

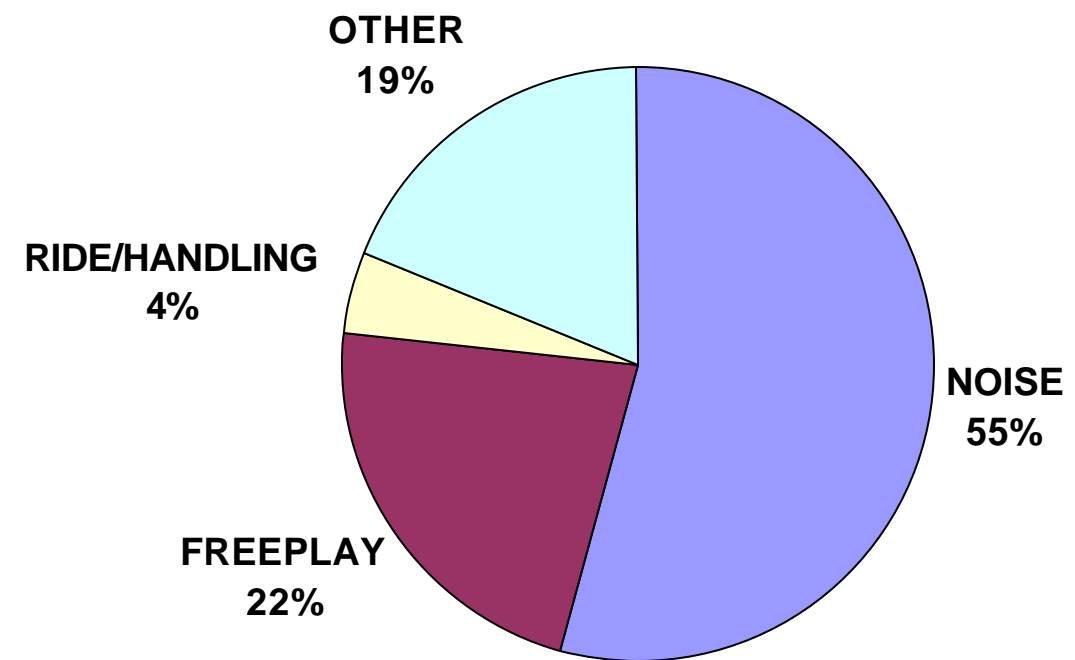
# BALL JOINT TRIBOLOGY

Powers and Sons LLC

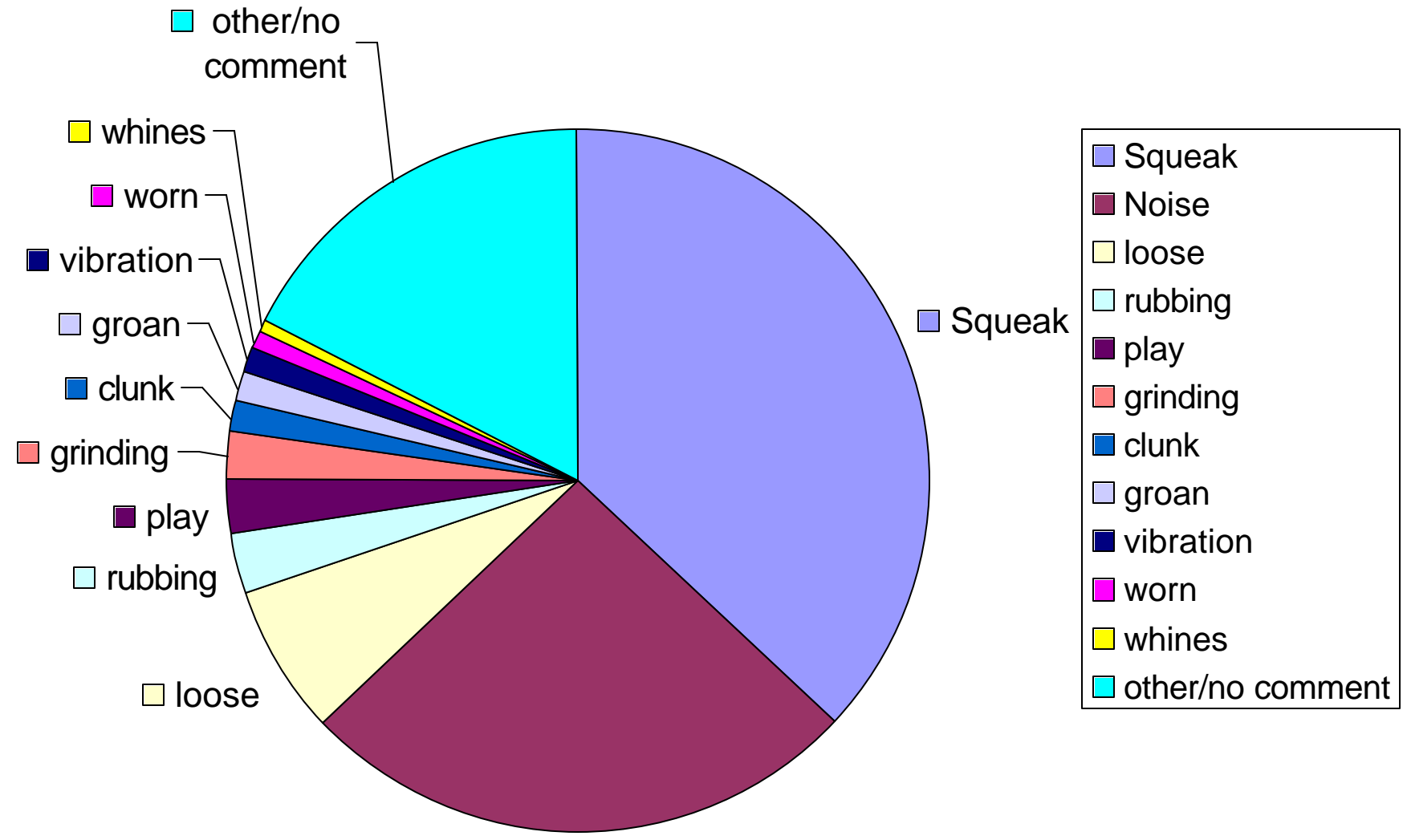
# PURPOSE

- TO ISOLATE CONTRIBUTIONS TO WEAR IN A BALL JOINT AND IMPROVE WEAR LIFE
  - LUBRICATION
  - BEARING MATERIAL
  - INTERNAL PRESSURE
  - SURFACE FINISHES
  - BALL HARDNESS

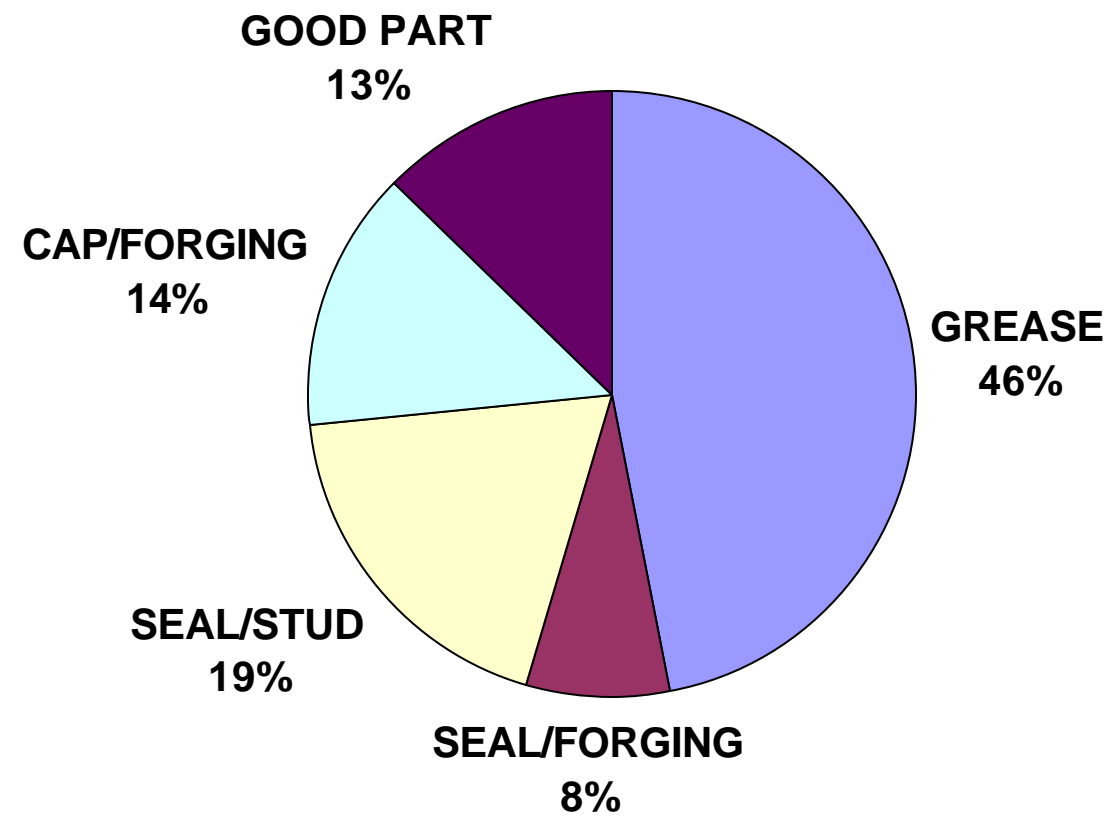
**COMPLAINT BY CUSTOMER CODE**  
**PASSENGER CAR TIE ROD ENDS, PITMAN, IDLER ARMS**  
**MILEAGE > 36,000**



### Complaint Codes by Verbatims >36000 miles



**CAUSAL FACTORS  
RETURNED PARTS ANALYSIS  
>36000 MILES  
79 PIECES**



# P-DIAGRAM

## Control Factors

- Seal / forging interface
- Seal material
- Spin Pressure (cap to forging)
- Cap to forging interface
- Bearing surface finish
- Selection of lubricant
- Dunnage
- Seal / stud interface
- Rotating torque of joints
- Geometry
- Bearing Material

**Signal Factor (M)**

Customer turns the wheel

Tie Rod Ball Joints

**Response (Y) Ideal Function**

Transmit motion / load uniformly

Noise Factors

- Plant Grease on steering stop
- Customer usage- Police/Taxi; demographics
- Contamination
- Proximity to brake rotor
- In plant handling damage
- Misdiagnosis

Error States

- Excessive free play
- Squeaks
- High initial rotating torque

## Design Variables Which Affect Ball Joint Life

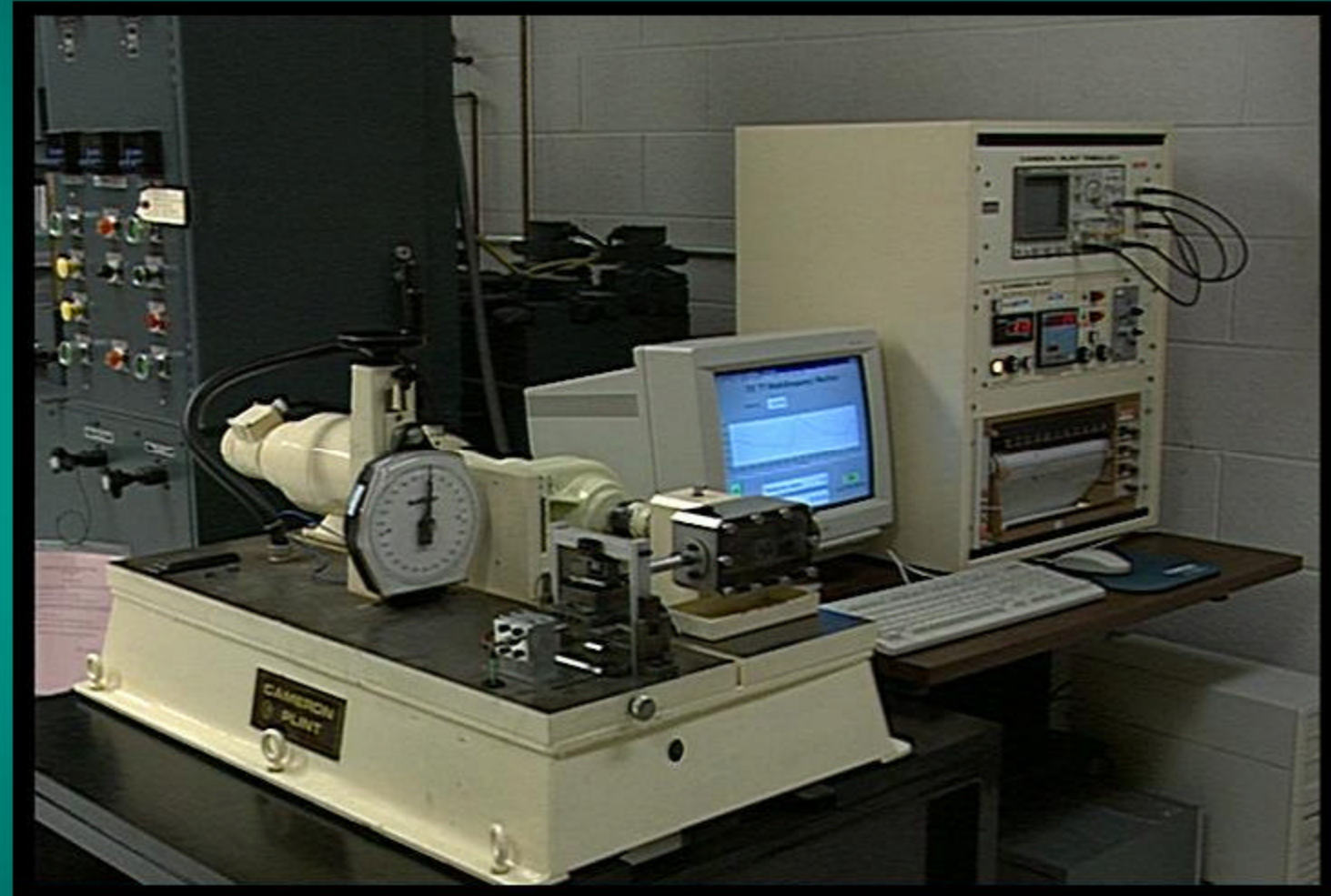
- Seal Effectiveness
- Grease Type
- Static Internal Pressure
- Bearing Material
- Ballstud Surface Finish
- Bearing Surface Finish

# Development Testing

- Current industry standards
  - Bench wear test
  - Vehicle durability tests
  - Vehicle fleet tests
- Current designs pass ES and Vehicle Tests meaning current test methods are inadequate for identifying High Mileage concerns

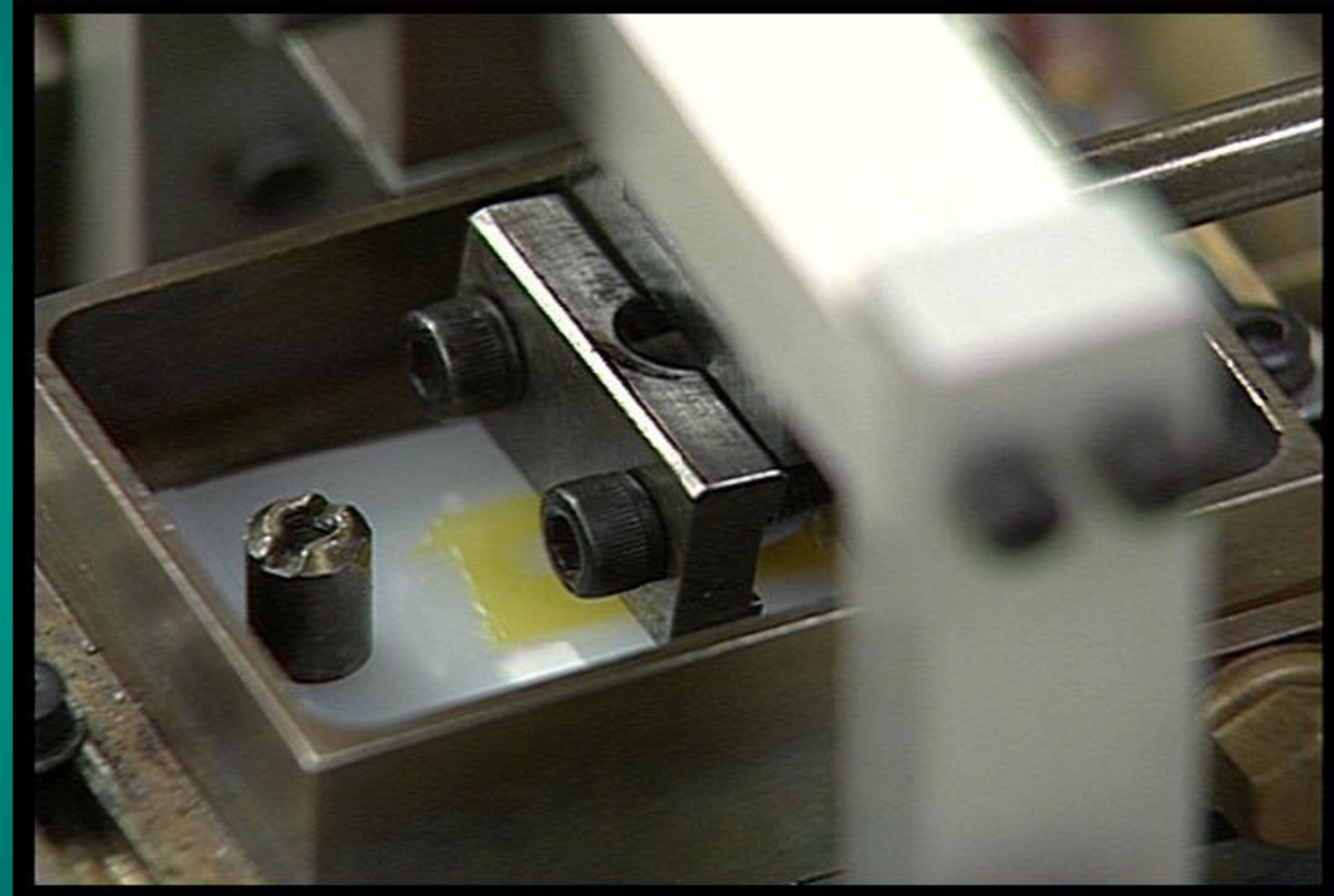


# Ball Joint Test Program



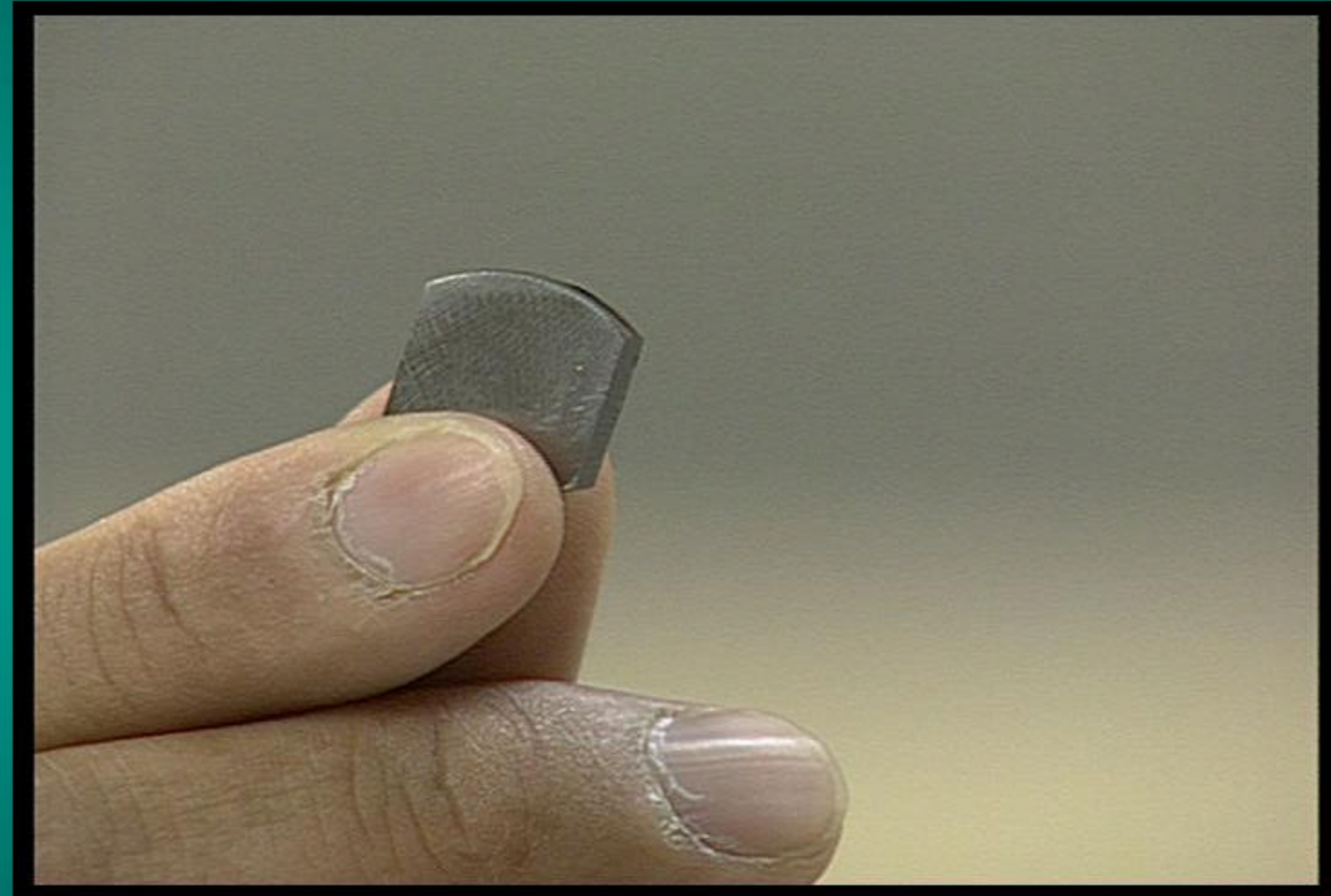
*Dow Corning Corporation*

## Ball Joint Test Program



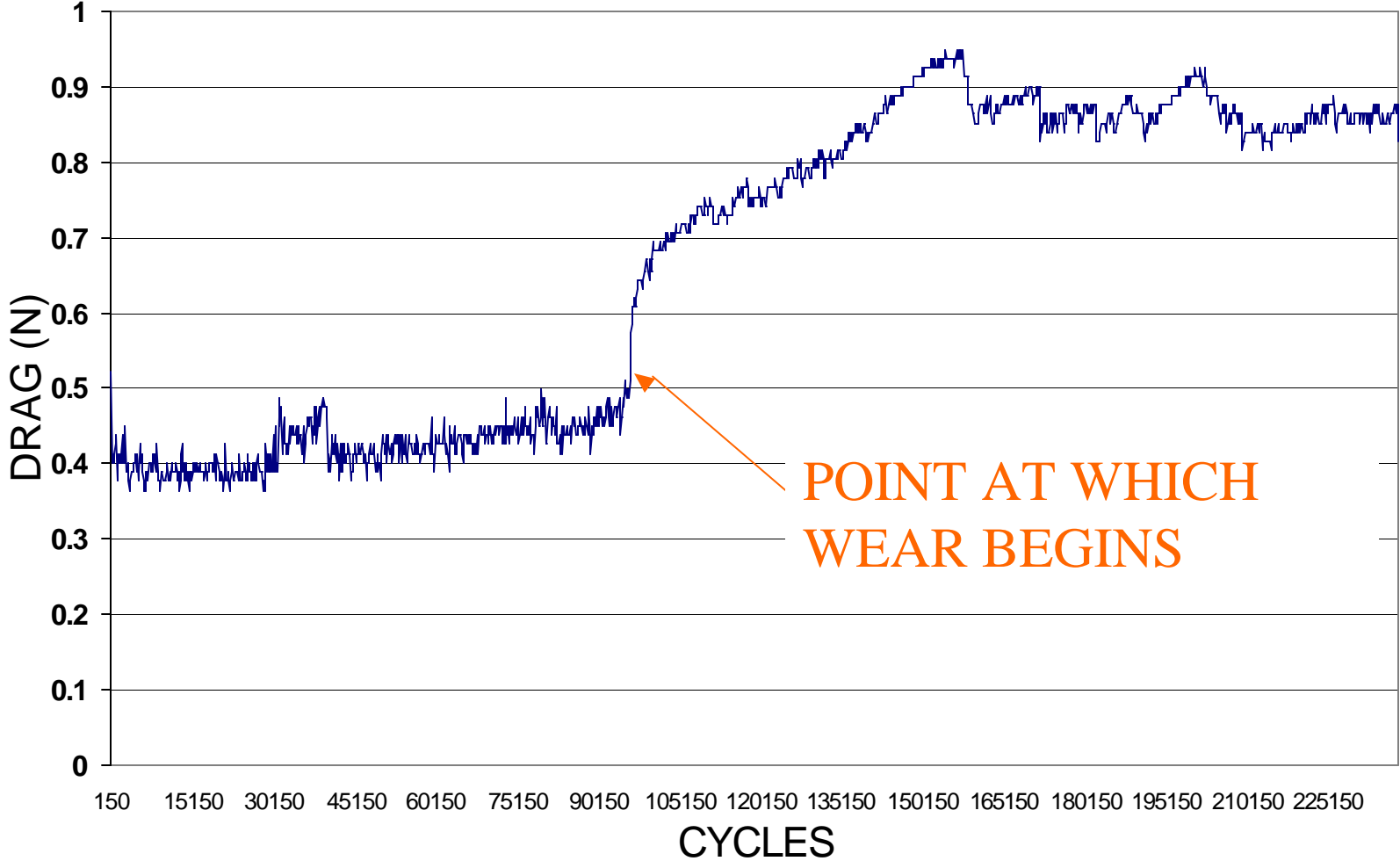
*Dow Corning Corporation*

# Ball Joint Test Program



*Dow Corning Corporation*

**BASELINE WEAR TEST**  
**SMOOTH NYLON 6/6, CLIMAX GREASE, Ra32 BALL, 10N NORMAL LOAD**  
**TRAVEL +/-1MM, 5 Hz**



# Development of Test

- Goal
  - Develop Key Life Test
  - Simulate interaction between component materials in a ball joint
- First inputs were developed
  - The Normal load to apply between surfaces
  - Length of path travel
  - Frequency of path travel
- Then wear test began with the following DOE variables:
  - Grease type
  - Ballstud surface finish
  - Bearing material type
  - Bearing material surface finish

<b>DOE - Full Factorial 32 runs (4x2x2x2) for Cameron Plint study</b>				
Load of 10N, speed of 5 Hz, and stroke of +/- .5mm				
Run	Grease 0,1,2,3	Plastic 0,1	Stud finish 0,1	Bearing finish 0,1
1	Climax	Nylon	Ra32	smooth
2	Climax	Nylon	Ra32	fine
3	Climax	Nylon	Ra5	smooth
4	Climax	Nylon	Ra5	fine
5	Climax	Acetal	Ra32	smooth
6	Climax	Acetal	Ra32	fine
7	Climax	Acetal	Ra5	smooth
8	Climax	Acetal	Ra5	fine
9	Nye	Nylon	Ra32	smooth
10	Nye	Nylon	Ra32	fine
11	Nye	Nylon	Ra5	smooth
12	Nye	Nylon	Ra5	fine
13	Nye	Acetal	Ra32	smooth
14	Nye	Acetal	Ra32	fine
15	Nye	Acetal	Ra5	smooth
16	Nye	Acetal	Ra5	fine
17	LT278	Nylon	Ra32	smooth
18	LT278	Nylon	Ra32	fine
19	LT278	Nylon	Ra5	smooth
20	LT278	Nylon	Ra5	fine
21	LT278	Acetal	Ra32	smooth
22	LT278	Acetal	Ra32	fine
23	LT278	Acetal	Ra5	smooth
24	LT278	Acetal	Ra5	fine
25	PG75	Nylon	Ra32	smooth
26	PG75	Nylon	Ra32	fine
27	PG75	Nylon	Ra5	smooth
28	PG75	Nylon	Ra5	fine
29	PG75	Acetal	Ra32	smooth
30	PG75	Acetal	Ra32	fine
31	PG75	Acetal	Ra5	smooth
32	PG75	Acetal	Ra5	fine

# STATIC INTERNAL JOINT PRESSURE

- MEASURED JOINT ROT. TORQUE = .56 N-M
- BEARING/BALL SURFACE CONTACT = 938 SQ. MM
- EFFECTIVE TORQUE RADIUS = 9.44 MM
- DRAG = TORQUE/RADIUS =  $.56/.00944 = 59\text{N}$
- NORMAL LOAD = DRAG/COEFF. OF FRICTION =  $59/.02=2950\text{N}$
- STATIC INTERNAL JOINT PRESSURE= NORMAL  
LOAD/SURFACE CONTACT AREA =  $2950/938 = 3.15 \text{ N/SQ. MM}$

## WORKING PRESSURE UNDER LOAD

- WORKING RADIAL LOAD = 600N
- PROJECTED BALL AREA = 270 SQ. MM.
- PRESSURE = LOAD/AREA =  $600/270 = 2.22\text{N/SQ. MM.}$

# NORMAL LOAD DETERMINATION

- TOTAL PRESSURE = STATIC +  
WORKING =  $3.15+2.22 = 5.37$  N/SQ.  
MM.
- CAMERON PLINT MEASURED  
CONTACT AREA = 2 SQ. MM
- NORMAL LOAD = PRESSURE \* AREA  
 $= 5.37*2 = 10.74$  N
- C-P WEAR TESTING RUN @ 10N  
NORMAL LOAD

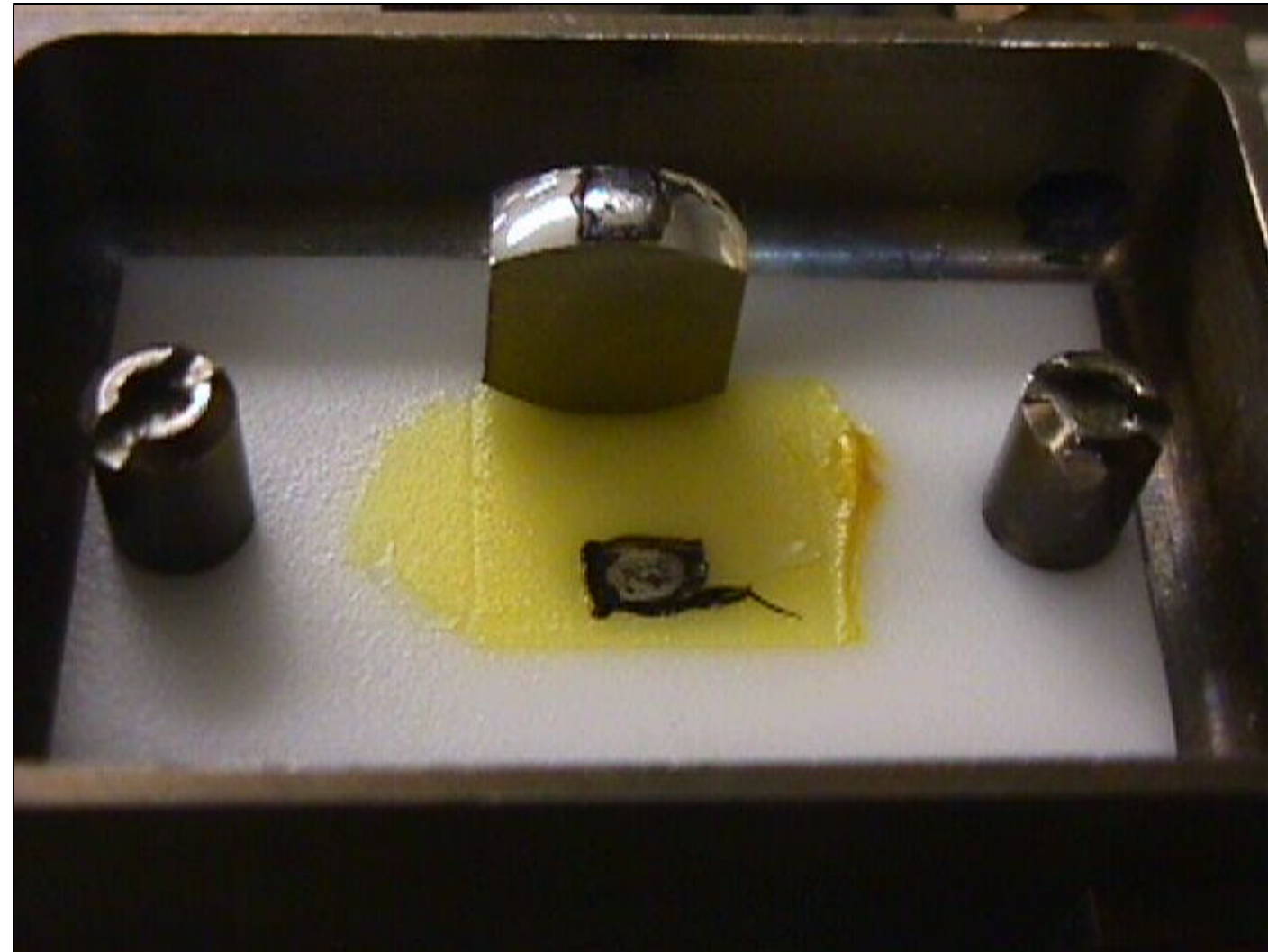
# TRAVEL DETERMINATION

- 90TH PERCENTILE ARTICULATION/  
ROTATION TRAVEL < 6 DEGREES
- LINEAR TRAVEL FOR 22MM BALL AT  
6 DEGREES = 1.17 MM
- C-P WEAR TESTING RUN AT +/- 1 MM  
TRAVEL

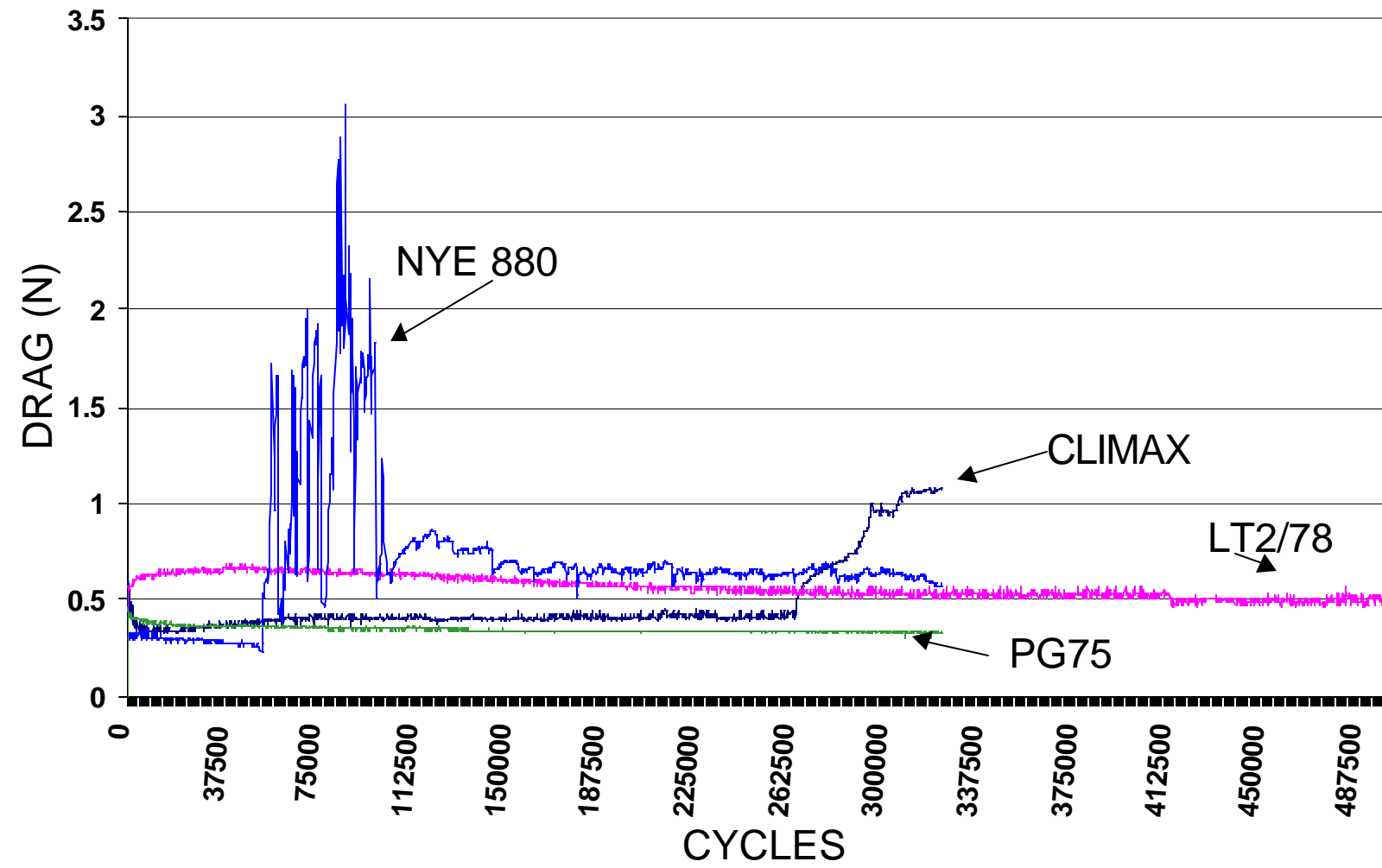
# Climax Grease Failure Modes

- Oxidation instability
- Poor moisture resistance
- Reacts adversely under static design and road load pressure

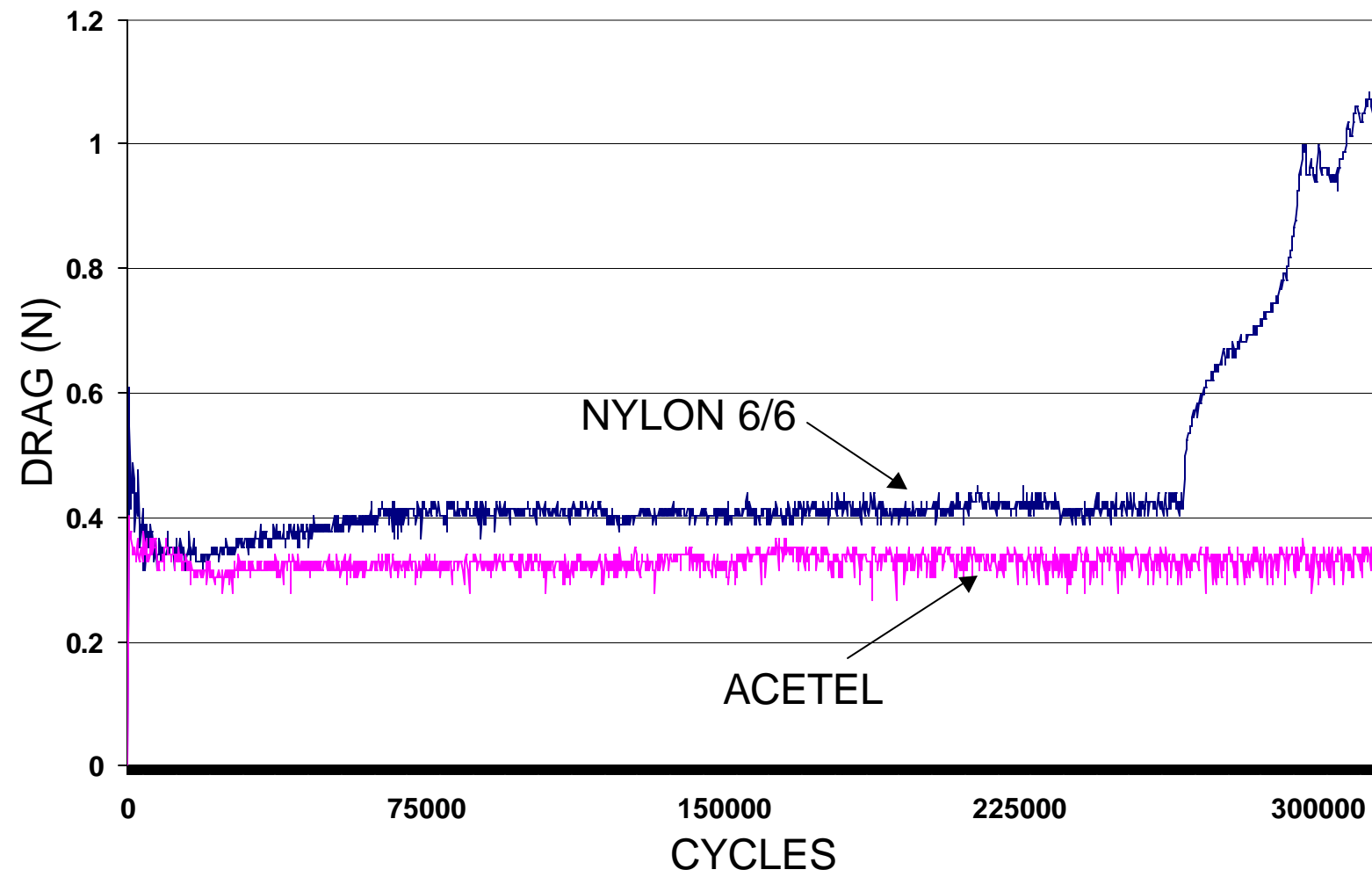
# Oxidized Climax



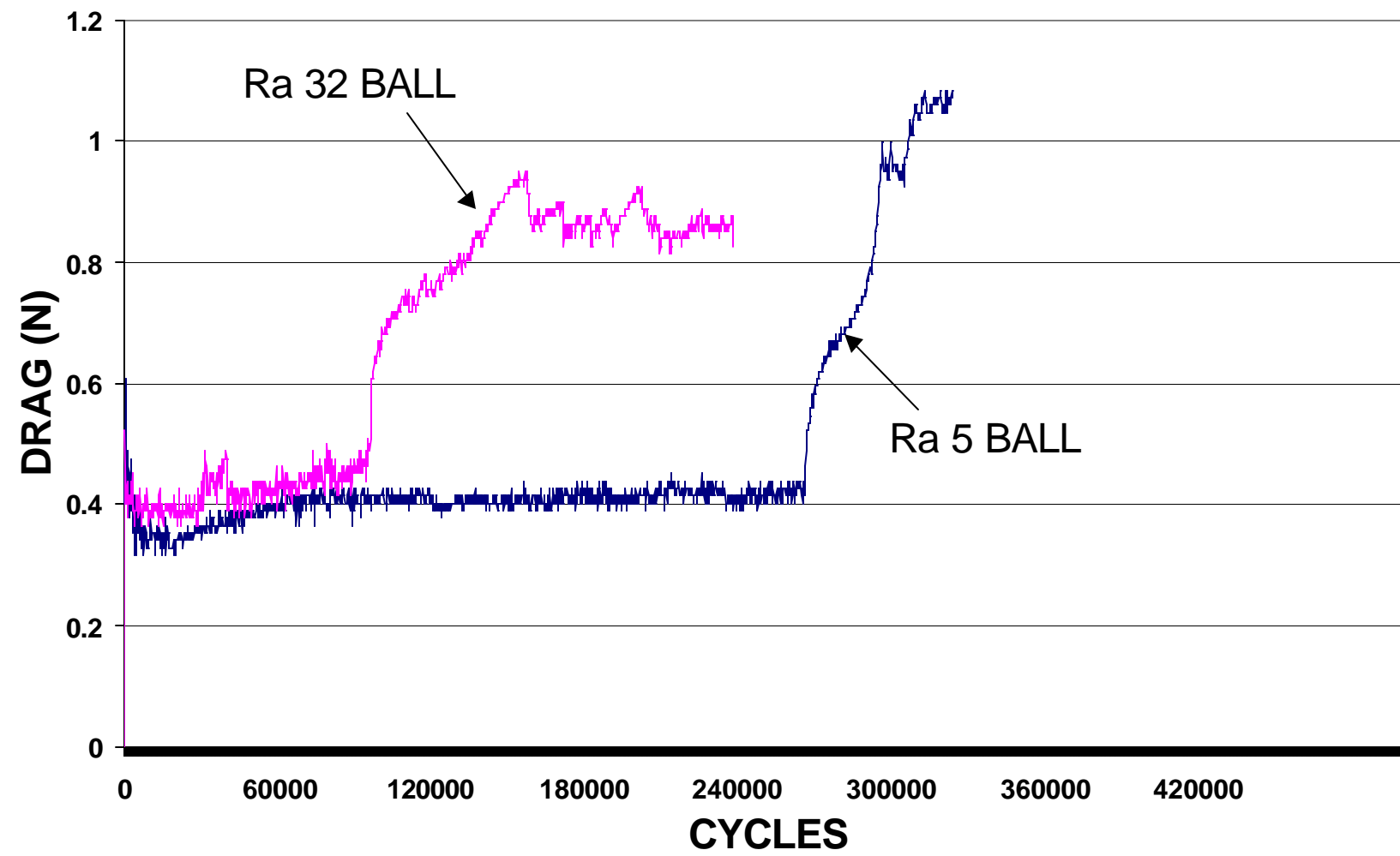
**CAMERON PLINT WEAR TEST**  
**NYLON 6/6, SMOOTH BEARING, Ra5 BALL STUD,**  
**10N LOAD, +/- 1 MM TRAVEL, 5 HZ**



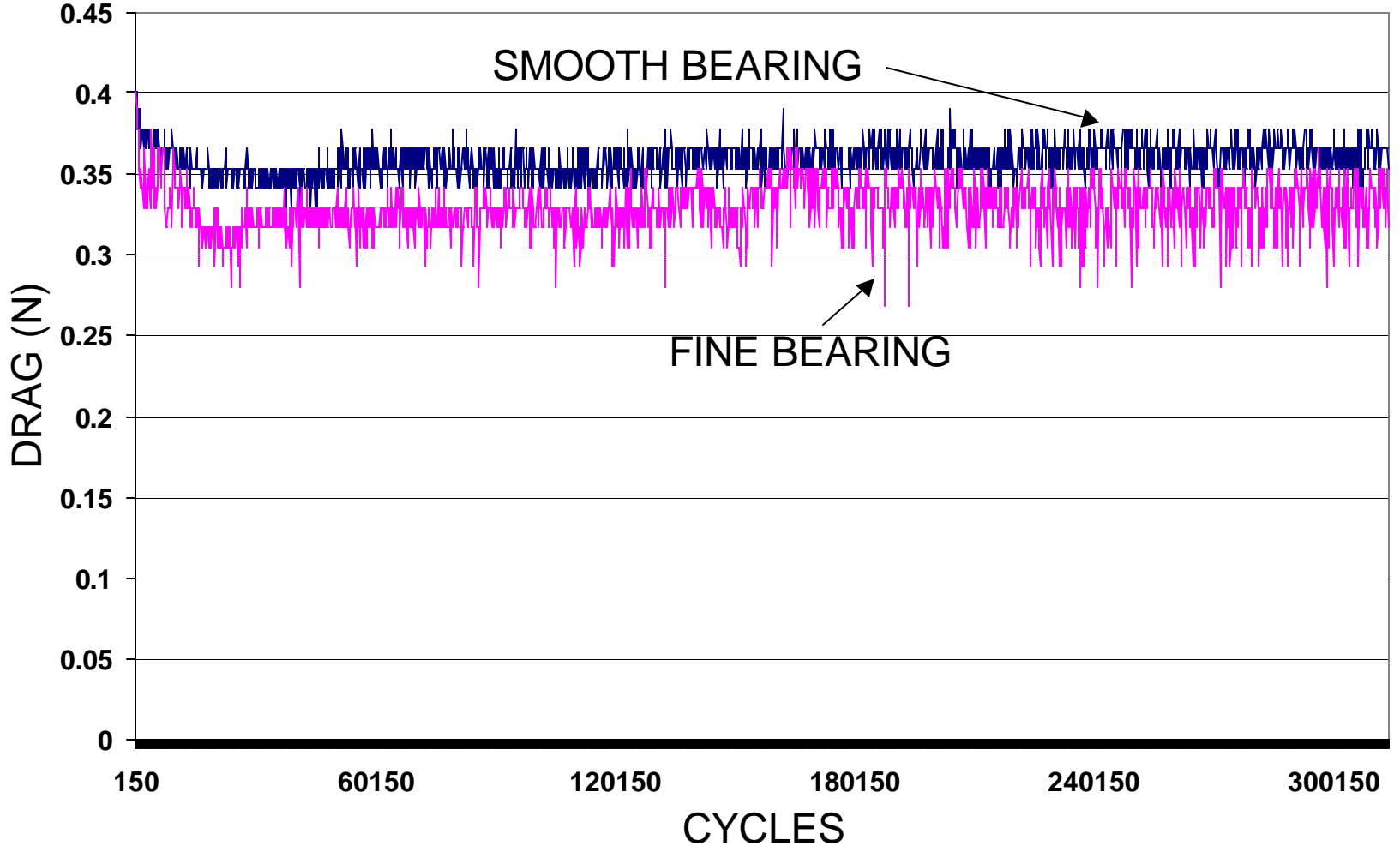
**EFFECT OF BEARING MATERIAL ON WEAR LIFE  
CLIMAX GREASE SMOOTH NYLON 6/6 BEARING  
Ra5 BALL STUD, 10N LOAD, +/- 1MM TRAVEL, 5HZ**



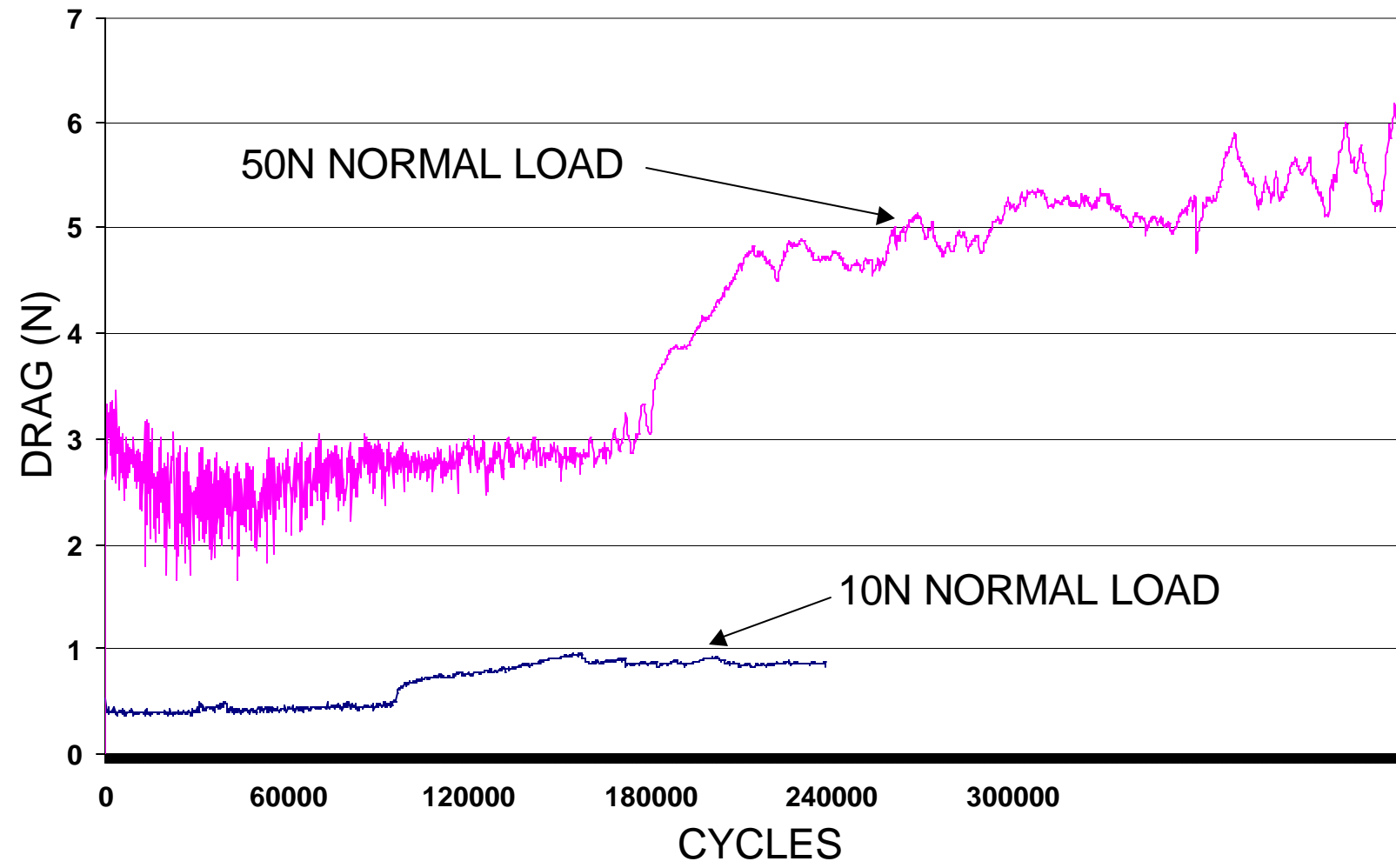
**EFFECT OF BALL SURFACE FINISH ON COEFFICIENT OF FRICTION  
CLIMAX GREASE, SMOOTH NYLON 6/6 PLATE,  
10N NORMAL LOAD, +/- 1MM TRAVEL, 5HZ**



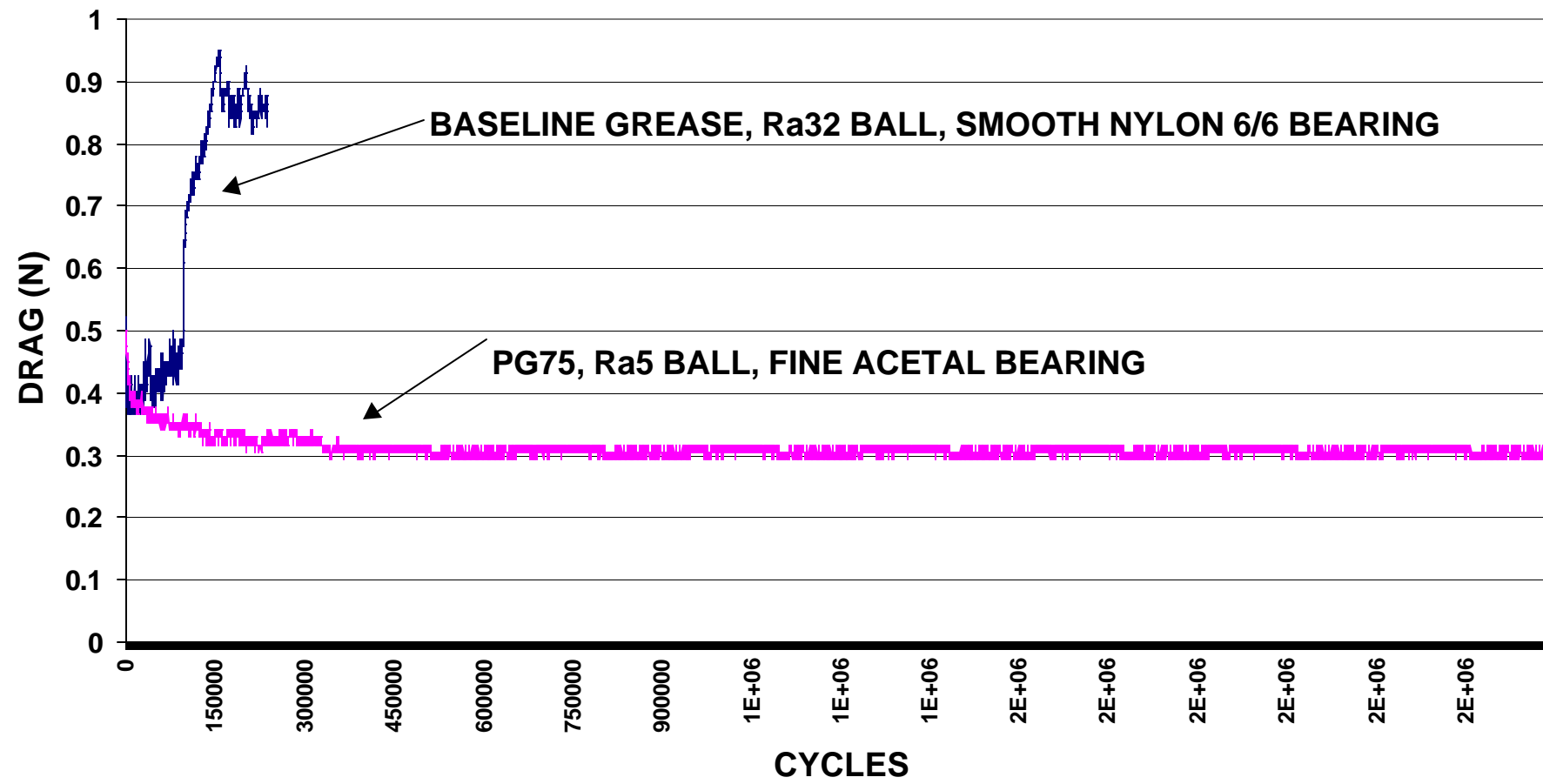
**EFFECT OF BEARING SURFACE FINISH ON WEAR LIFE**  
**ACETEL BEARING, Ra32 BALL, CLIMAX GREASE**  
**10N LOAD, +/- 1MM, 5 Hz**



**EFFECT OF NORMAL LOAD ON DRAG**  
**CLIMAX GREASE, SMOOTH NYLON 6/6 PLATE, Ra32 BALL**  
**+/-1MM STROKE, 5 Hz**



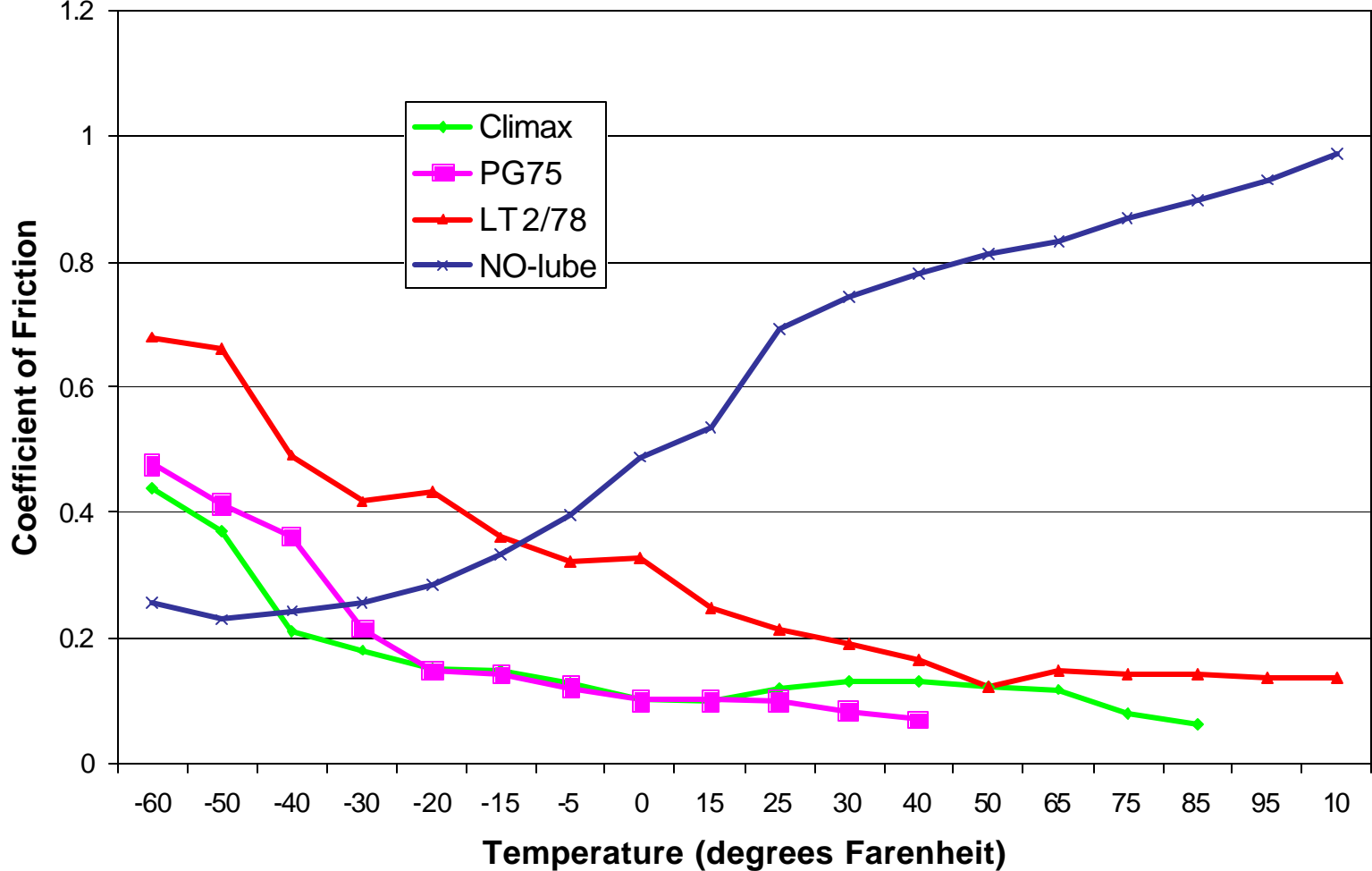
**BASELINE TO BEST**  
**10N NORMAL LOAD, +/- 1MM STROKE, 5Hz**



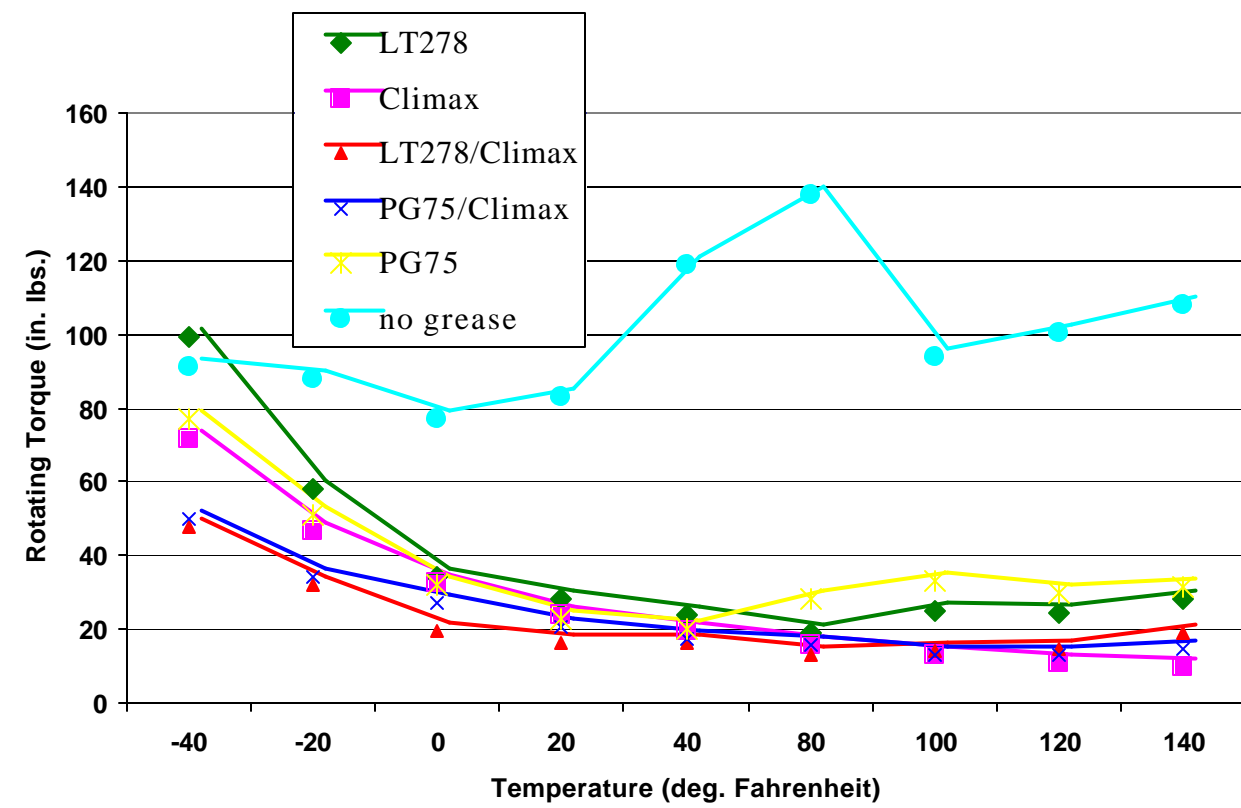
**CONTRIBUTION TO WEAR LIFE IMPROVEMENTS  
BASED UPON F DISTRIBUTION WITH TEST SUSPENDED AT 4000  
MINUTES OR FAILURE**



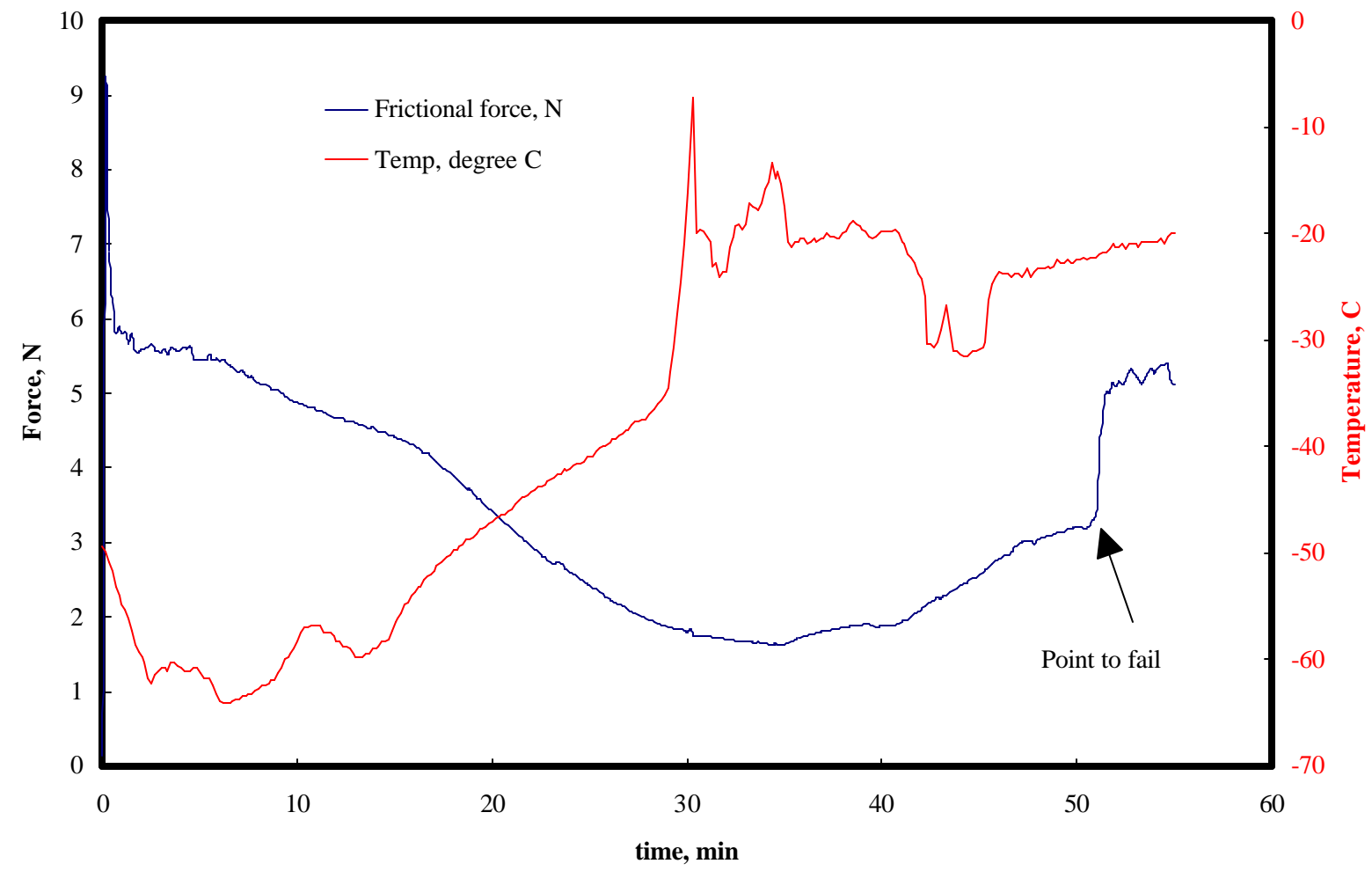
Coefficient of Friction with Nylon 6/6 bearing and Ra32 ball stud at full temperature range measured on Cameron Plint at Dow



Operating Temperature Range Rotating Torque on 2000 M.Y. Windstar Tie Rod Ends



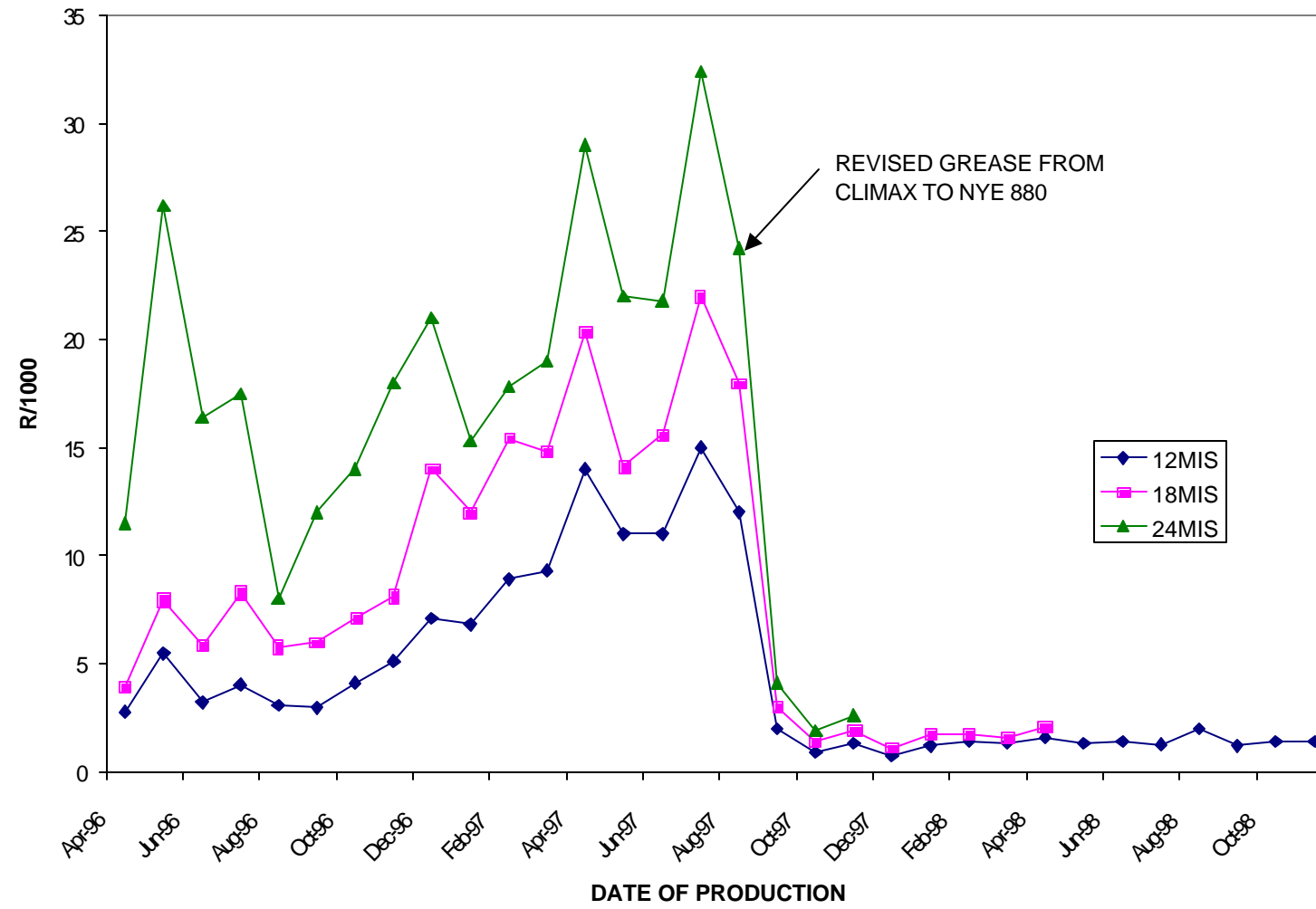
**Climax grease, 10N load, 5Hz, Ra 32 on Smooth Nylon**



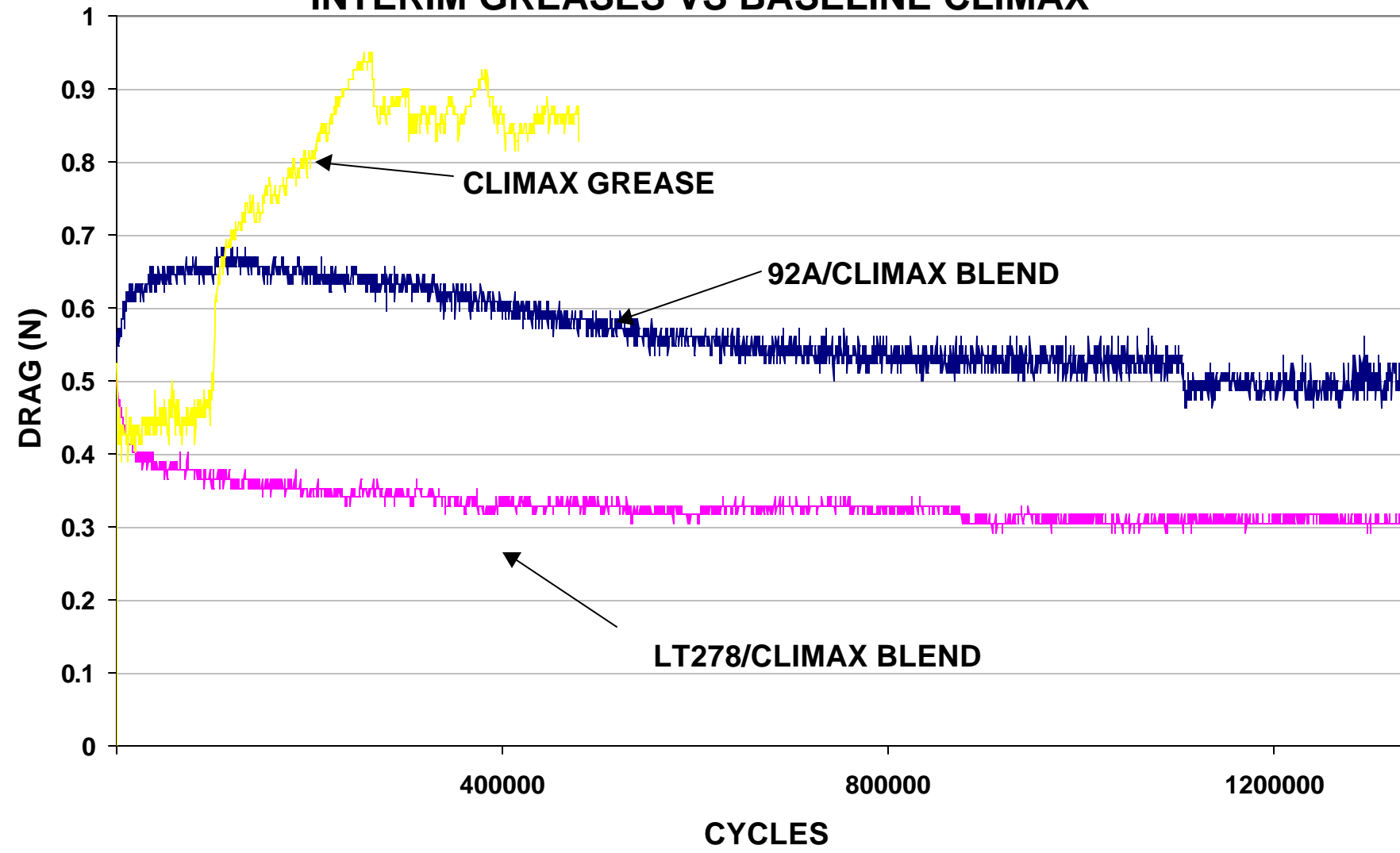
# Conclusions from Cameron Plint

- Grease is primary constituent to improving joint life
  - **Grease of choice is Dow Corning PG75**
- Minor improvement is found with:
  - **Acetel vs. Nylon 6/6**
  - **Polished ballstud surface**
  - **Fine texture bearing surface vs. current smooth texture**
- Lowering Ball Joint Internal Static Pressure will add to joint life

PN96 PITMAN ARM (3590) WARRANTY VS DATE OF PRODUCTION



# INTERIM GREASES VS BASELINE CLIMAX



# Design Solutions

- New Joint- bearings, grease, and ballstud developed through:
  - Benchmarking
  - Cameron Plint Testing
  - ES Bench Testing
  - 150K mile AEMS fleet test