Overview

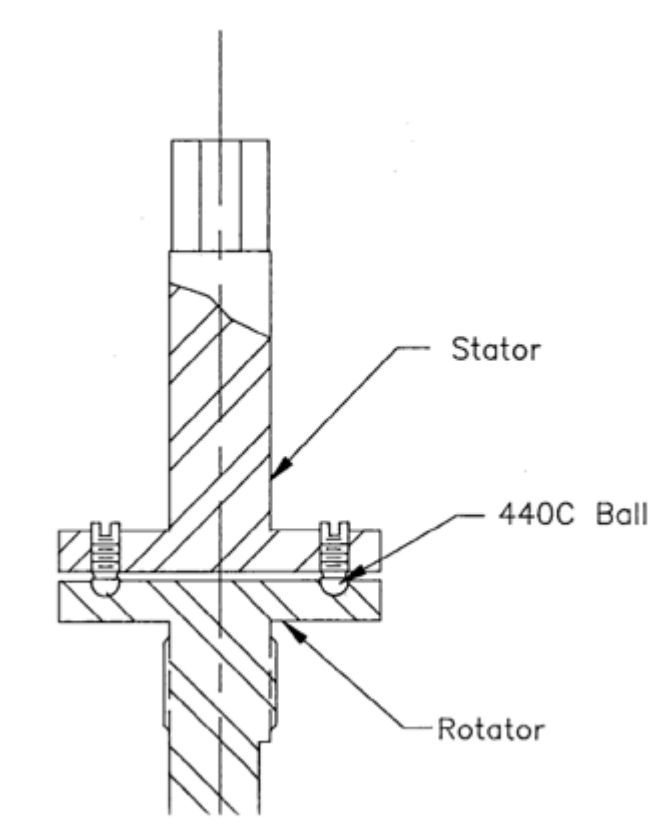
- Introduction and Background
- Test Objective
- Test Plan Overview
- Test Hardware Description
  - Parameters and Approach
- Results and Discussion
- Conclusion

Introduction and Background

- Three Z-1 bearing assemblies were tested in support of Z-2 Suit development.
- Bearing constructed of titanium
  - Titanium is extremely easy to ignite
  - Will sustain burning in sub-ambient pressures
- Early 90's Test of ZPS Mk III
  - Ignitions were obtained
  - No bulk material burning

Introduction and Background

Early 90's Test Configuration



Test Results

Test Objective

- Evaluate whether a damaged or failing bearing could result in ignition of the titanium race material due to friction.
  - Simulated worst-case environment, with operational loads, and anticipated flaw conditions
  - Loads were comprised of plug and manned loads
  - Values for these loads used in the testing were derived from previous testing done on the current Extravehicular Mobility Unit (EMU)

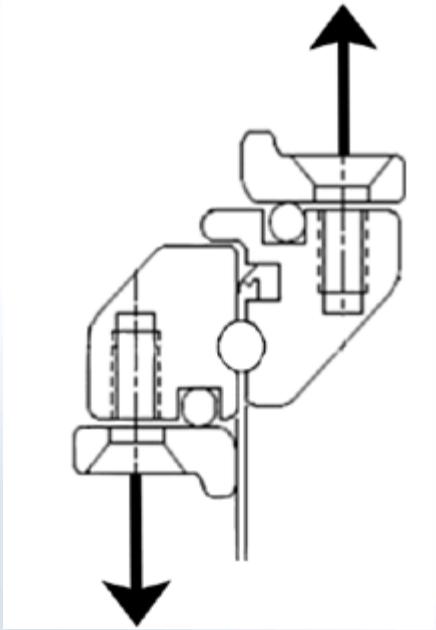
Test Plan Overview

- Testing simulated two simultaneous undetected failures
  - Inner seal leak sufficient to pressurize the race with +99 percent oxygen.
  - Improperly installed or mismatched ball port that created a protrusion in the ball bearing race, partially obstructing the nominal rolling path of each ball bearing.
    - Simulated mismatched ball port is a significant source of friction that would be caused by an assembly error.
- Two Phases of testing
  - 96 hours of cycle time
    - Cycle rate, speed, and simulated loads based on previous manned suit testing
  - Increased load on each bearing for 30 minutes
  - Tests done at 12.4 psia

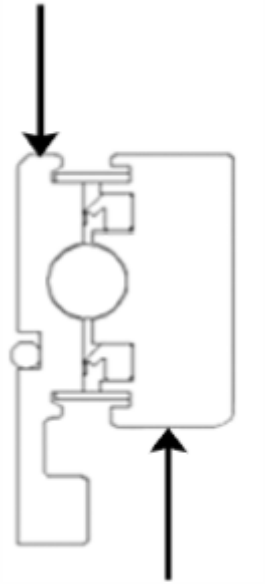
Test Hardware Description

- Three bearing assemblies representing the hip bearing, scye (shoulder) bearing, waist.

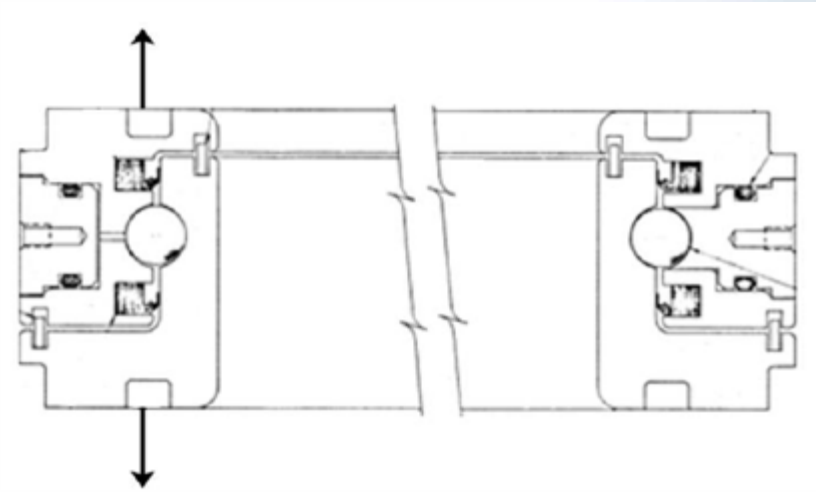
Hip Cross section



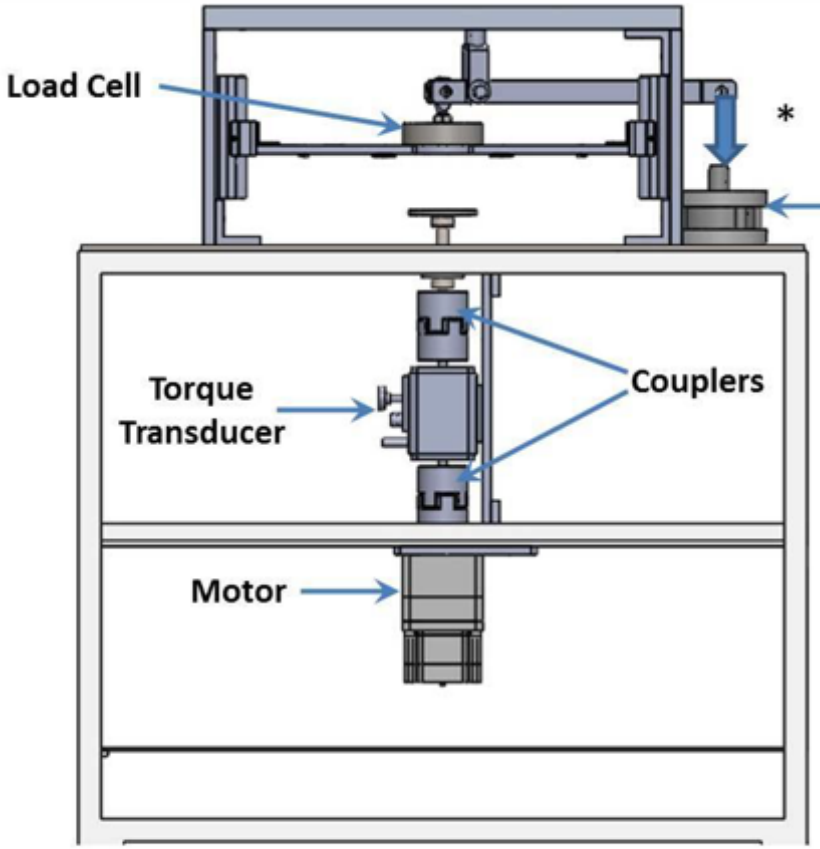
Scye Cross section



Waist Cross section



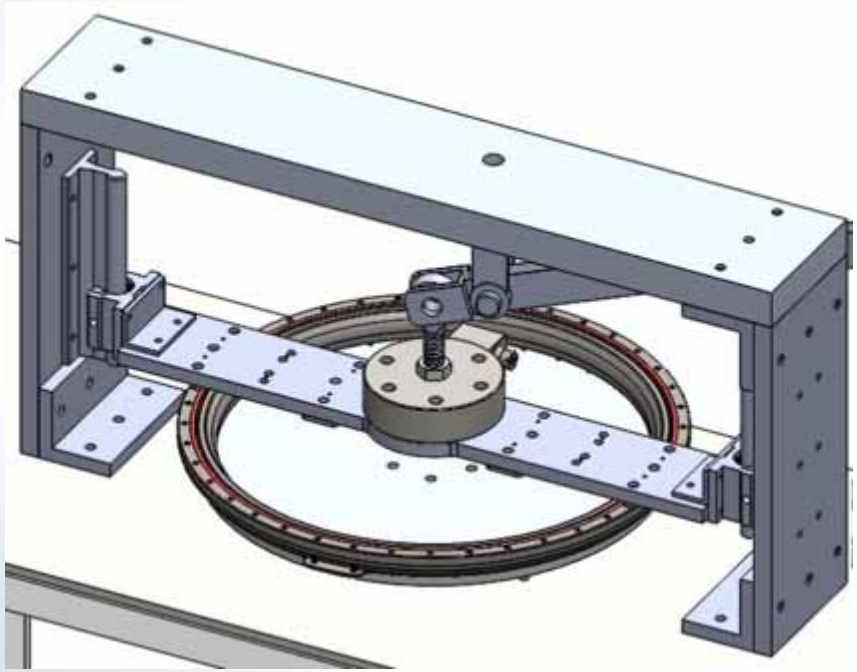
Test Hardware Description

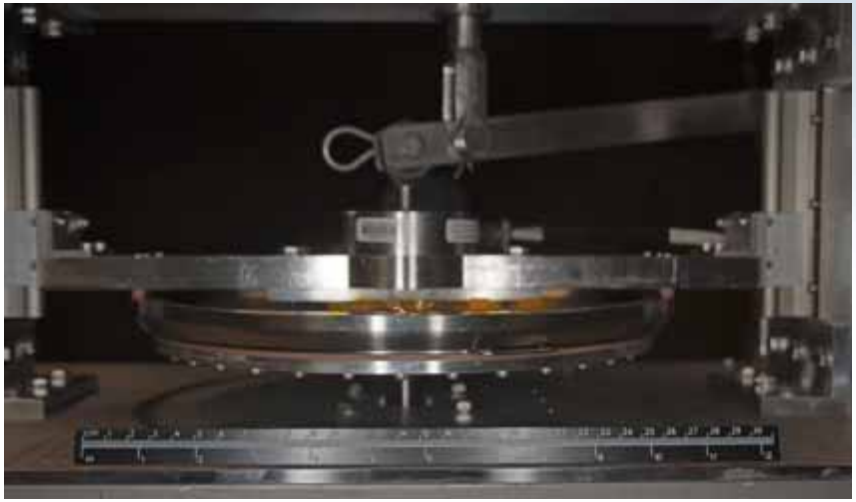


*Adjustable linkage between cylinder and pivot arm not shown

Test Hardware Description

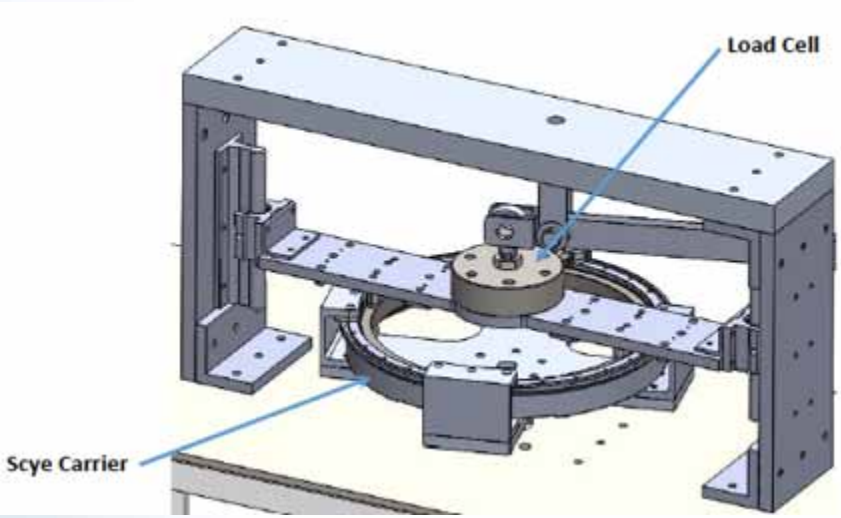
Hip Bearing Test Configuration

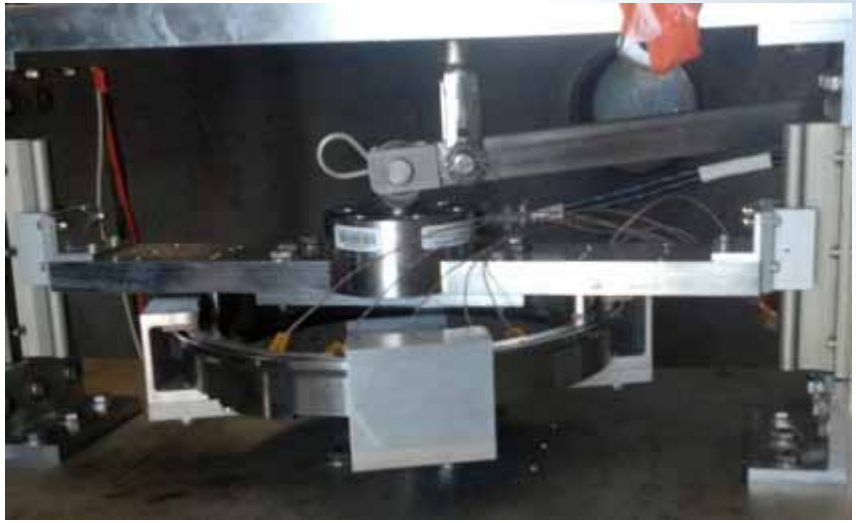




Test Hardware Description

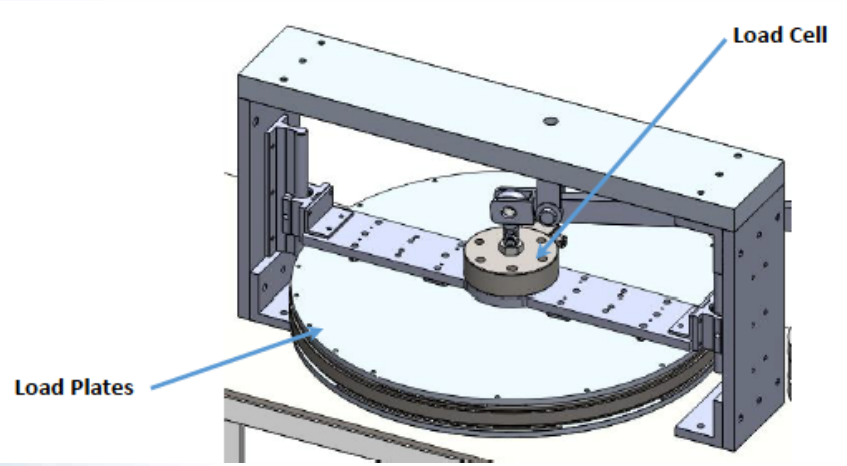
Scye Bearing Test Configuration





Test Hardware Description

Waist Bearing Test Configuration



Test Parameters

Table 1. Test Profiles

Test Article	Max Velocity (deg/s)	Max Arc (deg)	Cycles	Bearing Diameter (in.)	Bearing Diameter (mm)	Pressure (psia)	Pressure (kPa)	Media O_2	Load[a] (lb)	Load[a] (kg)
Hip	78	45	***96 h*** of 20/min - 1 h 40/min - 45 min 52/min - 30 min	11.74	298.19	12.4	85.5	+99%	1111	504
			Phase II: 30 min @ 52/min						1305	592
Scye	135	135	***96 h*** @ 20/h	9.21	233.93	12.4	85.5	+99%	720	326.6
			Phase II: 30 min @ 20/h						850.2	385.6
Waist	52	30	***96 h*** of 20/min - 1 h 40/min - 45 min 52/min - 30 min	15.53	394.46	12.4	85.5	+99%	1983	899.4
			Phase II: 30 min @ 52/min						2324	1054

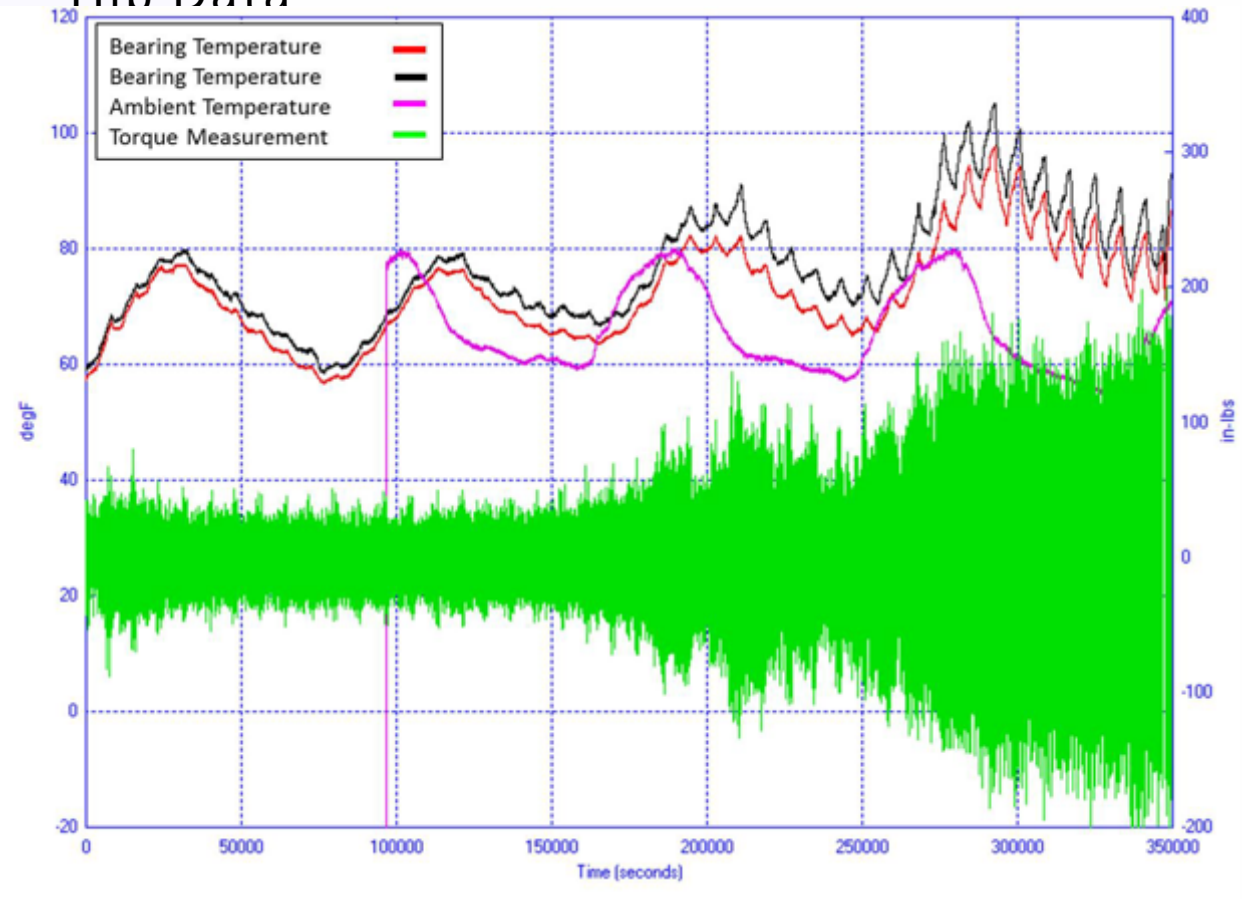
[a] Sum of plug loads @ 8.8 psia (60.7 kPa) and manned loads.

Results and Discussion

- Hip Bearing ”Failure”

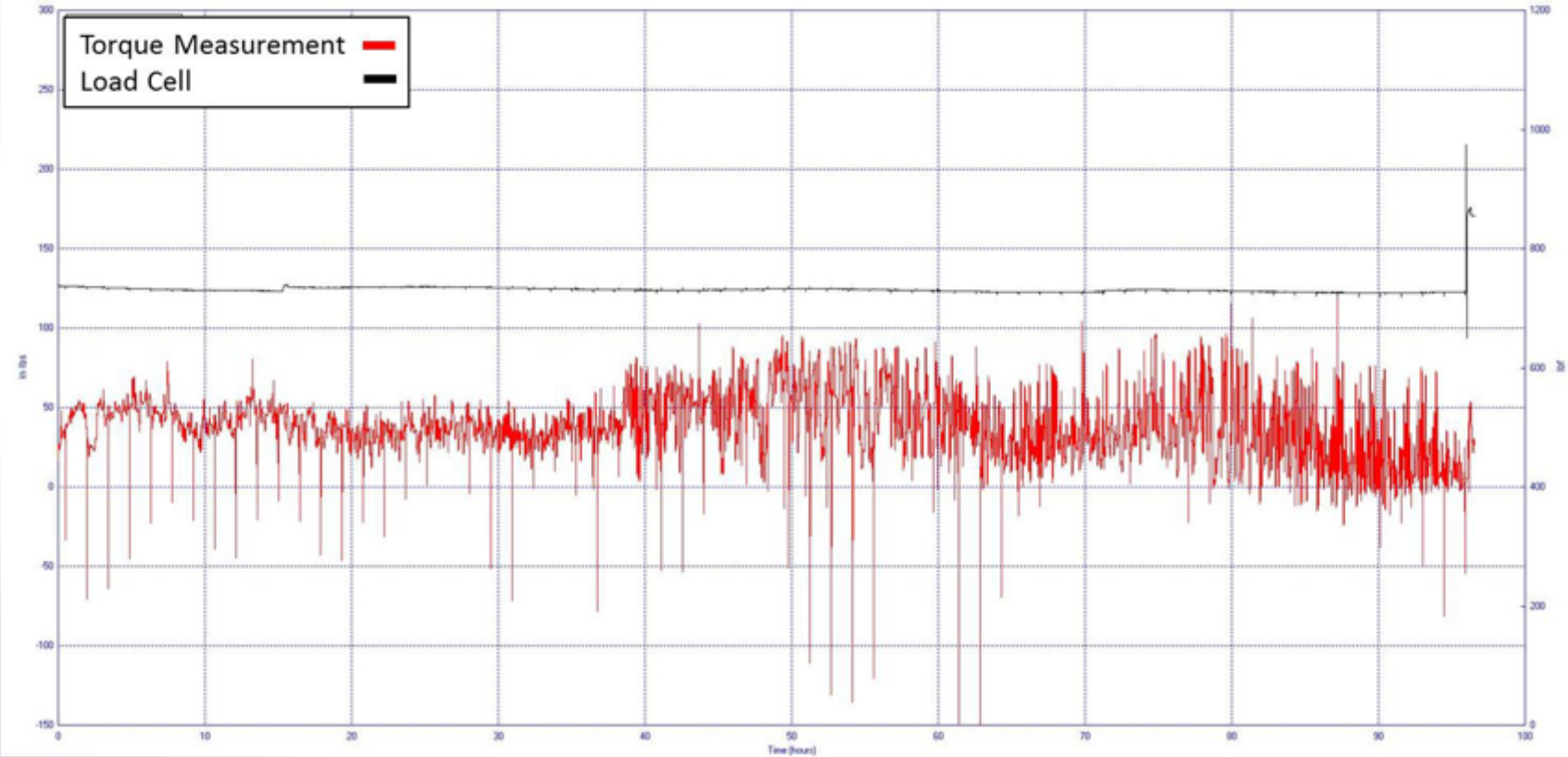
Results and Discussion

- Hip Data



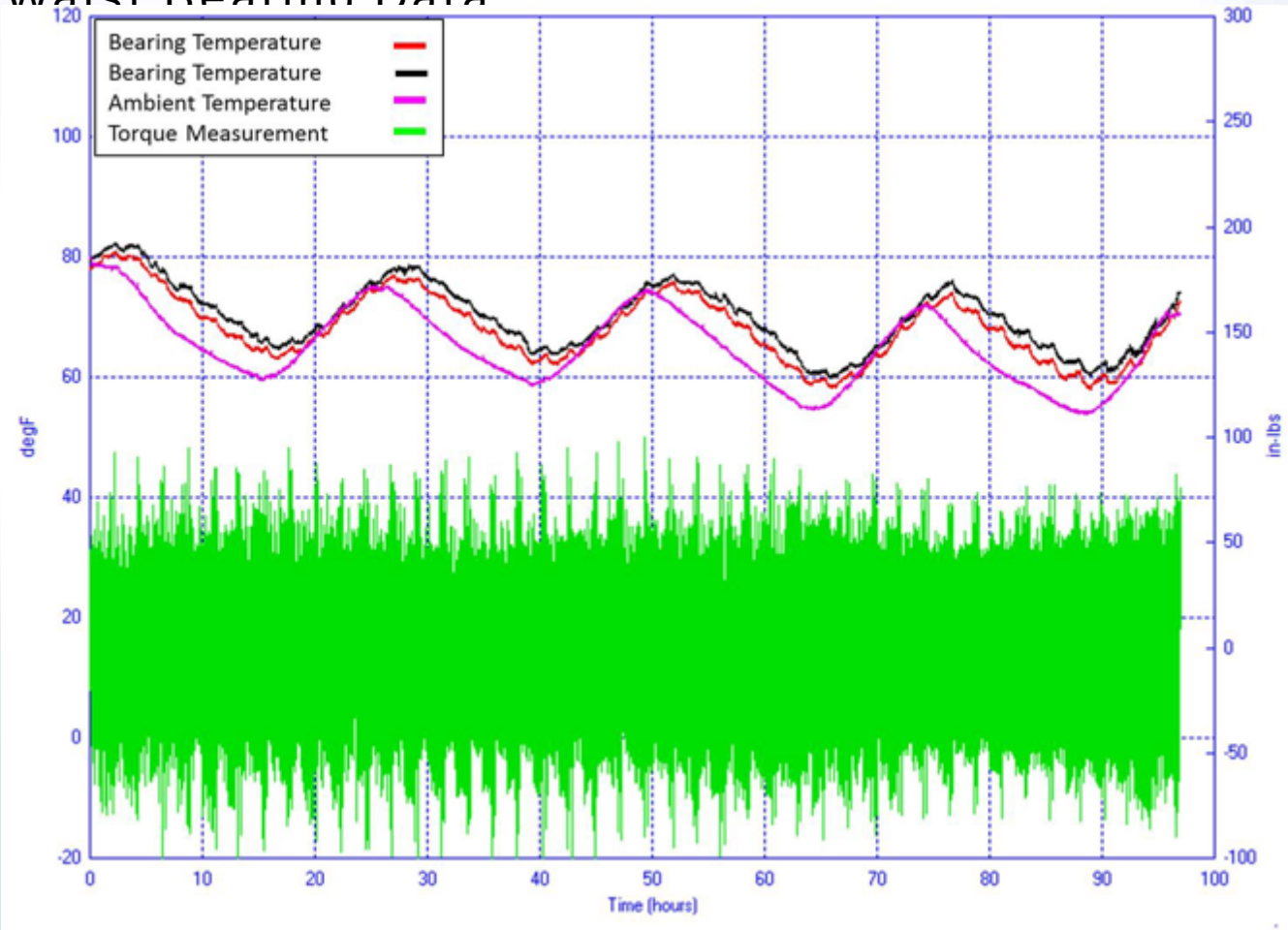
Results and Discussion

- Scye Bearing Data



Results and Discussion

- Waist Bearing Data



Results and Discussion

- Follow on Testing
  - Additional testing performed on a hip bearing assembly to further investigate the mechanical wear of the bearing witnessed and the effect of maintenance on the performance of the bearing.
  - After the massive amounts of wear and debris seen in the hip, it was suspected that the bearing lubricant was drying out and the buildup of worn ball bearing debris was then becoming a contributing factor to the overall bearing wear.
  - It is now believed that the ball bearing wear was more of a contact stress problem.

Conclusion

- Testing in 1990s showed titanium in the tested configuration was difficult to ignite - in extreme test conditions.
- A different bearing design and the understanding of how to safely use previously unacceptable materials (like titanium) has matured from 20 years ago.
  - This series more refined and more in line with the way the bearings would be used and or might fail.
- None of the bearings tested exhibited signs of ignition upon posttest bearing disassembly and inspection.
- The test results demonstrated that the use of titanium in this specific application is worth pursuing in further maturing the bearing and suit design.


THANK YOU