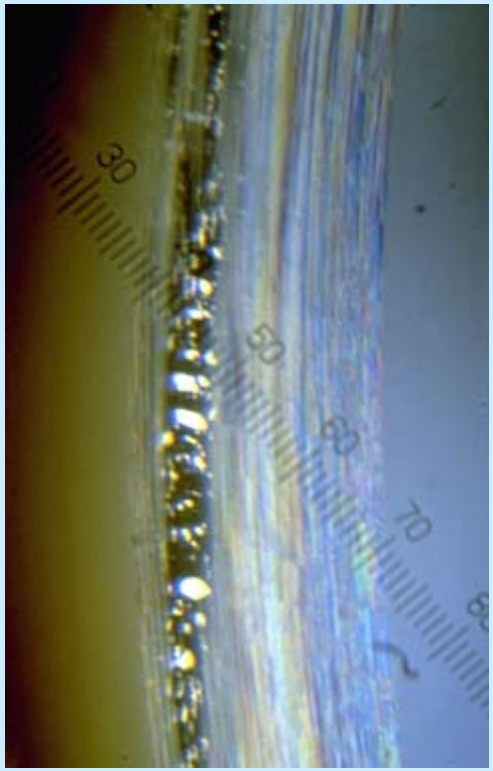
Direct rubbing, higher friction, heat, and wear

Optical Studies



Hydrodynamic Seal

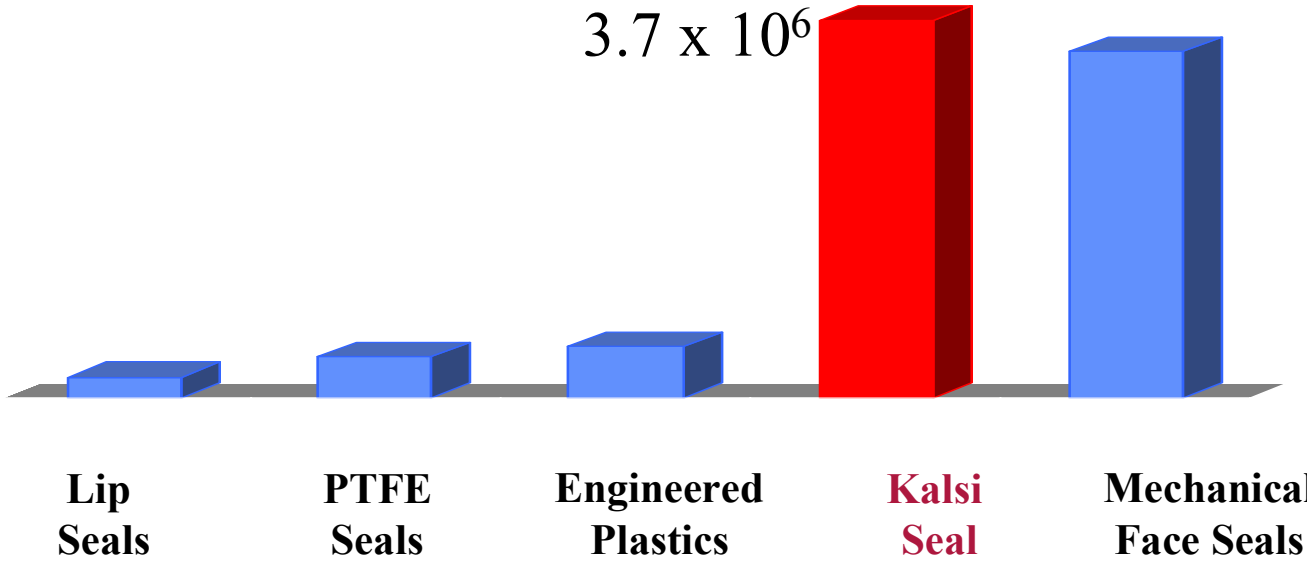
High ΔP Operation



Conventional Seal

- **Hydrodynamic performance advantage maintained at high pressures**

Kalsi Seals Performance Comparison



- *Kalsi Seals PV Limits are more than 10 times higher than other polymeric seals*
- *Provides reliability and cost advantage over mechanical seals for downhole applications*

Seal Development

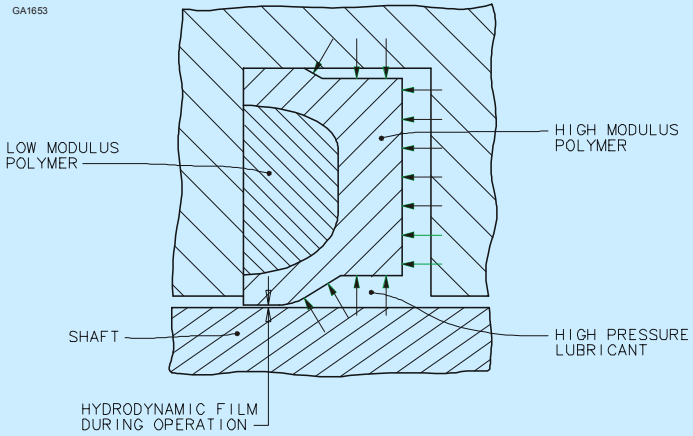


Figure 4A

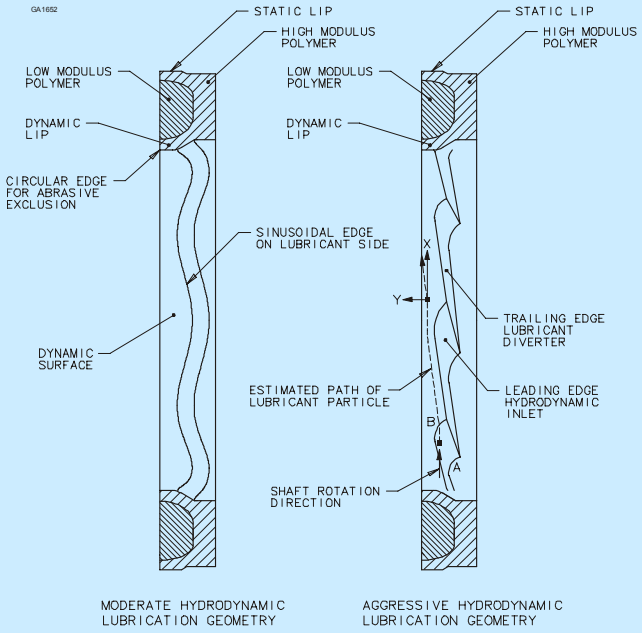


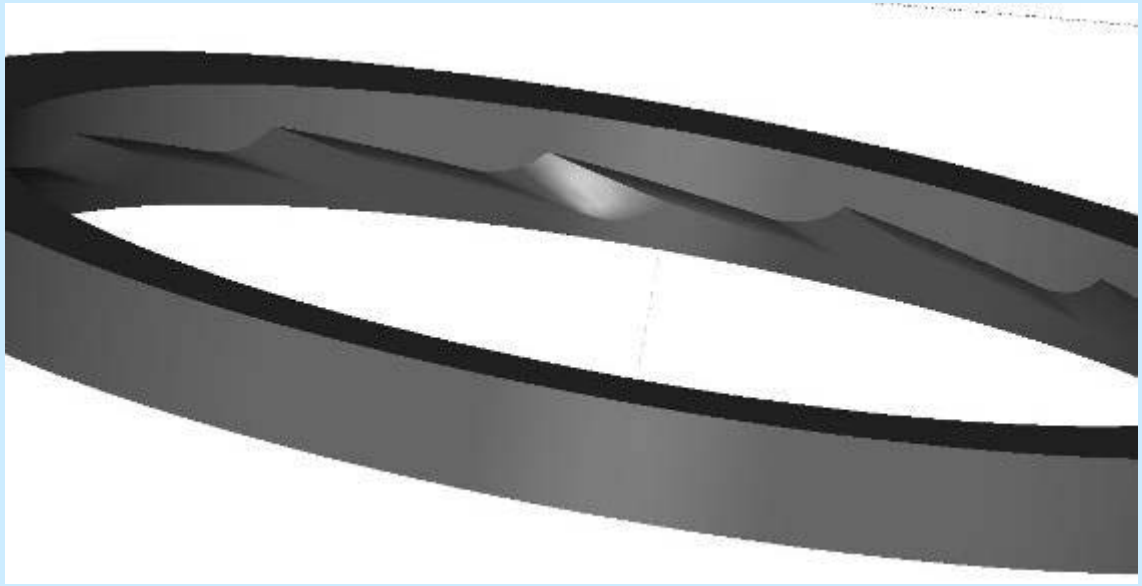
Figure 4B

Figure 4C

Advanced Rotary Seal Design Concepts for Microhole Applications

- Higher radial compression required to accommodate radial shaft motion, smaller cross sections
- Increase hydrodynamic action introduced to accommodate higher radial compression, higher ΔP's and speeds

Seal Development

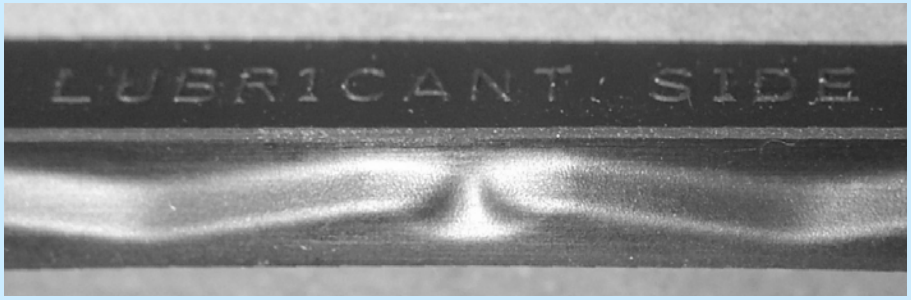


High Film Kalsi Seal

An aggressive unidirectional hydrodynamic geometry lowers friction

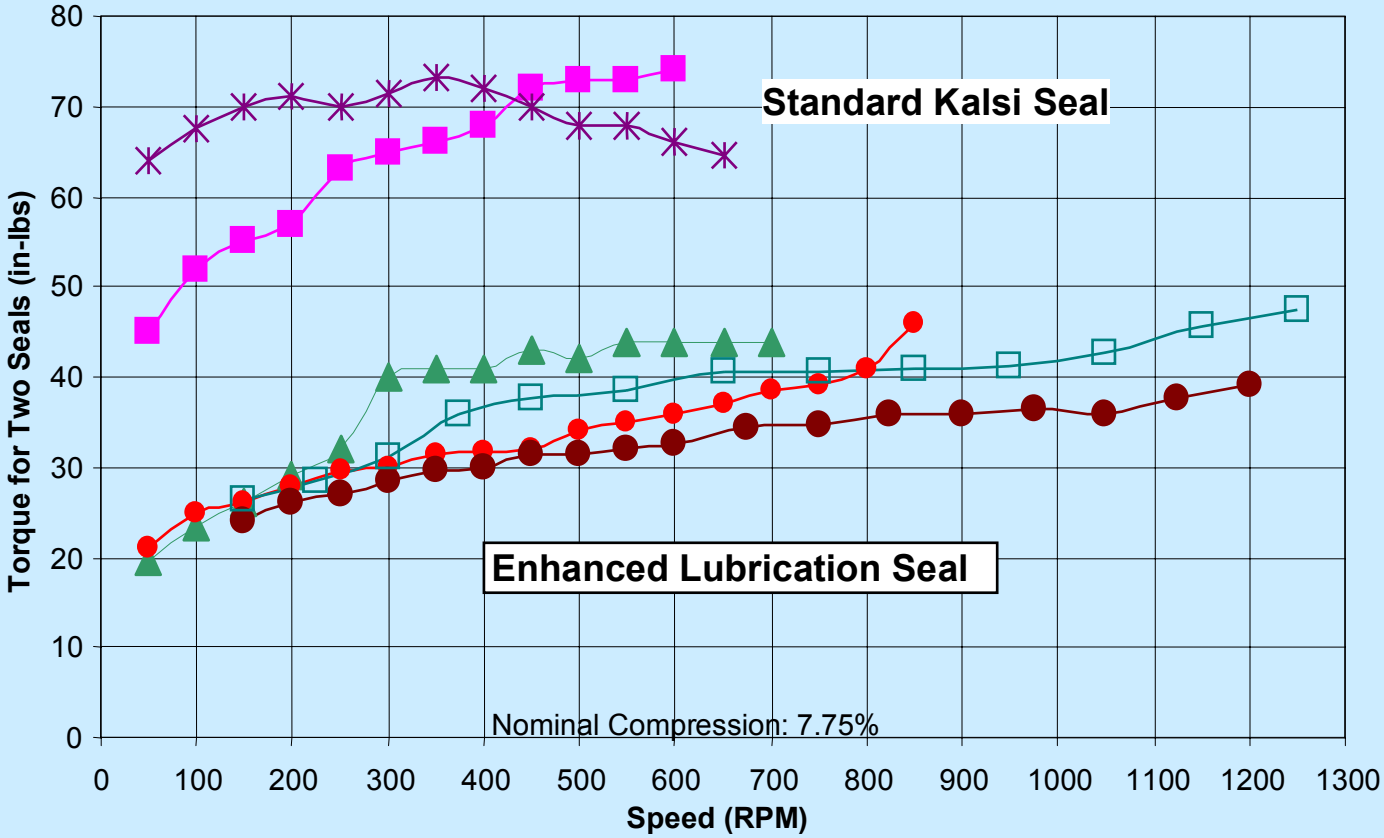
- suitable for higher DP's, higher speeds
- ***leakage much higher than standard Kalsi Seals, unacceptable for downhole tools***

Enhanced Lubrication Seal



- Enhanced Lubrication (EL) Seal combines the performance advantages of Kalsi Standard Seal and High Film Seal
- EL Seal had 45% less torque in un-cooled low ΔP (15 psi) testing with an ISO 32 VG lubricant, allowing 2X rotary speeds (80 Shore A Seals).
- Leakage in the same range as Standard Kalsi Seal suitable for microhole and other downhole applications

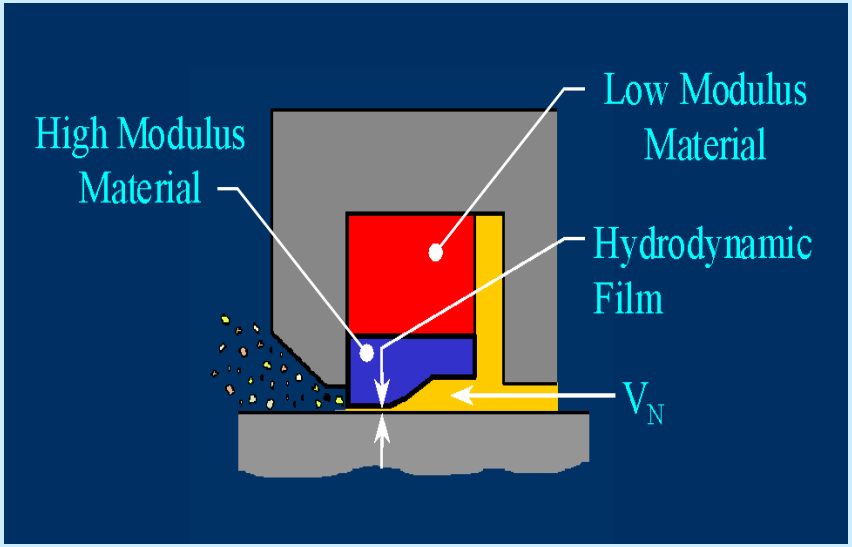
Enhanced Lubrication Seal Results

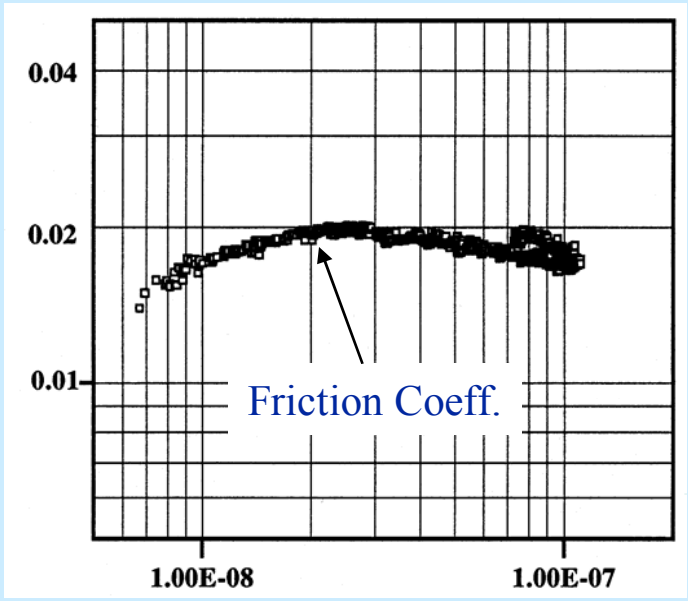


Comparison of Standard (344-25-10) and Enhanced Lubrication (548-10-10) Kalsi Seal

Geometries with No Active Cooling, Speed vs. Torque for Two 2.75" Dia Seals

Seal Development

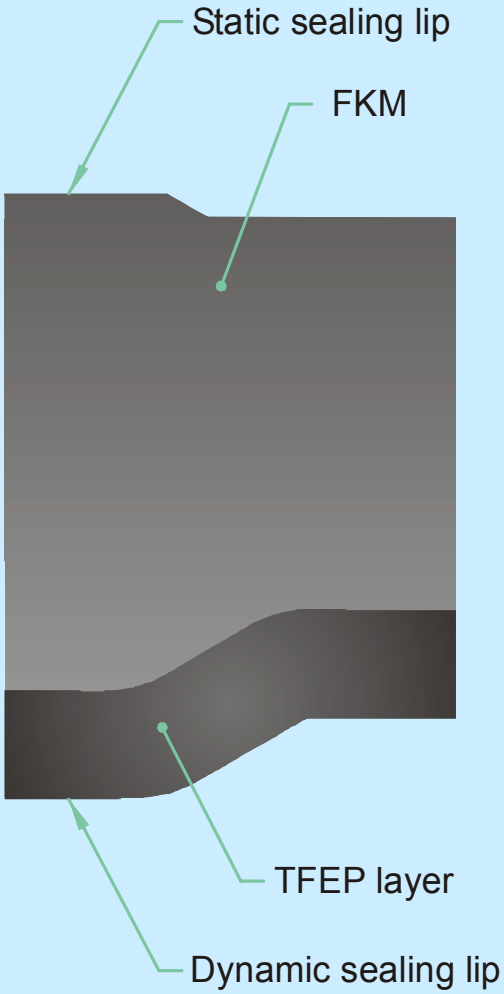




Dual Modulus Seal

- **Dual Modulus Kalsi Seal extends performance to:**
  - **5000 psi (34.5 Mpa) and 3.7 x 10^6 psi ft/min**
  - **Very low friction coefficient**

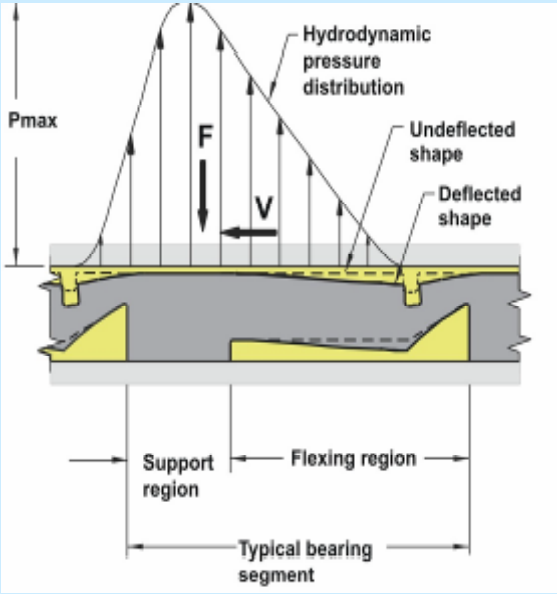
Seal Development



High Temperature Technology

- **Integral FKM/TFEP composite construction.**
- **FKM compensates for poor compression set resistance of TFEP.**
- **TFEP compensates for poor running characteristics of FKM.**
- **Successfully tested under low to medium ΔP high temperature service (200°C); higher ΔP tests to be performed.**

Hydrodynamic Thrust Bearing

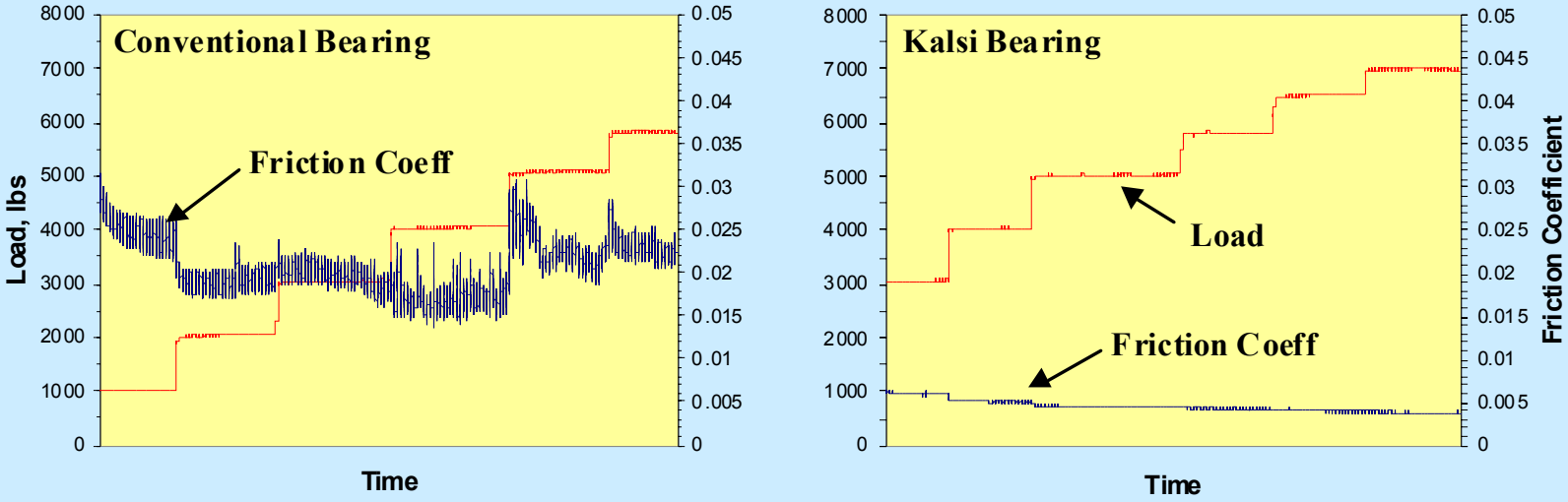


Principle Operation of the Load Responsive Hydrodynamic Kalsi Thrust Bearing

Compared to rolling element bearings:

- ***Higher thrust capacity***
- ***Tolerates significantly higher shock loads, vibration***

Kalsi Seals Hydrodynamic Thrust Bearing



- Typical Test Results Show More Than Five-Fold Reduction in Friction
- Suitable for Higher Speeds and Higher Loads Required for High Performance Drilling
- Only One On-Bottom and One Off-Bottom Bearing Required Instead of Multiple Bearings in Present Design Motors

Status

- Intensive FEA analyses, design and testing in progress
- Phase I results very promising
- Goal of 500 – 1000 hour life looks feasible
- Higher speed applications (over 5000 rpm) for other microhole motor concepts to be included in Phase II