Prevailing Torque Locking Feature Wear-out

by

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A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Mechanical Engineering
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Date of Approval:
November 13, 2012

Keywords: Fastener, Locknut, Reuse Life, Seated, Preload

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Abstract

This thesis provides much needed representative sample data for reuse life of fully seated and torqued locknuts. Most national requirements for prevailing torque locking fasteners only specify unseated reuse life. This could create a potentially dangerous situation if unseated is misinterpreted for seated. This thesis provides comparative data for seated verses unseated configuration. Six aerospace, 3 all-metal and 3 nylon insert, and one non-aerospace locknuts were tested at preloads levels of unseated, 66%, 75%, and 85% of yield of bolt. The locknuts tested are MS21043-4, NAS1291-4, NAS1805-4, MS17825-4, MS21044D4, NAS1021N4, and Grade 8. A fixture was created in order to allow for the simultaneous data collection of the applied preload and torque, along with the removal of preload without loosening the locknut. The results from testing indicate the number of reuse cycles is greater for nylon locknuts than the all-metal locknuts. Large losses, on the order of 20-50%, in prevailing torque occur between the first and second cycle of each locknut under all preloads. Tightening Torque required to achieve a certain preload was found to increase with reuse. Application of lubrication to nylon locknuts had a significant effect, reducing the reuse life and prevailing torque performance. The testing indicated the effect of preload reduced the number of reuse cycles to failure, failure occurs when the prevailing torque is measured outside the range of 3.5 to 30 in-lb. All locknuts survived unseated and 66% Y preload testing,

except MS21043 which lasted about 14.5 reuse cycles at 66% Y and NAS1805 which survived 8 reuse cycles for unseated and 12.67 reuse cycles at 66% Y. NAS1805's loss of reuse life is due to hardness and material compatibility issues. The scatter of the torque measurements was low for the first three to five cycles, then as the coatings and lubrications are worn the scatter increases. The data collected from testing agrees with the torque friction equation.

1 Introduction and Overview

Prevailing torque locking features are commonly used with threaded fasteners in a variety of applications. A common use of this locking feature is in locknuts, in the form of distorted threads, tapered profiles, or nylon inserts. Locking features can also be integrated into bolts, screws, and inserts. Once the locking feature is engaged these types of fasteners require application of a torque, known as prevailing torque, until seated; standard threaded fasteners lack this feature, requiring no torque and spin freely until seated. A locknut is seated when the nut face is engaged with the clamped component's surface, i.e. washer or fixture. Unseated is defined when the nut face does not engage or touch the clamped component's surface. Full definitions for terms are provided in Appendix J.

Many industries require use of prevailing torque locking fasteners, particularly the aerospace industry. The aerospace industry has three principal reasons for using prevailing torque locking fasteners. Most notably these types of devises offer a directly verifiable and measureable torque during assembly. Another important characteristic is the all-metal varieties of locking features are usable in high temperature applications. Thirdly, there is significantly less labor involved with installing these fasteners than required for installing mechanical locking hardware such as lock wire and cotter pins. Experience has shown these locking features have the following characteristics: In severe vibration and shock environments, the main feature of prevailing torque locking devises is to prevent complete separation and loss of fasteners (i.e., provide foreign object debris protection), not to maintain preload.

Most qualification standards specify acceptable prevailing torque ranges for prevailing torque locking fasteners for unseated life. However, a seated fastener will undergo additional loading stresses and will experience additional wear and plastic deformation. Within industry applications, specifically aerospace, prevailing torque fasteners are typically seated. Since the qualification standards for these fasteners lack seated life requirements or poses limited seated requirements, it is unclear how the devises behave under preload because there is no described seated life. This thesis' purpose is to provide much needed data for the seated behavior of prevailing torque locking features.

1.1 Background

As mentioned previously, most current qualification standards only provide unseated and limited seated requirements or do not specify any required seated life specifications. The standard NASM25027 [1] specifies unseated reuse life requirements of fifteen cycles within the range of 3.5 to 30 in-lb prevailing torque and has no seated life requirements. Standard NAS3350 [2] only requires the first cycle to be seated with the remaining fourteen reuse cycles unseated with prevailing torque range of 3.5 to 30 in-lb. This leaves the industry with a potentially dangerous issue of misinterpreting the unseated life as seated life. Numerous company policies do not allow reuse of prevailing torque locking fasteners, while in other cases some reuse is permitted. With little data on seated life, the performance of these devises with reuse is unknown. Very little published material exists relating to locking feature wear-out.

There is limited scattered data on the seated life of prevailing torque locking features. A 1978 study by Light and Strange [8] performed static and vibration reuse tests to determine the reuse characteristics of nine fastener systems, three being locknuts. The vibration testing subjected torque tightened fasteners in a Junker transverse vibration test machine and vibrated them for 1000 cycles at 12.5 Hz. The testing found Simonds locknut PA 108 (M6 annular nylon element, showed no apparent trend with five reuses) gradual degradation of the locking feature with fifteen reuses, and the prevailing torque was non-existent by the ninth reuse. Simonds locknut PH 135M (M6 all-metal with elliptically deformed upper threads) static retightening caused an increase in friction and degradation occurs within the first five reuses. The BS A125/66 locknut (0.25" UNF all-metal with deformed upper threads) reuse had no predominant effect on torque-tension. This thesis differs with the study by Light and Strange with respect to different preload levels and comparison of unseated and seated testing.

The standard IFI 100/107 [10] rates prevailing torque performance by classifying locknuts as Grades A, B, C, F, and G. Grades A, B, and C are steel hex nuts sized No. 4 to 1.5 inches, and Grades F and G are steel hex flange nuts sized 0.25 to 0.75 inches. The proof load stress for Grade A is 90,000 psi. Proof load stress for No. 4 to 1 in Grade B locknut is 120,000 psi, while over 1in to 1.5 in is 105,000 psi. Both Grades C and G have proof load stresses of 150,000 psi, and Grade F has a proof load stress of 120,000 psi. Along with the prevailing torque the torque tension capability is also set forth by the standard. This standard is one of two, the other MIL-DTL-18240F [6], referenced standards with more than a single seated cycle requirement. For the prevailing torque test, a 0.25" – 28 UNF locknut must perform a torque measurement of less than 30 in-lb for the first install. The locknut is then seated and tightened to a preload matching the clamp load of 2300 lb. For the first removal the minimum torque shall not be less than 5.0 in-lb. The fifth removal with the minimum torque of 1.5 in-lb. In the definition, the standard claims that for most locknuts the Breakloose Torque is greater than the Tightening Torque.

Bickford [9] describes a torque friction equation used to relate the torque applied to a nut to friction and elastic reactions to that torque.

$$T_{on} = F_p \left(\frac{P}{2\pi} + \frac{\mu_t r_t}{cos\beta} + \mu_n r_n \right) + T_p \qquad \text{Equation 1.1}$$

The result of the equation provides that 50% of the torque is due to thread friction, 40% from other frictions, and 10% from bolt stretch. The testing performed adds support to this equation. This is explored further in section 4.7.

The purpose of this thesis is to add to the literature and data of prevailing torque locking feature wear-out by: publishing data, the collection of torque and preload data concurrently, wear-out as a function of seated reuse cycles, wear-out as a function of preload, testing and comparing a variety of locknuts primarily aerospace and one non-aerospace.

The lack of published data is being filled by testing the reuse of a variety of locknuts for publication of the results for use by industry. Figure 1-1 shows a sketched aid of the torque verses relative turn between the locknut and bolt. It provides points where torque measurements are recorded and describes the phases of one reuse cycle. The collecting of torque and preload data concurrently is achieved by use of a special test fixture, which allows for the application of preload to the locknut then for the removal of the preload without loosening the locknut. Wear-out as a function of seated reuse cycles is performed by testing each locknut up to 15 cycles or failure while being seated. Two different trial types are performed; one where the preload is removed from the locknut without loosening the locknut, and the other where the preload is removed by loosening the locknut. Wear-out as a function of preload is performed by testing each locknut with

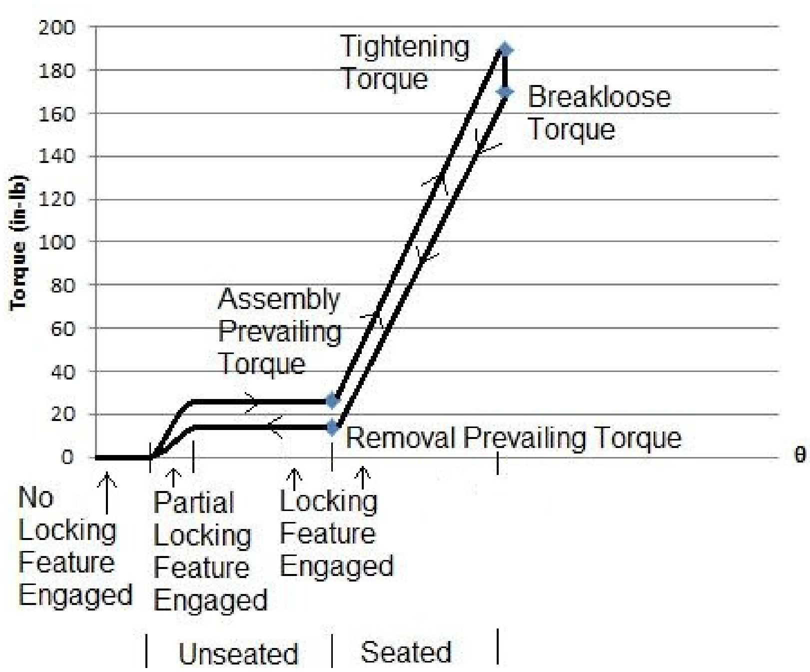

Figure 1-1: Example of Torque vs. Relative Turn between Nut and Bolt; 66% Y

preloads of 66%, 75%, and 85% of bolt yield. Seven different locknuts are tested, including six aerospace grade locknuts, three being all-metal and three nylon insert, and one non-aerospace grade locknut. The aerospace locknuts tested are: MS21043-4, NAS1291-4, NAS1805-4, MS17825-4, MS21044D4, and NAS1021N4. The non-aerospace locknut tested is a standard Grade 8 nylon insert locknut. Between each reuse cycle the locknut is completely removed from the test bolt.

1.2 Outline

This paper is divided into six chapters plus an appendix. The next chapter covers the testing fixture, tools used, locknut specimens, bolts, washers, and the test plan. In this thesis the locknuts are listed and described in the order of the six aerospace locknuts first, then followed by the non-aerospace locknut. The six aerospace locknuts' order will be the three all-metal first followed by the three nylon inset locknuts. The order of the locknuts is: MS21043-4, NAS1291-4, NAS1805-4, MS17825-4, MS21044D4, NAS1021N4, and Grade 8. Chapter 3 contains the graphed data of the locknut testing performed for all seven locknuts. The graphs include plots of Assembly and Removal Prevailing Torques, Tightening and Breakloose Torques, the percent difference between the assembly and removal prevailing torque of a given cycle, and the life of the locknut. The data plots are then analyzed and discussed in Chapter 4, describing trends, irregularities, and other points of interest. After the data is analyzed conclusions are drawn from the testing and analysis, these conclusions are described in Chapter 5. The final chapter provides the references used in this thesis. In the appendix, additional information is provided that supplements the main body of the thesis.

2 Testing

This chapter describes the testing and data acquisition for this paper. Topics include the testing fixture, tools used, locknut specimens, bolts, washers, and finally the test plan.

2.1 Fixture

The testing fixture is a three tiered steel assembly, with the top plate able to be lowered by three grade 5 bolts and a load cell between the middle and bottom plate. The fixture is designed with two principal purposes in mind. The first was to allow for the removal of the preload from the locknut without loosening the locknut. The second motive was to enable the measuring of the preload and torque on the locknut simultaneously.

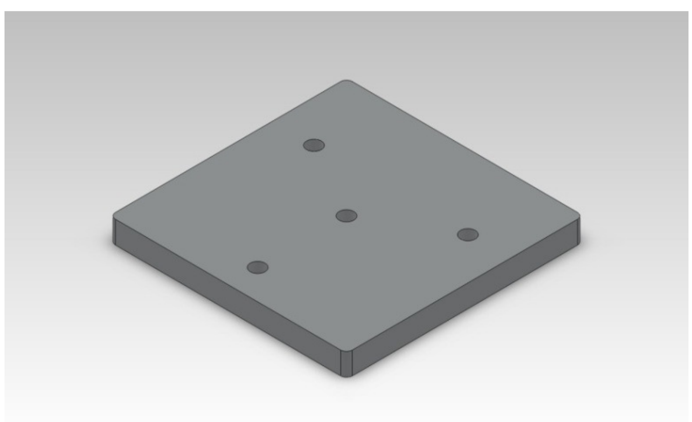

Figure 2-1: Top Plate

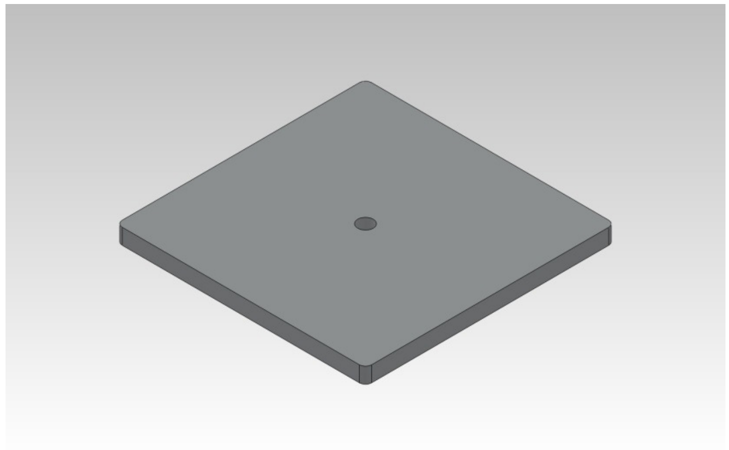

Figure 2-2: Middle Plate

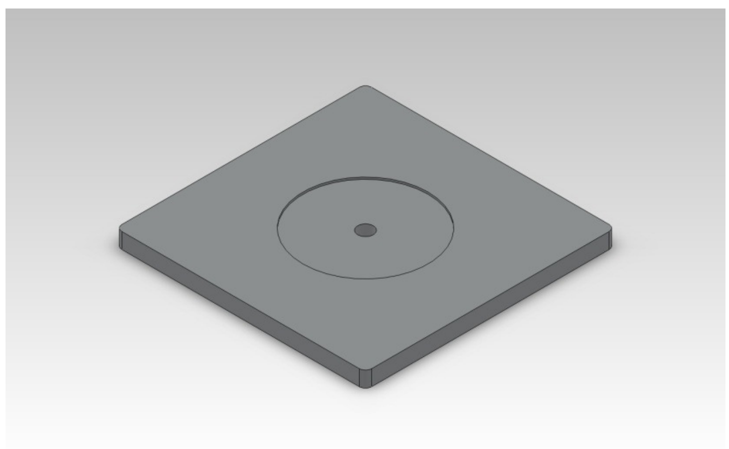

Figure 2-3: Bottom Plate

The material the fixture plates are manufactured from is alloy steel. Each plate is square with 4.0 inch sides. The top plate has a depth of 0.38 inches while the middle and lower plates are 0.25 inches thick. The plates' dimensions are designed with the use of Solidworks to allow the fixture to withstand a preload of 5000lb with less than 0.005 inches of deflection. Each of the three plates has a through hole with a diameter of 0.25 inches at its center point. The top plate has three 0.25" – 28 UNF tapped holes

120° apart and 1.5 inches from the center point. The bottom plate has a counterbore of 0.031 inches depth and 2 inches diameter, this is to keep a load cell centered in the fixture.

The plates are assembled in a specific manner in order for the fixture to operate properly. The bottom plate is firmly secured in a 5.5 inch jaw bench vise. On top of the bottom plate sits a 5000lb capacity 2in diameter donut style load cell, connected with display, within the counterbore circular hole. The load cell was manufactured by Sensotec (model D/7074-06), and its display also from Sensotec (serial number 557260).

The middle plate is positioned on top of the load cell. Three 0.25" x 1.25" – 28 Grade 5 bolts are inserted into the threaded holes in the top plate. Then the top plate is placed on the middle plate with the bolt heads up. Once the plates are stacked in the correct orientation, align the center 0.25" hole in the center of each plate with each of the others. When the holes are aligned, the test bolt can be inserted with a washer and the test specimen locknut can then be secured to the test bolt. Figures 4 through 6 show the fixture assembly, for dimensioned drawings of the plates and fixture see Appendix B.

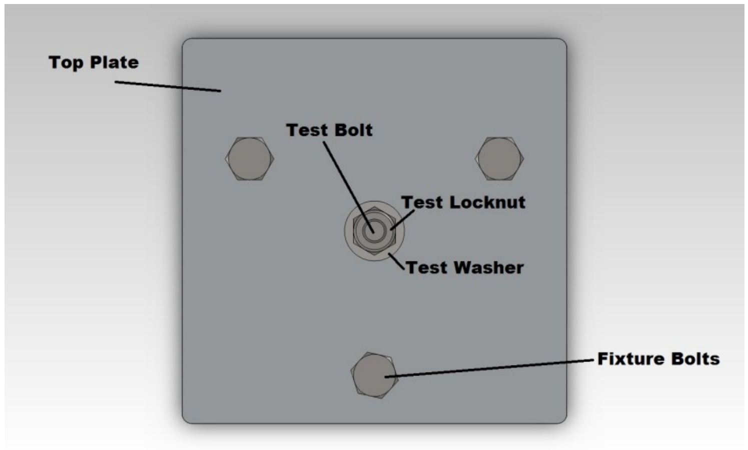

Figure 2-4: Fixture Top View

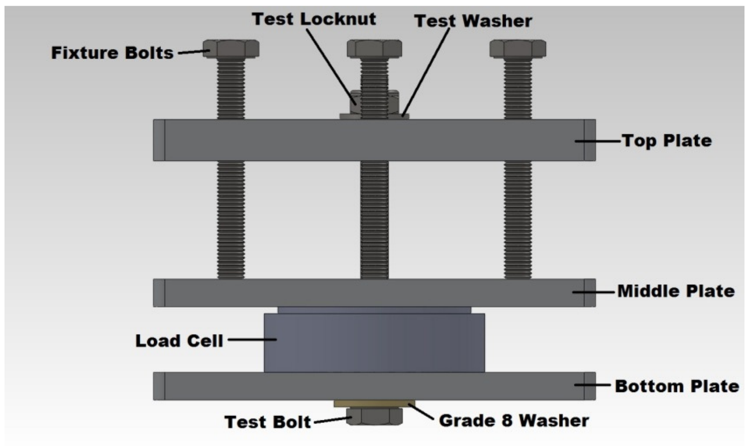

Figure 2-5: Fixture Side View

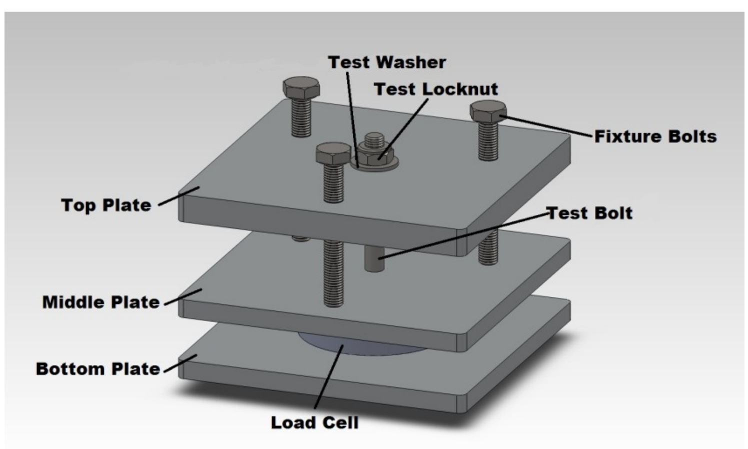

Figure 2-6: Fixture Dimetric View

2.2 Wrenches and Sockets

Testing the locknuts required the used a quantity of five separate torque wrenches, a single box/open wrench, and six sockets.

2.2.1 Torque Wrenches

Table 2-1: Torque Wrenches

Manufacturer	Model	Torque Range (in-lb)	Increment Scale (in-lb)	Accuracy*	Drive Size (in)
Snap-on	TQS1FUA	0 – 12	0.25	±2%	$^1/_4$
Proto	J6168F	0 – 30	0.5	±4%	$^1/_4$
Proto	6169A	0 – 75	1.0	±3%	$^1/_4$
Proto	6177A	0 – 250	5.0	±3%	$^3/_8$
Proto	6181A	0 – 600	10.0	±3%	$^3/_8$

*of the reading from 20% of full scale to 100% full scale clockwise and counterclockwise

The torque wrenches used varied in torque range, accuracy, and drive size. Table 1 contains information of the torque wrenches used. In further detail the Model 6169A, renamed J6169F, manufactured by Stanley Proto Industrial Tools exhibits a range of 0 – 75 in-lb with measurement increments of 1.0 in-lb. The accuracy of the measured torque values are ±3% of the torque reading CW/CCW at 20% of full scale to 100% of full scale. This torque wrench has a drive size of $^1/_4$ inch.

2.2.2 Hand Wrench

Only one hand wrench was used in the process of testing. The wrench was a $^7/_{16}$ inch Craftsman box/open wrench.

2.2.3 *Sockets*

Due to the different sizes of the locknut heads, bolt heads, and locknut head shape; several different sockets were required to perform the testing. The sockets used are:

- $^5/_{16}$" 6-Point with a $^3/_8$" drive
- $^5/_{16}$" 6-Point with a $^1/_4$" drive
- $^7/_{16}$" 6-Point with a $^3/_8$" drive
- $^7/_{16}$" 6-Point with a $^1/_4$" drive
- $^5/_{16}$" 12-Point with a $^3/_8$" drive
- $^5/_{16}$" 12-Point with a $^1/_4$" drive

2.3 Locknut Specimens

Seven different locknuts, chosen for representing different materials and locking feature types, are utilized in the testing, six of which are aerospace grade with the remaining being grade 8. In Table 2-2 each locknut tested is described, for further information of the locknuts see Appendix A and Manufacturers' Certifications in Appendix H. Specifications common to the aerospace locknuts are: thread size 0.25 inches, thread pitch 28 – UNJ, maximum torque value 30 in-lb, and minimum torque value 3.5 in-lb. Grade 8 locknut specifications are thread size 0.25 inches, thread pitch 28 – UNF, maximum torque 40 in-lb, and minimum torque value 5.0 in-lb. Each tested as received.

Table 2-2: Locknut Information

Locknut	Locknut Material	Locking Feature	Coating or Plating	Lubrication	Applicable Standards
MS21043	AMS 5731-L Steel	All-Metal Distorted Thread	AMS 2410 Silver	Dry Film	NASM25027
NAS1291	QQ-P-416C Steel	All-Metal Distorted Thread	Cadmium	Dry Film	NASM25027
NAS1805	A-286 Steel	All-Metal Distorted Elliptical Thread	AMS 2700 Type 2 Rev. C Passivate	Solid Film	NAS3350
MS17825	1137 Steel	Nylon	Cadmium and Yellow Chromate	None	NASM25027; ASTM D4066-94B
MS21044	2024 T4 Aluminum	Nylon	Anodized and Blue Dye	None	NASM25027; ASTM D4066-94B
NAS1021	AMS 5040 Steel	Nylon	Cadmium	None	NASM25027; ASTM D4006-00
Grade 8	Steel	Nylon	Plain Finish	Naphthenic Oil	IFI 100/107

2.4 Bolt Specimens

Two bolts are used for testing. One aerospace grade, NAS1004, and the other grade 8. Both are 0.25 – 28, with the thread type for NAS1004 UNJ and the grade 8 UNF. Neither bolt has lubrication and both are cleaned with MEK. MEK is an industrial solvent. The test bolt are completely submerged and cleaned for 15 minutes in an ultrasonic cleaner.

Table 2-3: Bolt Information

Bolt	NAS1004-29A	Grade 8
Bolt Length (in)	2.356	2.0
Thread Length (in)	0.541	0.75
Material	A-286 Steel	Alloy Steel
Coating/Plating	QQP35C Passivate	Yellow Zinc
Applicable Standards	AS7477 A	SAE J429 and ASME B18.2.1
0.2% Yield Strength (psi)	100,000	130,000
Tensile Stress Area (in^2)	0.0364	0.0364
100% Y Preload (lb)*	3640	4730
66% Y Preload (lb)*	2400	3120
75% Y Preload (lb)*	2730	3550
85% Y Preload (lb)*	3100	4020

* Preload calculations in Appendix F

2.5 Washer Specifications

Two washers are used in testing. One washer is aerospace grade, NAS1149, and the other is grade 8. Both washers have a nominal diameter of 0.25 inches and have no lubrication applied. The washers are tested as received without cleaning.

Table 2-4: Washer Information

Washer	NAS1149C0463R	Grade 8
Outer Diameter (in)	0.50	0.75
Inner Diameter (in)	0.265	0.31
Thickness (in)	0.063	0.051 – 0.080
Material	CRES	Through Hardened Steel
Coating/Plating	QQ-P-35	Yellow Zinc
Applicable Standards	MIL-S-5059 and UNSPSC 31161807	ASME/ASNI B 18.22 and ASTM F436

2.6 Test Plan

Below is a condensed form of the test plan. The full test plan is very detailed and provided in Appendix G. Between each reuse cycle the locknut is completely removed from the test bolt.

2.6.1 Test Plan – Condensed

I Prepare bench vise

- I.1 Separate jaws by 4 inches

II Unseated Testing

- II.1 Collect one test bolt, one locknuts, two washers, and wrenches
- II.2 Clean test bolt with MEK in ultra-sonic cleaner for 15 minutes
- II.3 Install test bolt into fixture from bottom plate with grade 8 washer
- II.4 Apply lubricant to locknut

II.4.1 Grade 8 apply 3-IN-ONE (Naphthenic Oil)

II.4.2 Other locknuts no lubricant

II.5 Measure and record Assembly Prevailing Torque

II.5.1 Locking feature is fully engaged when two of the test bolt's threads are visible

II.5.2 Measured from the average of one full revolution

II.6 Measure and record Removal Prevailing Torque

II.6.1 Measured from the average of one full revolution

II.7 Measure and record Assembly Prevailing Verification Torque

II.7.1 Turn locknut in tightening direction

II.8 Remove locknut from test bolt

II.9 Clean any debris from locknut and bolt with compressed air

II.10 Repeat for 15 cycles or 2 cycles after locking feature failure

II.11 Failure occurs when Prevailing Torque is measured below 3.5 in-lb, above 30 in-lb, locknut 6/12-point damage to prevent tightening of locknut, or bolt fails

III Prepare fixture

III.1 Place bottom plate in bench vise with counterbore facing up

III.2 Place load cell in counterbore; connect to display

III.3 Place middle plate on load cell; align center holes

III.4 Install three grade 5 bolts into perimeter holes of top plate

III.4.1 Install fixture bolts with maximum length below plate

III.5 Place the ends of the top plate's fixture bolts on middle plate; align center holes

IV Trial 1 Testing (Half Cycle)

IV.1 Collect test bolts, locknuts, washers, and wrenches

IV.2 Clean test bolt with MEK in ultra-sonic cleaner for 15 minutes

IV.3 Install test bolt into fixture from bottom plate with grade 8 washer

IV.4 Apply lubricant to locknut

IV.4.1 Grade 8 apply 3-IN-ONE, (Naphthenic Oil)

IV.4.2 Other locknuts no lubricant

IV.5 Place washer and locknut on test bolt protruding threads from top plate

IV.6 Measure and record Assembly Prevailing Torque

IV.6.1 Locking feature is fully engaged when two of the test bolt's threads are visible

IV.6.2 Measured from the average of one full revolution

IV.7 Tighten locknut to 66% Y preload and hold for 5 seconds

IV.7.1 Hold bolt head while turning locknut with torque wrench

IV.8 Record tightening torque needed to achieve preload

IV.9 Lower top plate of fixture to remove preload

IV.9.1 Turn the three fixture bolts counter clockwise

IV.10 Measure and record Removal Prevailing Torque

IV.10.1 Measured from the average of one full revolution

IV.11 Measure and record Assembly Prevailing Verification Torque

IV.11.1 Turn locknut in tightening direction

IV.12 Remove locknut from test bolt

IV.13 Clean any debris from locknut and bolt with compressed air

IV.14 Repeat for 15 cycles or 2 cycles after locking feature failure

IV.14.1 Failure occurs when Prevailing Torque is measured below 3.5 in-lb, above 30 in-lbs, locknut 6/12-point damage to prevent tightening of locknut, or bolt fails

V Trial 2 Testing (Full Cycle)

V.1 Collect new test bolts, locknuts, washers, and wrenches

V.2 Clean test bolt with MEK in ultra-sonic cleaner for 15 minutes

V.3 Install test bolt into fixture from bottom plate with grade 8 washer

V.4 Apply lubricant to locknut

V.4.1 Grade 8 apply 3-IN-ONE, (Naphthenic Oil)

V.4.2 Other locknuts apply no lubricant

V.5 Place washer and locknut on test bolt protruding threads from top plate

V.6 Measure and record Assembly Prevailing Torque

V.6.1 Locking feature is fully engaged when two of the test bolt's threads are visible

V.6.2 Measured from the average of one full revolution

V.7 Tighten locknut to 66% Y preload and hold for 5 seconds

V.7.1 Hold bolt head while turning locknut with torque wrench

V.8 Record tightening torque needed to achieve preload

V.9 Do not lower top plate of fixture to remove preload

V.10 Record Breakloose Torque

V.10.1 Hold bolt head while turning locknut counter clockwise with torque wrench

V.10.2 Loosen locknut until preload is fully removed

V.11 Measure and record Removal Prevailing Torque

V.11.1 Measured from the average of one full revolution

V.12 Remove locknut from test bolt

V.13 Clean any debris from locknut and bolt with compressed air

V.14 Repeat for 15 cycles or 2 cycles after locking feature failure

V.14.1 Failure occurs when Prevailing Torque is measured below 3.5 in-lb, above 30 in-lbs, locknut 6/12-point damage to prevent tightening of locknut, or bolt fails

VI Repeat Step V for Trial 3 Testing (Full Cycle) with new fastener specimens

VII Repeat Step V for Trial 4 Testing (Full Cycle) with new fastener specimens

VIII Repeat Steps II through V for preloads of 75% Y and 85% Y

IX Repeat Steps II through VIII for all locknuts

3 Data

3.1 Overview

This chapter introduces the data collected during testing in graphical format. As the raw data collected are tables full of individual data points and are difficult to perceive trends from, plots were generated from this data. The raw data in table format is provided in Appendix C. The values plotted are Assembly Prevailing Torque, Removal Prevailing Torque, Tightening Torque, Breakloose Torque, Percent Difference, Life Cycle, and Percent Decrease.

Assembly Prevailing Torque is the torque required to affect rotation in the forward or tightening direction to run the nut down a thread after the locking feature is fully engaged(after the bolt's threads can be seen protruding above the locknut). Removal Prevailing Torque is just like the Assembly Prevailing only in the reverse or loosening direction and up a thread. Tightening Torque is the torque required to affect the forward rotation needed to achieve the desired preload. Breakloose Torque is the torque required to affect reverse rotation when a preloaded threaded assembly is initially loosened. Percent Difference is the percentage difference between the Assembly Prevailing and Removal Prevailing torques during a respective cycle. Reuse Life Cycle is the number of cycles a locknut survived testing. The life plotted in the graphs includes failures of the locking feature, bolt failure, and damage to the 6/12-

point of the locknut preventing further testing. The raw data tables in Appendix C will describe which failure occurred. Percent Decrease is the percentage loss of the Assembly Prevailing Torque between Cycles 1 and 2.

Seven different prevailing torque locknuts are tested with six being aerospace grade and one non-aerospace grade. In order to make the presentation of data more manageable the data is presented in five main sections of combined plots. The sections are: 3.2 All-Metal Locknuts, 3.3 Nylon Locknuts, 3.4 Locknut Comparison, 3.5 MS21044D4 Lubrication Comparison, and 3.6 NAS1021N4 Lubrication Comparison. Individual plots for each locknut are provided in Appendix D. Each of these main sections is further separated into minor sections based on the preload the locknuts were subjected to; 3.#.1 Unseated, 3.#.2 66% Y Preload, 3.#.3 75% Y Preload, 3.#.4 85% Y Preload, and 3.#.5 Averaged Preload Comparison. Each locknut's plotted preload is the averaged data from Trials 2, 3, and 4 of their respective locknut. To view the standard deviations and ranges of measurements for the averaged data see Appendix E. Four trials with new fastener specimens for each trial at each preload were sampled. With a 95% confidence interval with the standard deviation values calculated from the tests performed, the sample size is reasonable for the testing; from a desired confidence interval and a known width, i.e. standard deviation.

3.2 All-Metal Locknuts

This section presents the plotted data for the three all-metal type locknuts. The all-metal type locknuts are MS21043-4, NAS1291-4, and NAS1805-4. Each point in the plots represents the average of trials 2, 3, and 4 of each preload test. Standard deviation calculations and spreads are provided in Appendix E.

3.2.1 Unseated

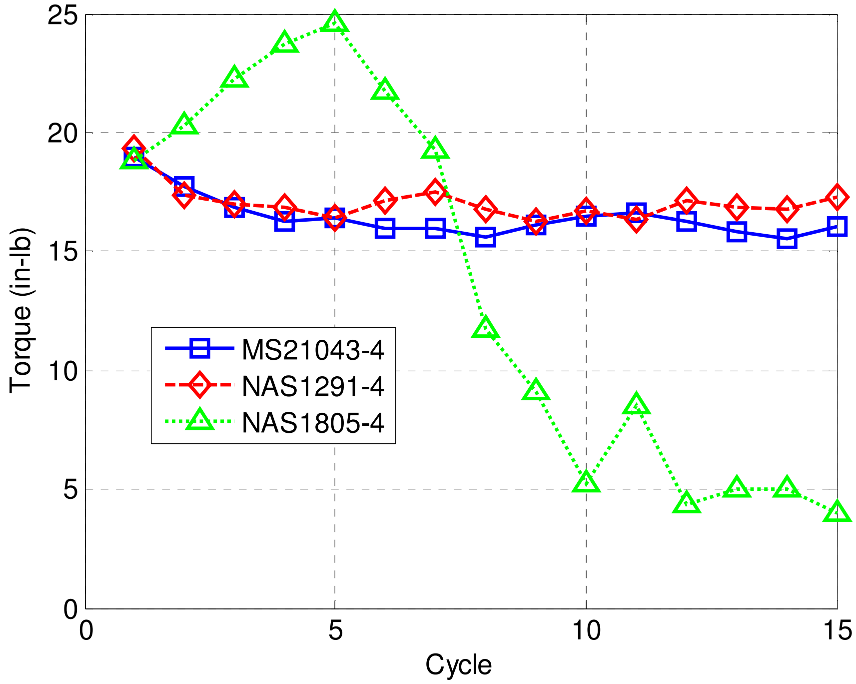

Figure 3-1: All-Metal Assembly Prevailing Torque; Unseated

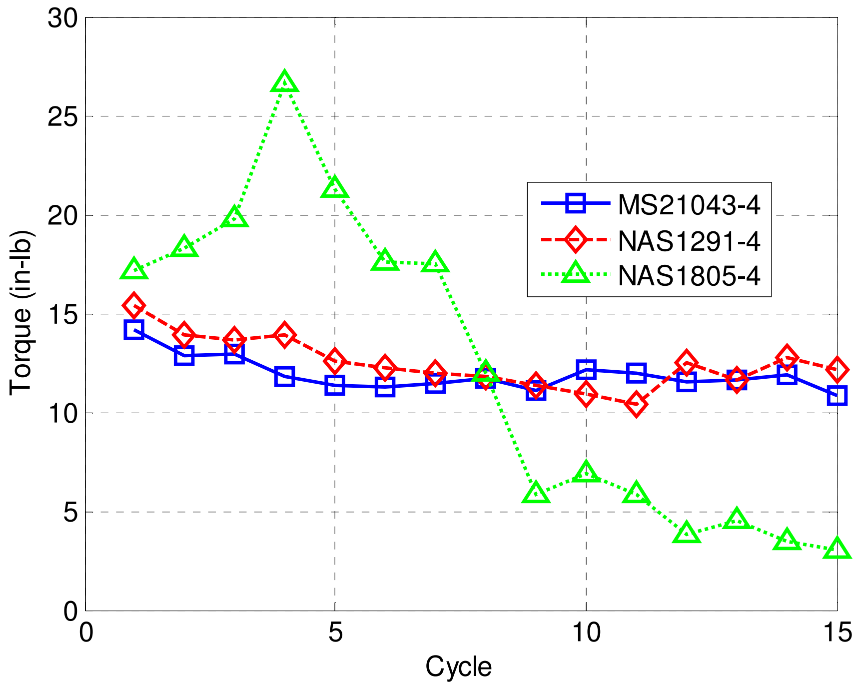

Figure 3-2: All-Metal Removal Prevailing Torque; Unseated

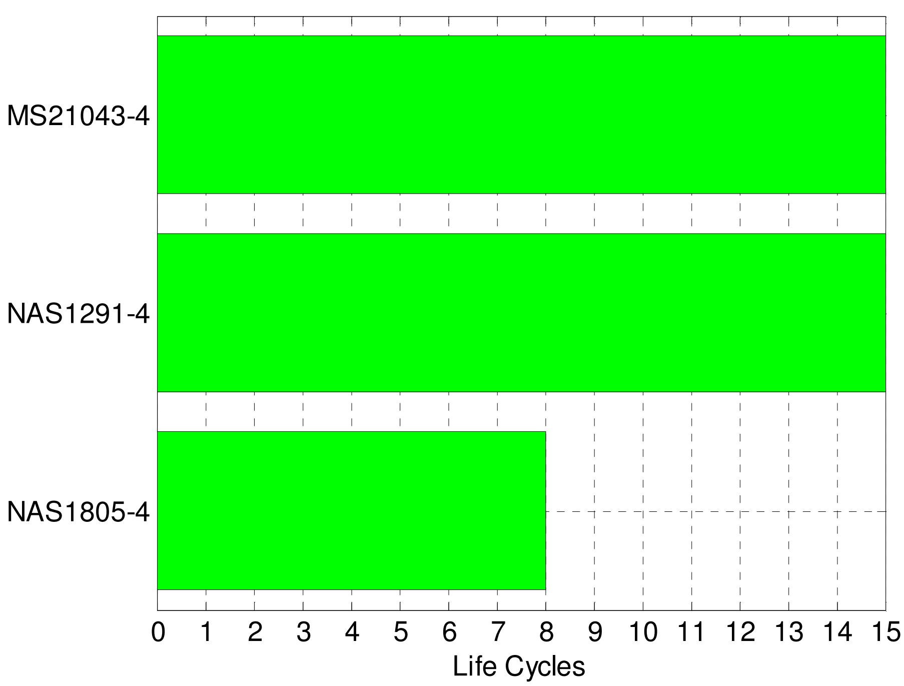

Figure 3-3: All-Metal Life; Unseated

3.2.2 66% Y Preload

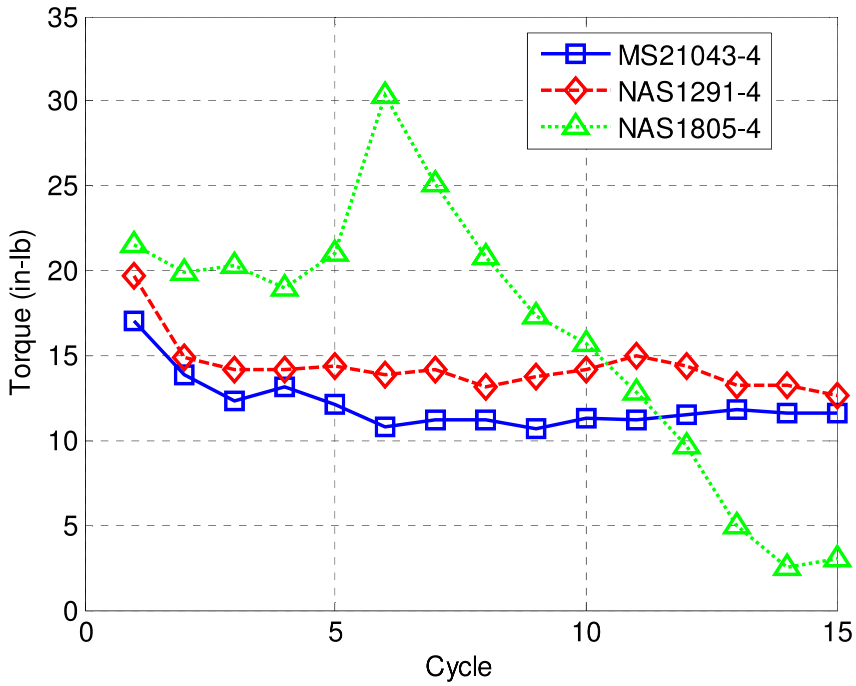

Figure 3-4: All-Metal Assembly Prevailing Torque; 66% Y Preload

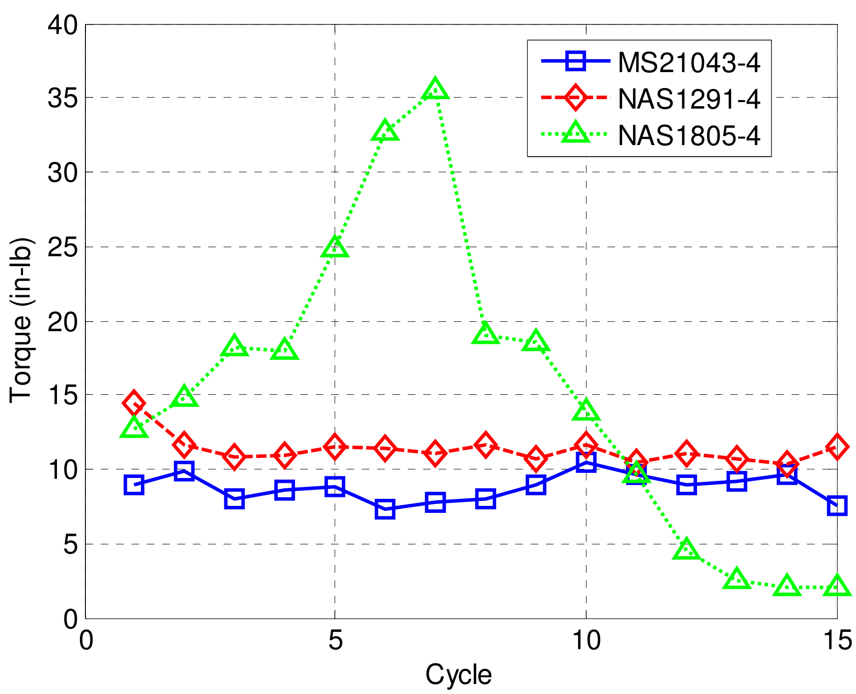

Figure 3-5: All-Metal Removal Prevailing Torque; 66% Y Preload

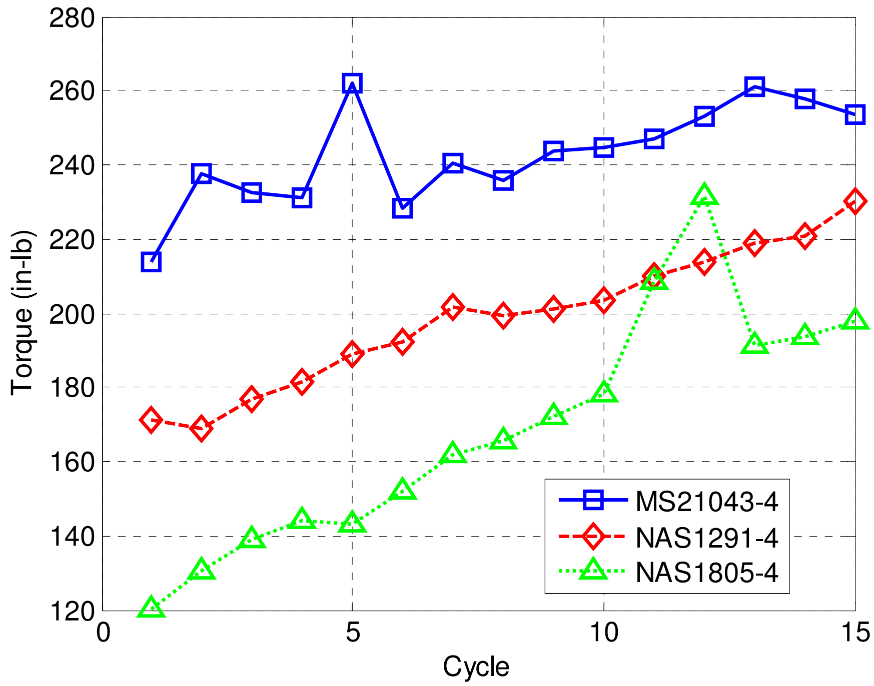

Figure 3-6: All-Metal Tightening Torque; 66% Y Preload

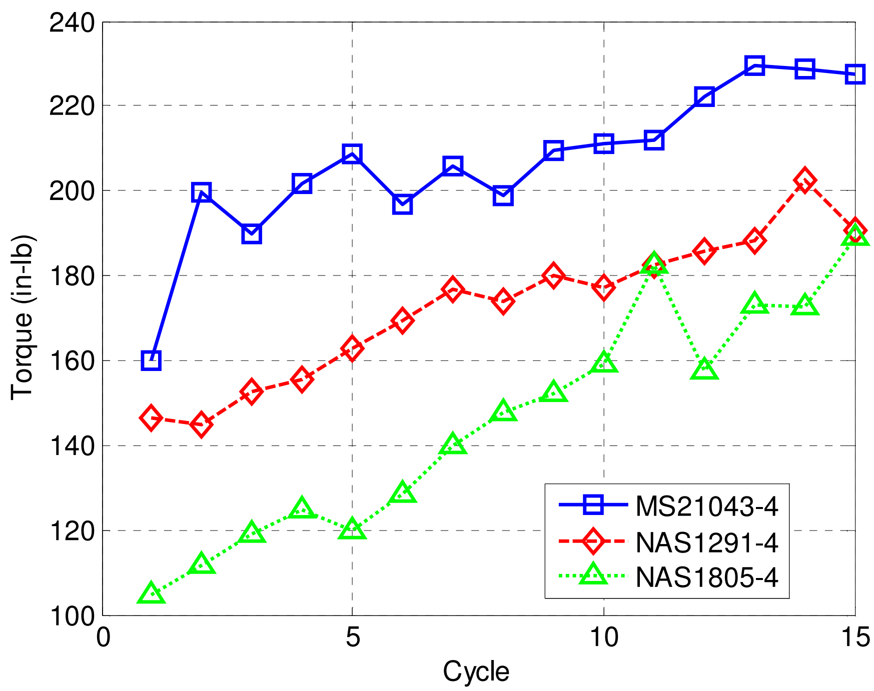

Figure 3-7: All-Metal Breakloose Torque; 66% Y Preload

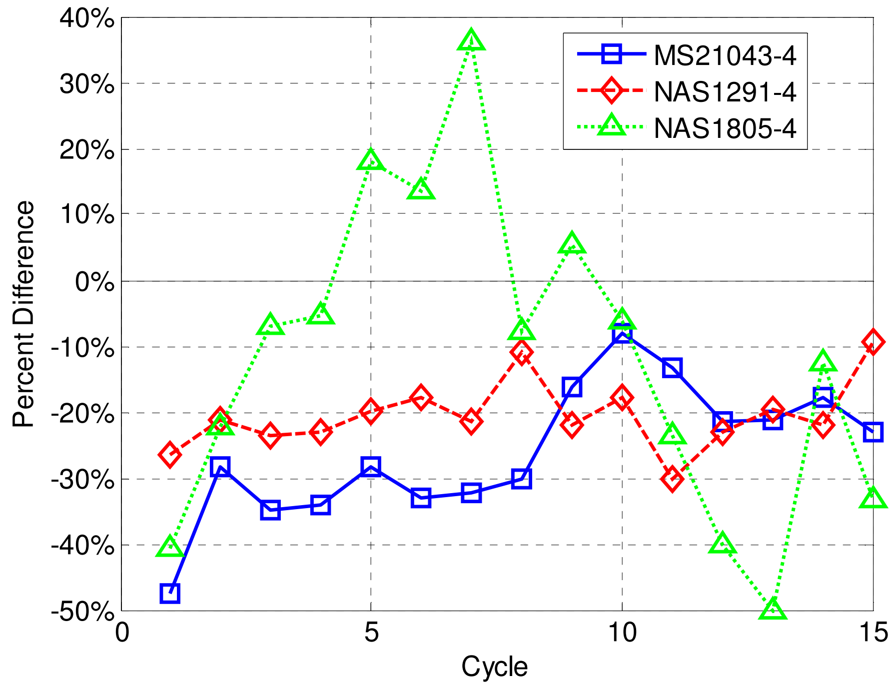

Figure 3-8: All-Metal Percent Difference; 66% Y Preload

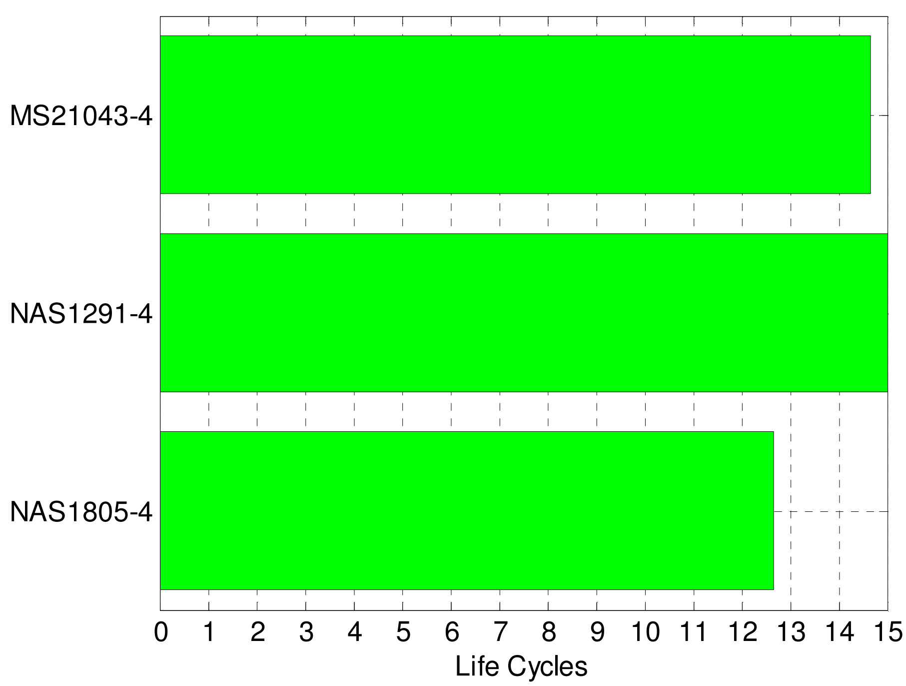

Figure 3-9: All-Metal Life; 66% Y Preload

3.2.3 75% Y Preload

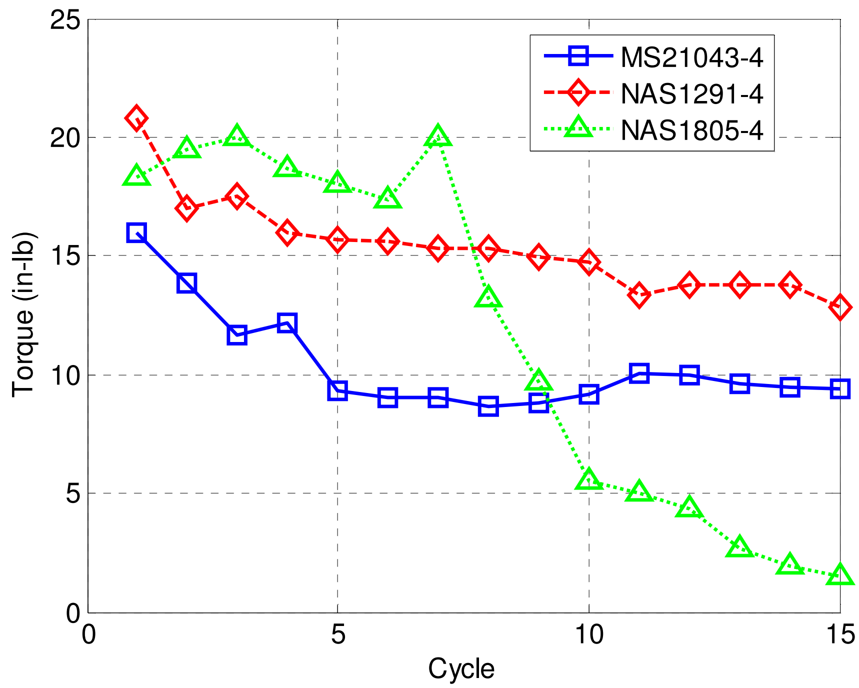

Figure 3-10: All-Metal Assembly Prevailing Torque; 75% Y Preload

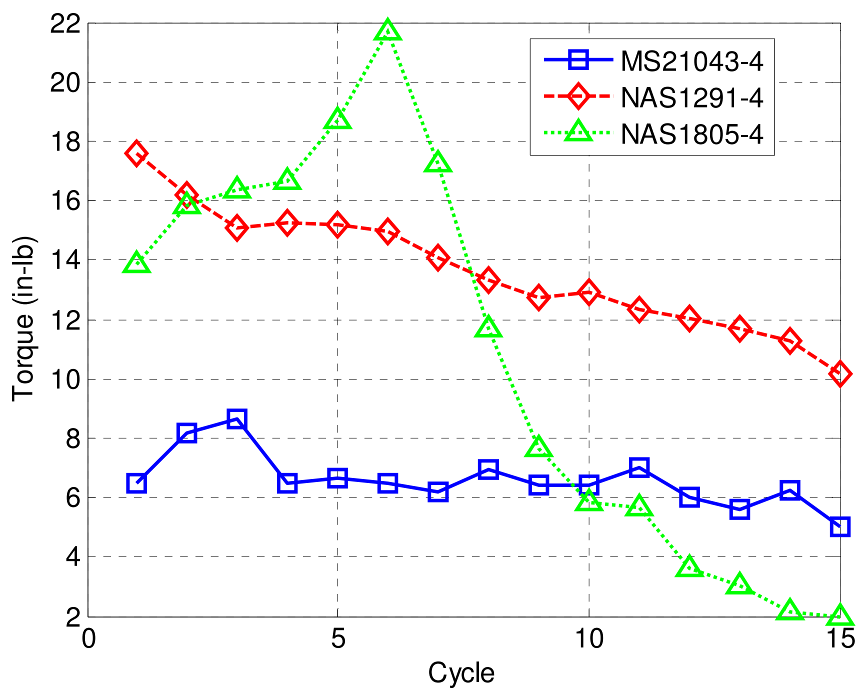

Figure 3-11: All-Metal Removal Prevailing Torque; 75% Y Preload

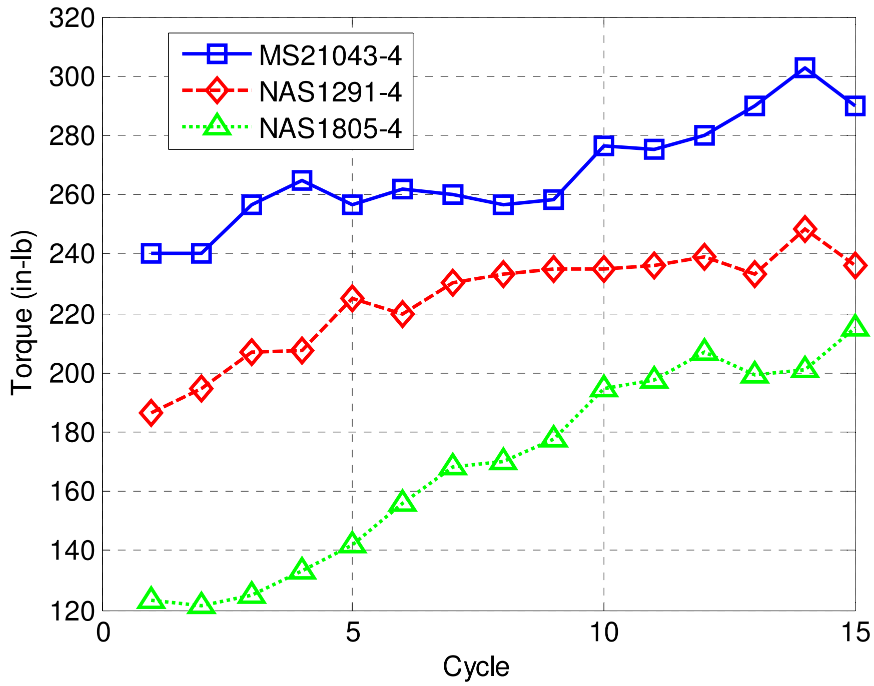

Figure 3-12: All-Metal Tightening Torque; 75% Y Preload

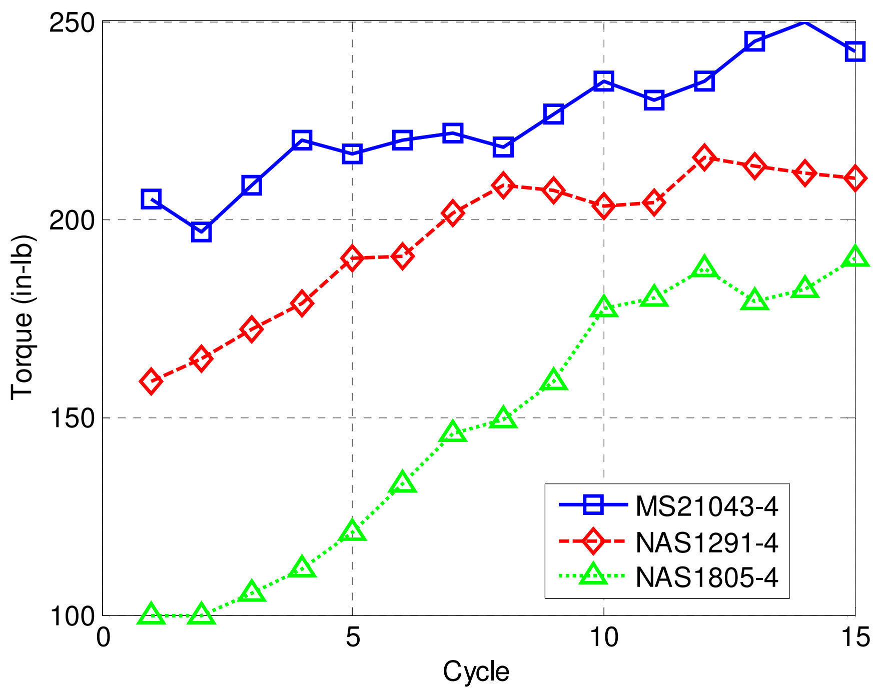

Figure 3-13: All-Metal Breakloose Torque; 75% Y Preload

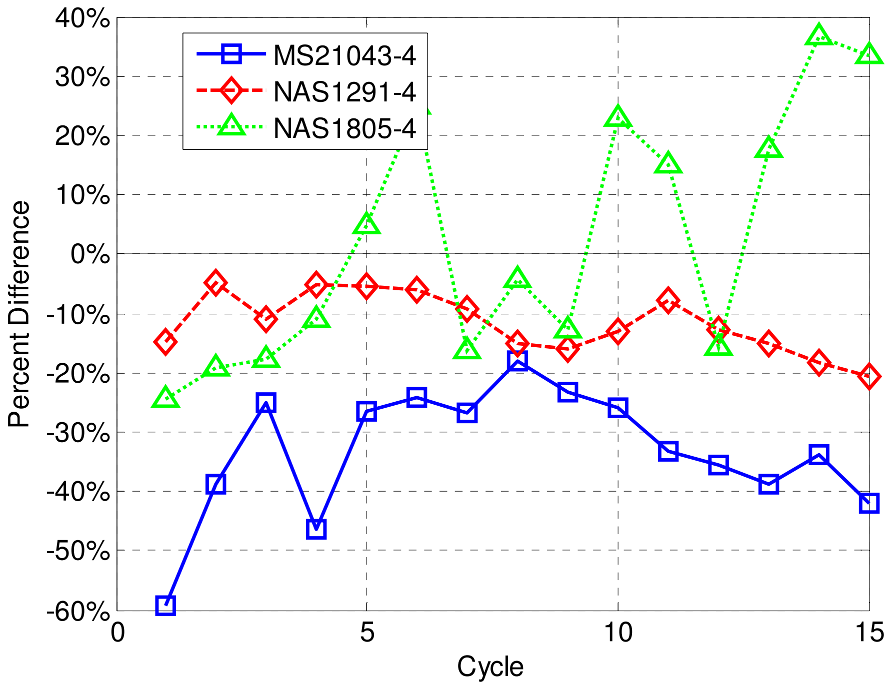

Figure 3-14: All-Metal Percent Difference; 75% Y Preload

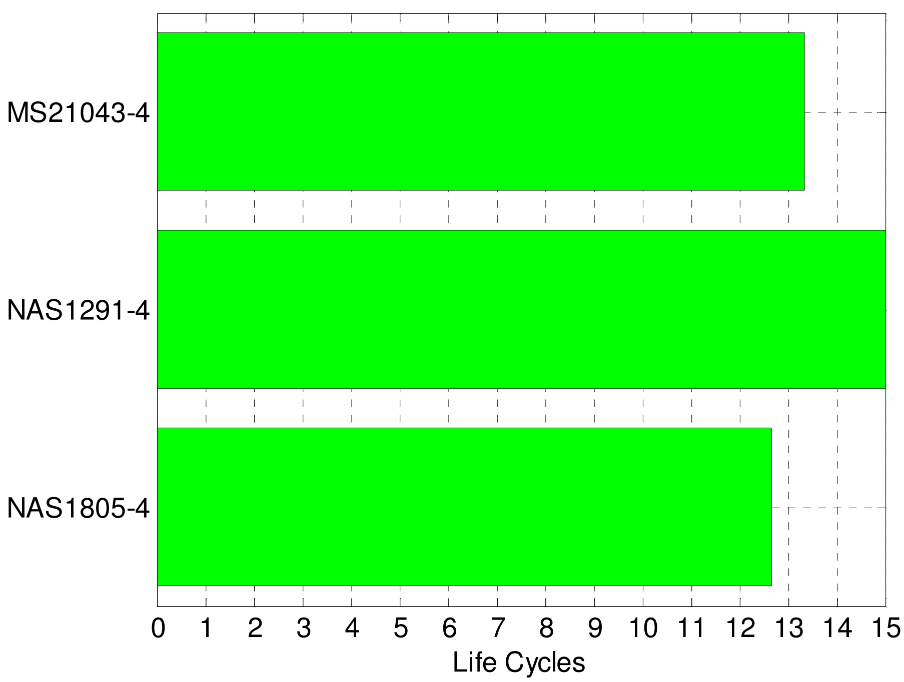

Figure 3-15: All-Metal Life; 75% Y Preload

3.2.4 85% Y Preload

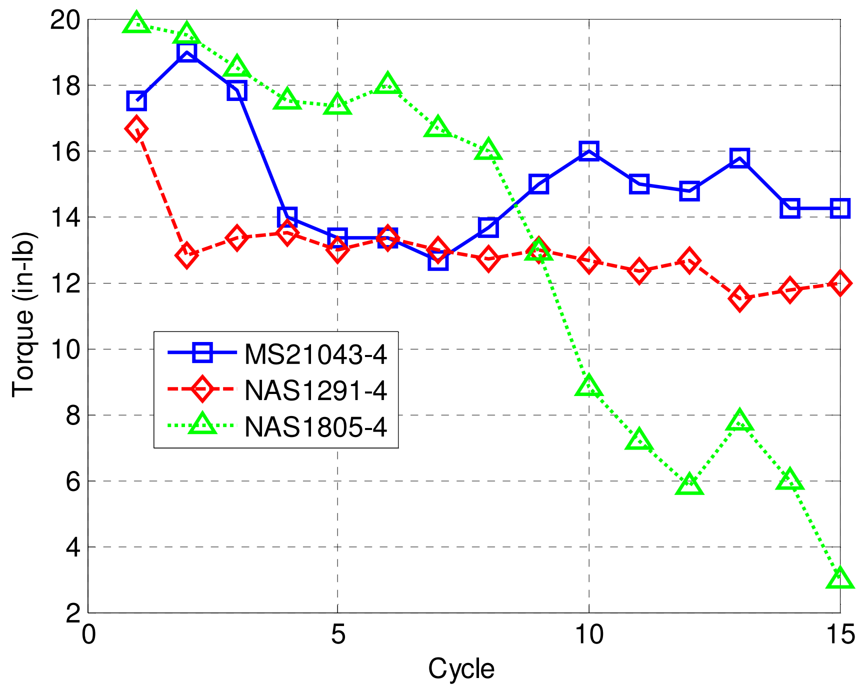

Figure 3-16: All-Metal Assembly Prevailing Torque; 85% Y Preload

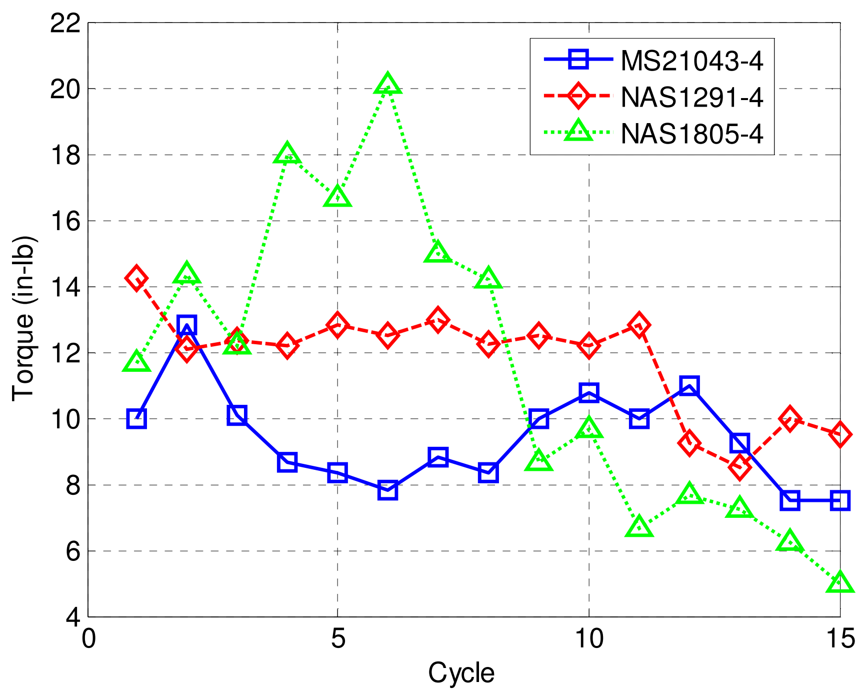

Figure 3-17: All-Metal Removal Prevailing Torque; 85% Y Preload

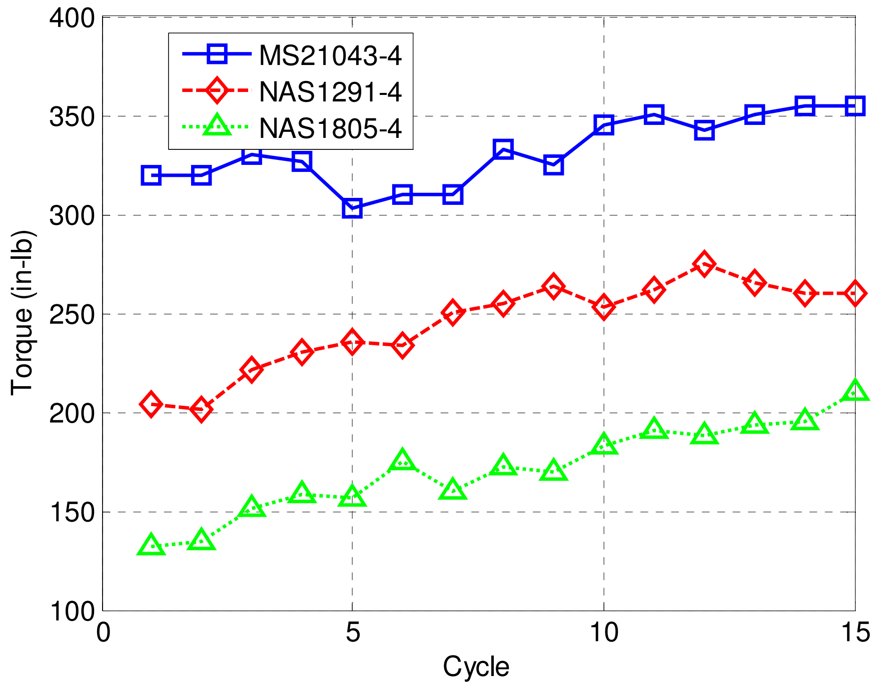

Figure 3-18: All-Metal Tightening Torque; 85% Y Preload

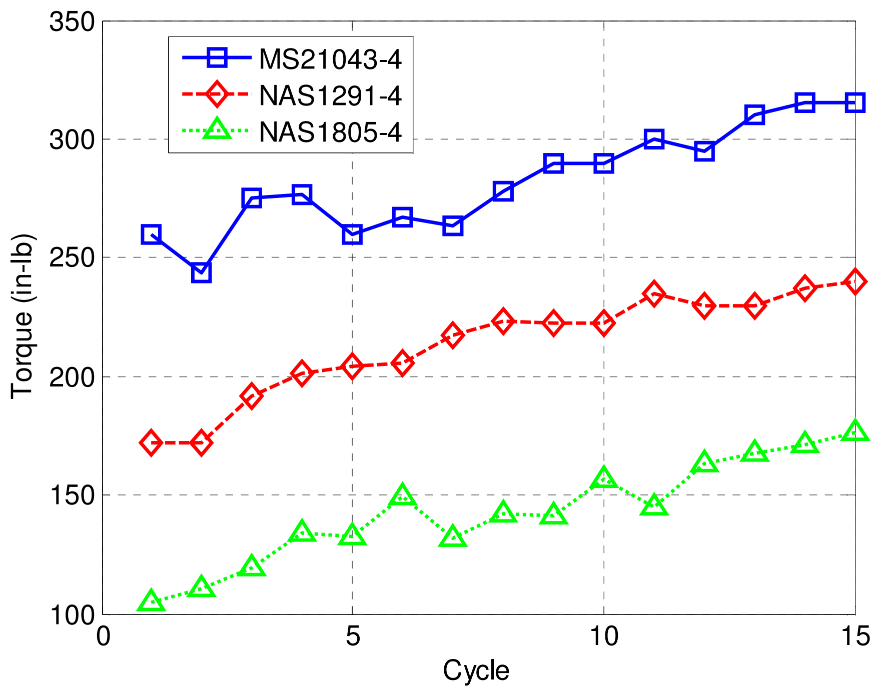

Figure 3-19: All-Metal Breakloose Torque; 85% Y Preload

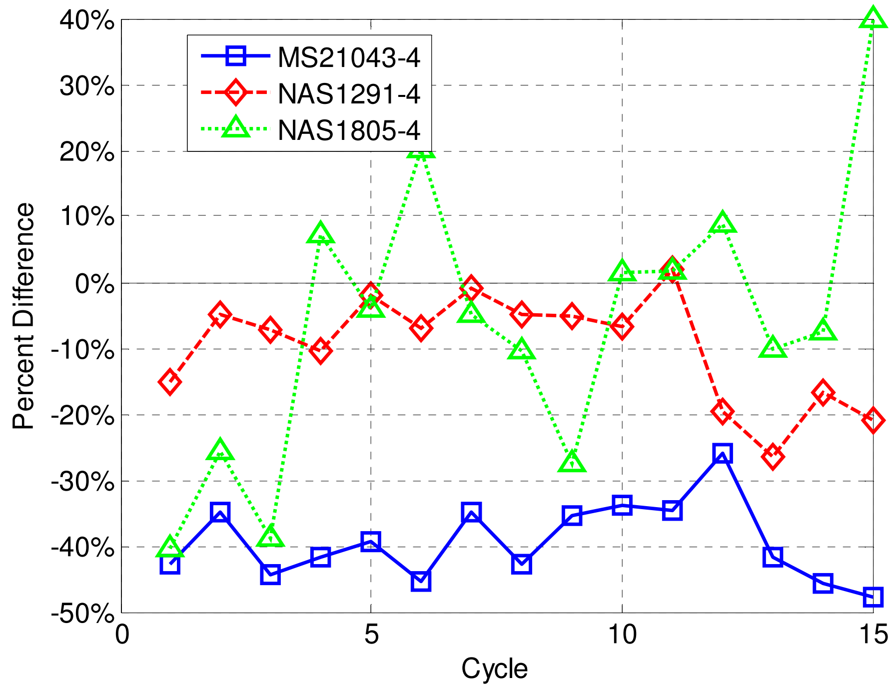

Figure 3-20: All-Metal Percent Difference; 85% Y Preload

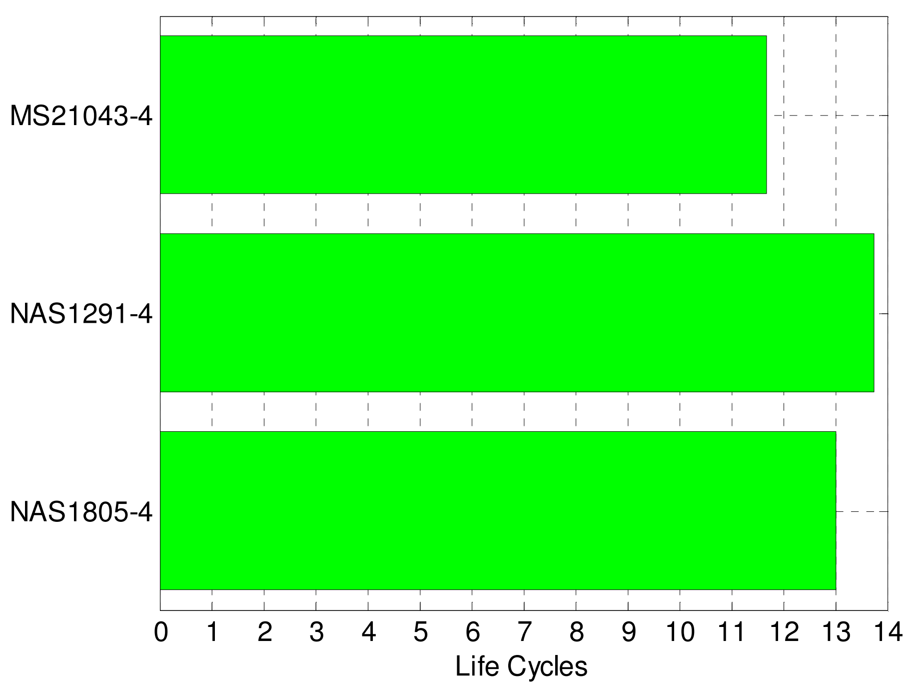

Figure 3-21: All-Metal Life; 85% Y Preload

3.2.5 *Averaged Preload Comparison*

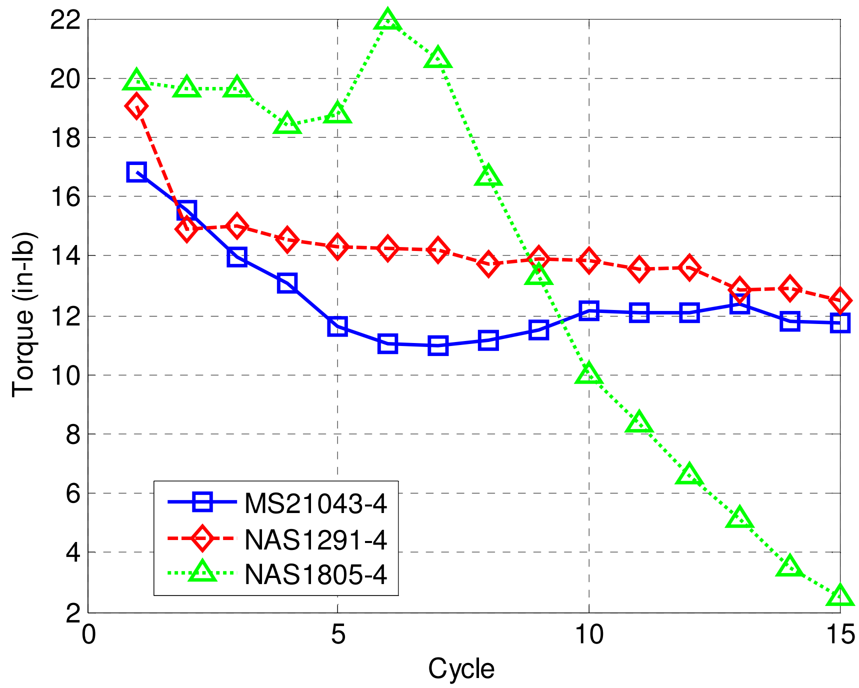

Figure 3-22: All-Metal Assembly Prevailing Torque; Averaged

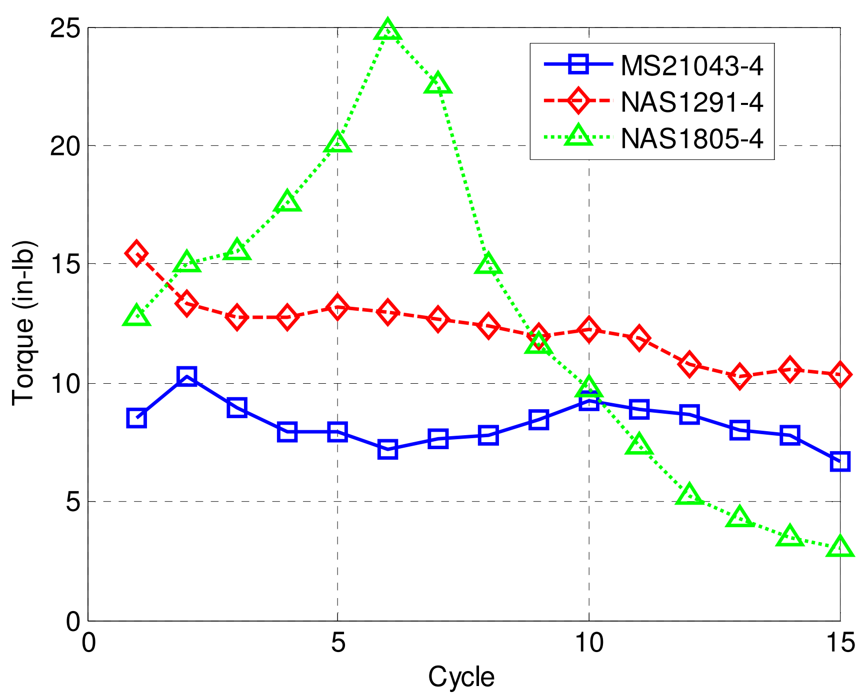

Figure 3-23: All-Metal Removal Prevailing Torque; Averaged

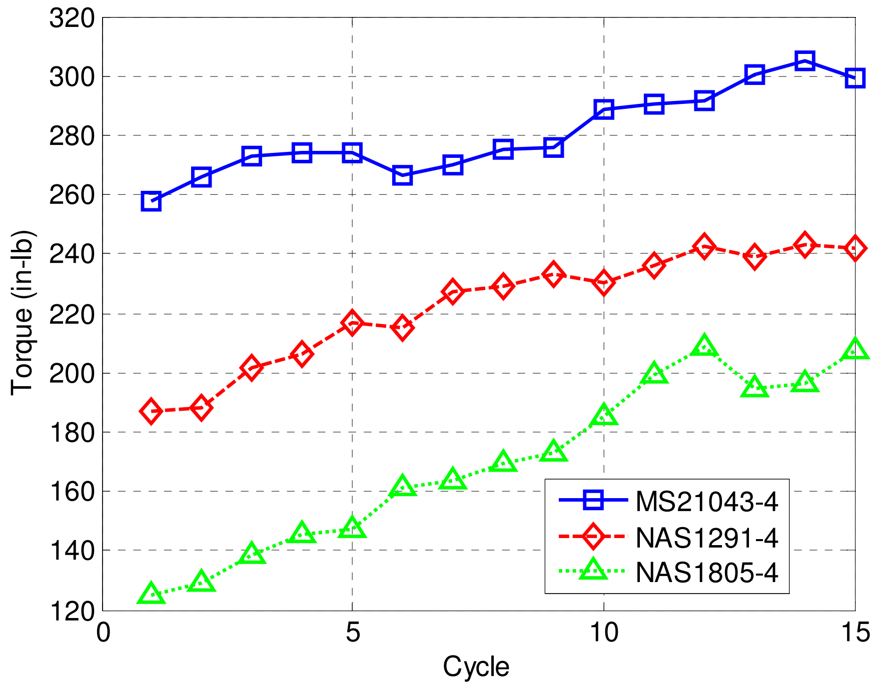

Figure 3-24: All-Metal Tightening Torque; Averaged

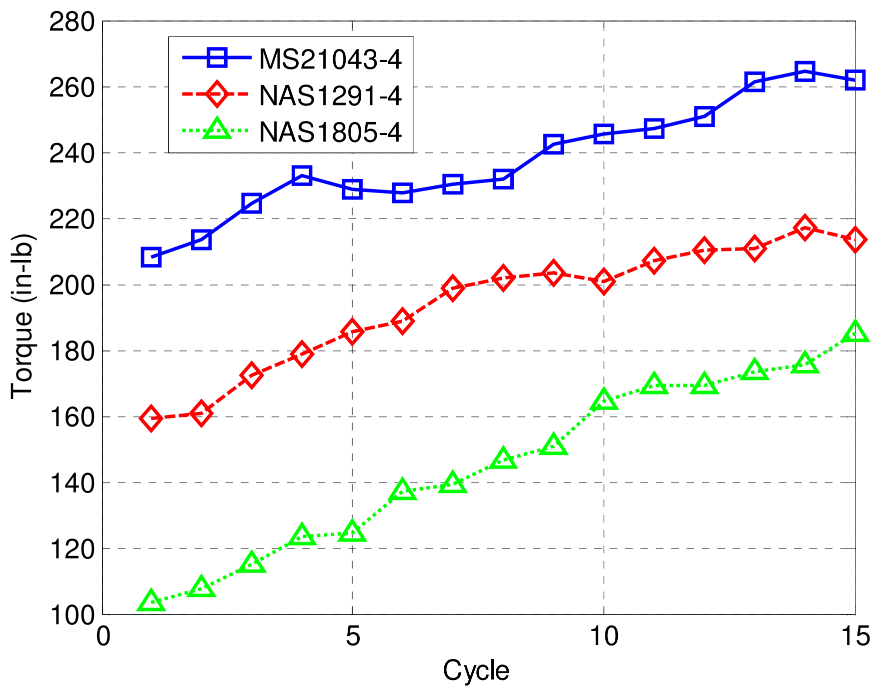

Figure 3-25: All-Metal Breakloose Torque; Averaged

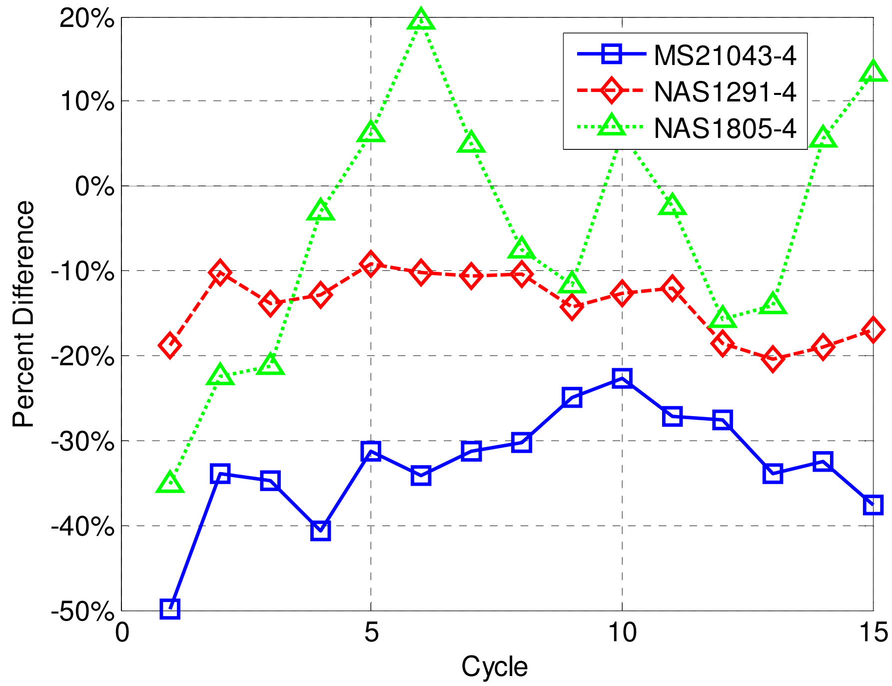

Figure 3-26: All-Metal Percent Difference; Averaged

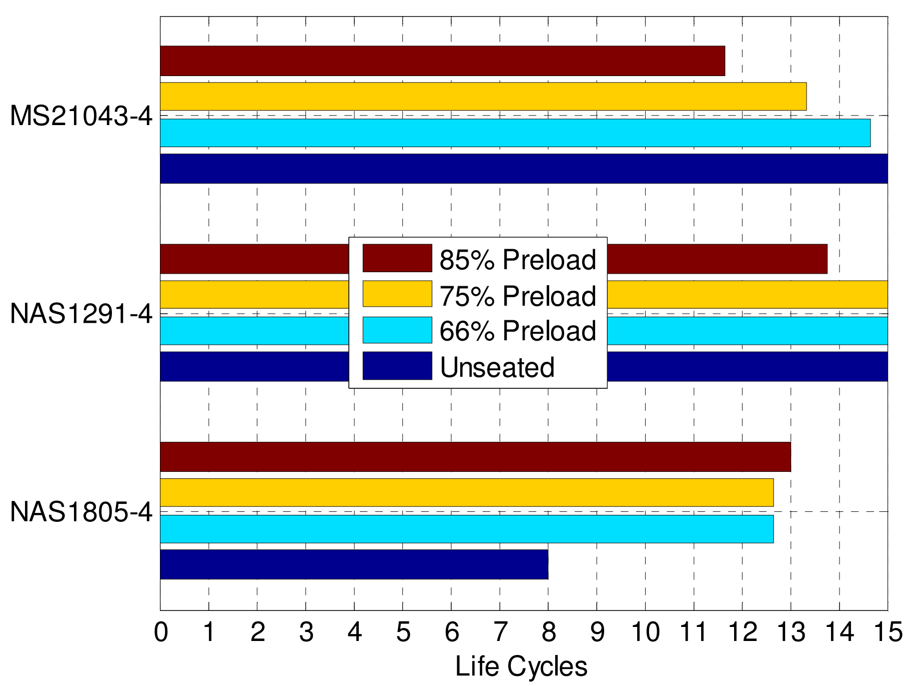

Figure 3-27: All-Metal Life; Averaged

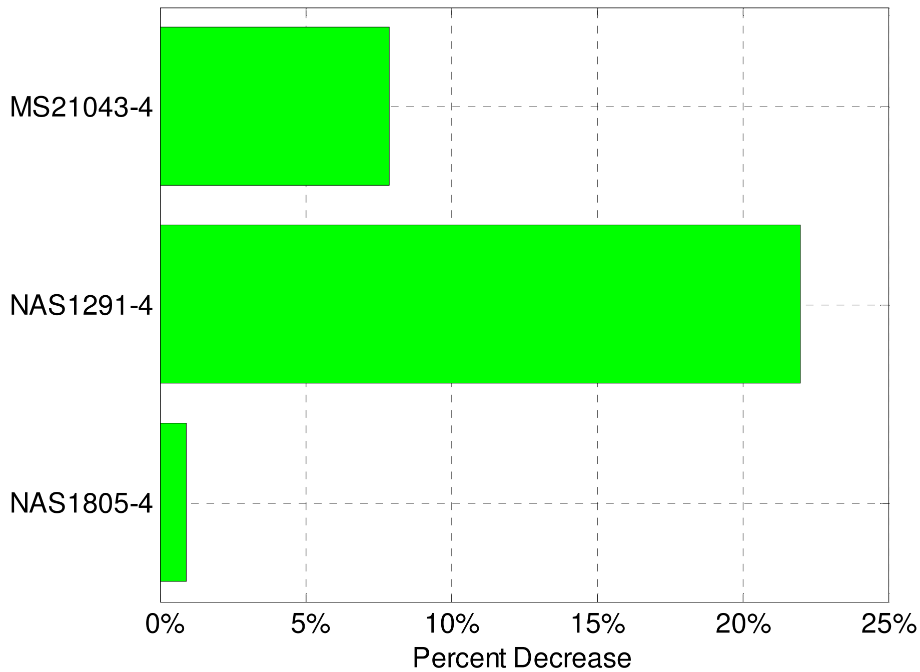

Figure 3-28: All-Metal Percent Decrease; Averaged

3.3 Nylon Locknuts

This section contains the plots for the four nylon insert locknuts. Those locknuts are MS17825-4, MS21044D4, NAS1021N4, and Grade 8. Each point in the plots represents the average of trials 2, 3, and 4 of each preload test. Standard deviation calculations and spreads are provided in Appendix E.

3.3.1 Unseated

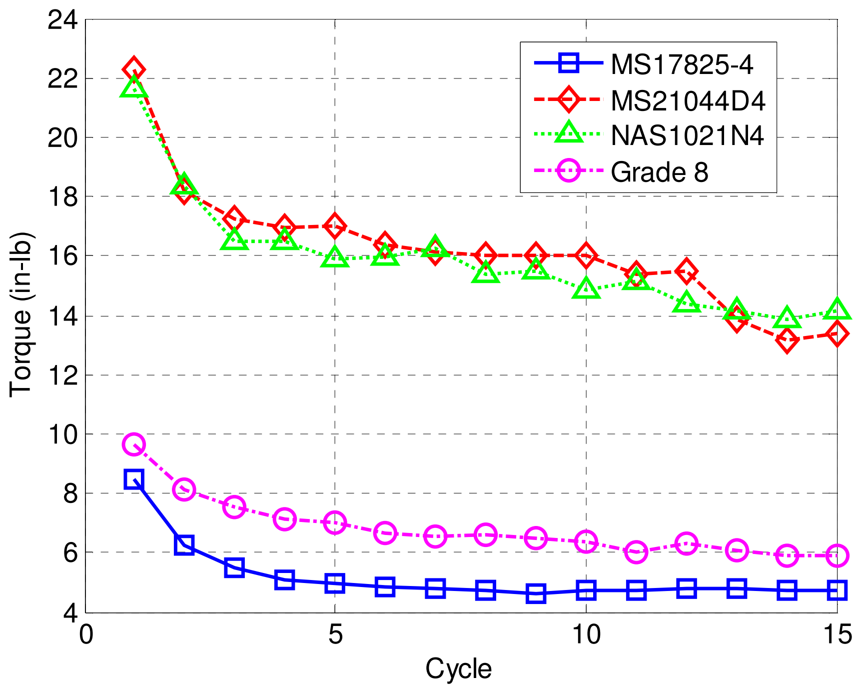

Figure 3-29: Nylon Assembly Prevailing Torque; Unseated

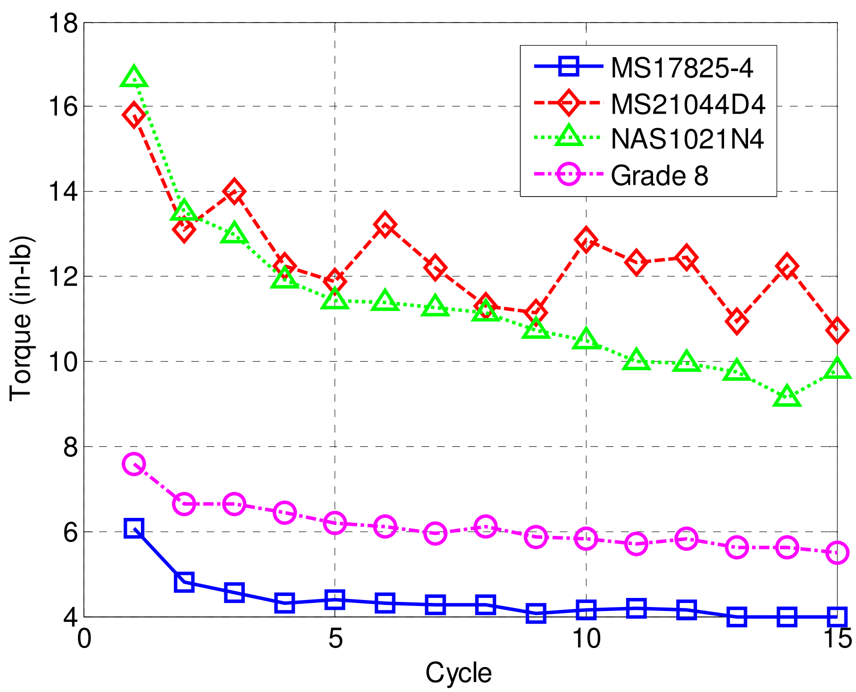

Figure 3-30: Nylon Removal Prevailing Torque; Unseated

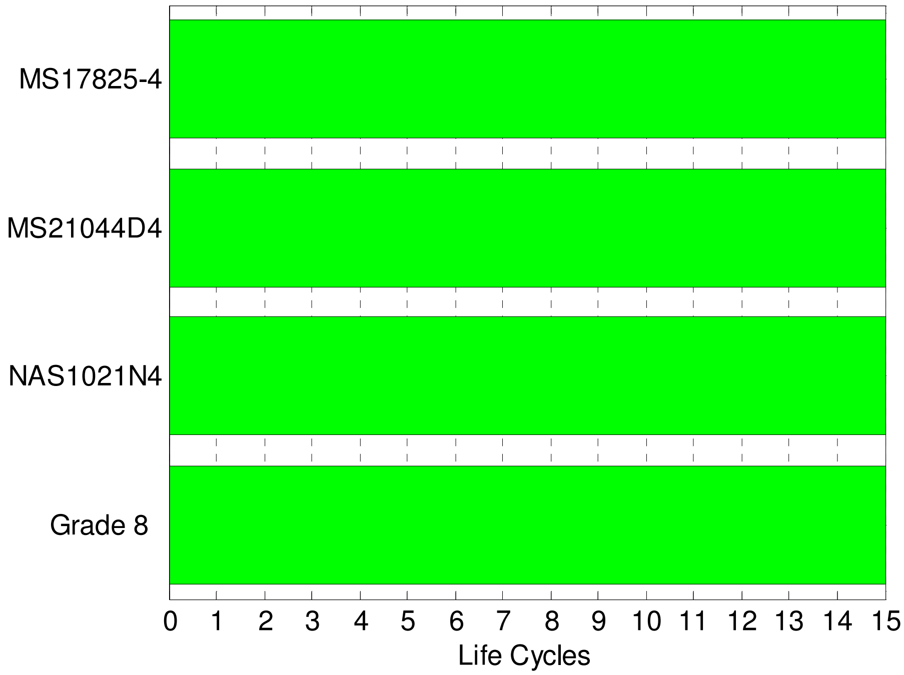

Figure 3-31: Nylon Life; Unseated

3.3.2 66% Y Preload

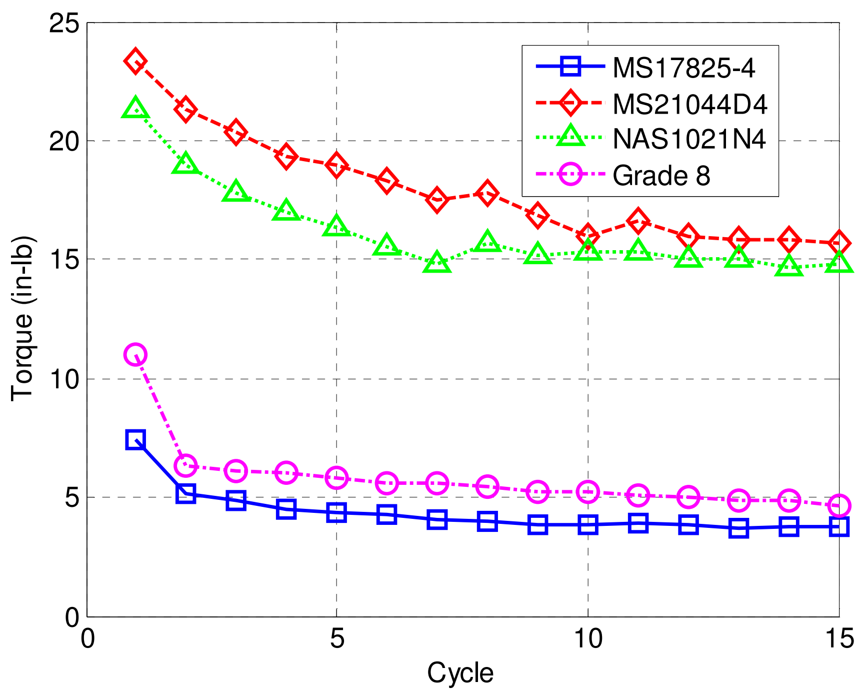

Figure 3-32: Nylon Assembly Prevailing Torque; 66% Y Preload

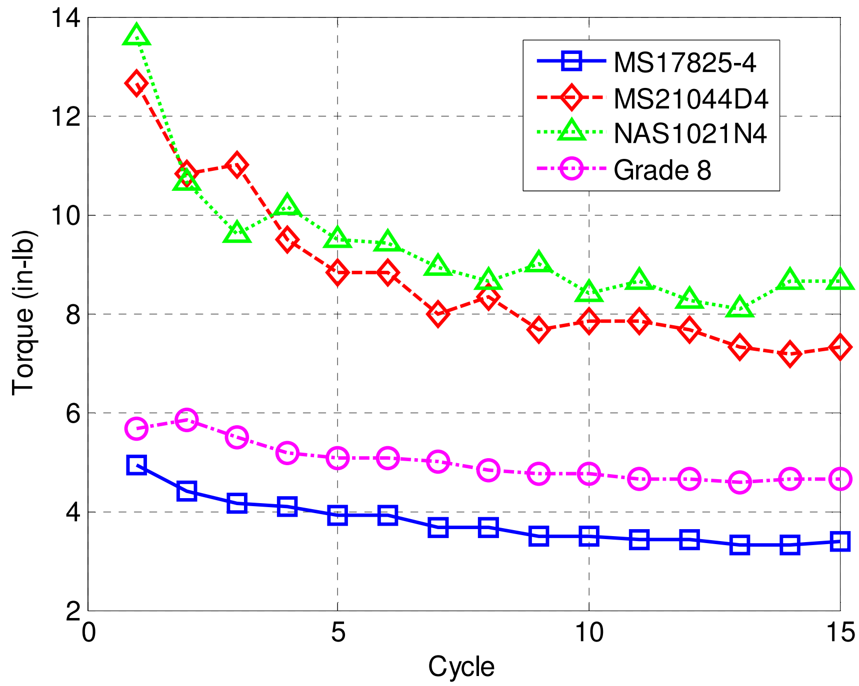

Figure 3-33: Nylon Removal Prevailing Torque; 66% Y Preload

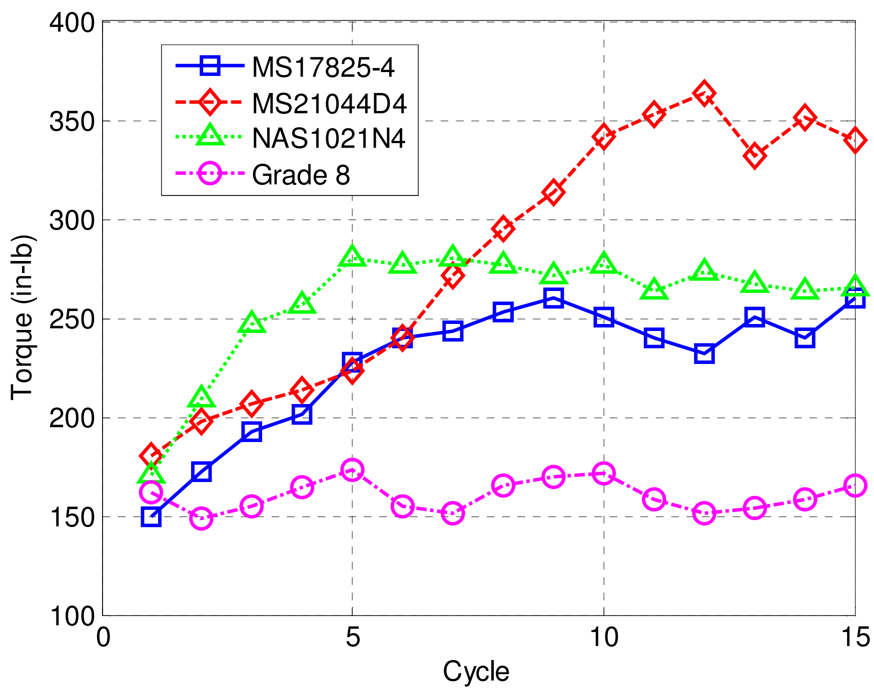

Figure 3-34: Nylon Tightening Torque; 66% Y Preload

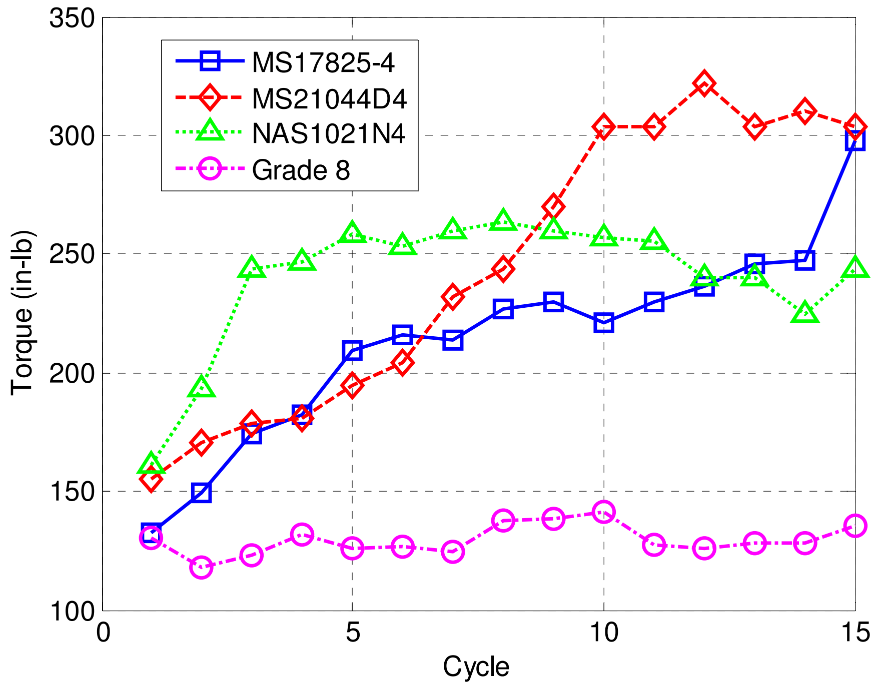

Figure 3-35: Nylon Breakloose Torque; 66% Y Preload

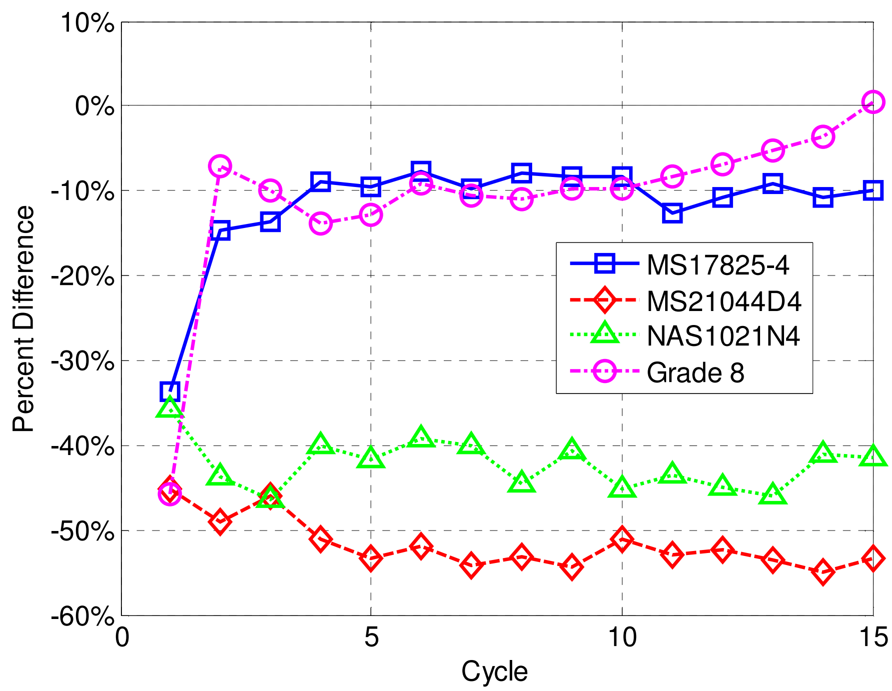

Figure 3-36: Nylon Percent Difference; 66% Y Preload

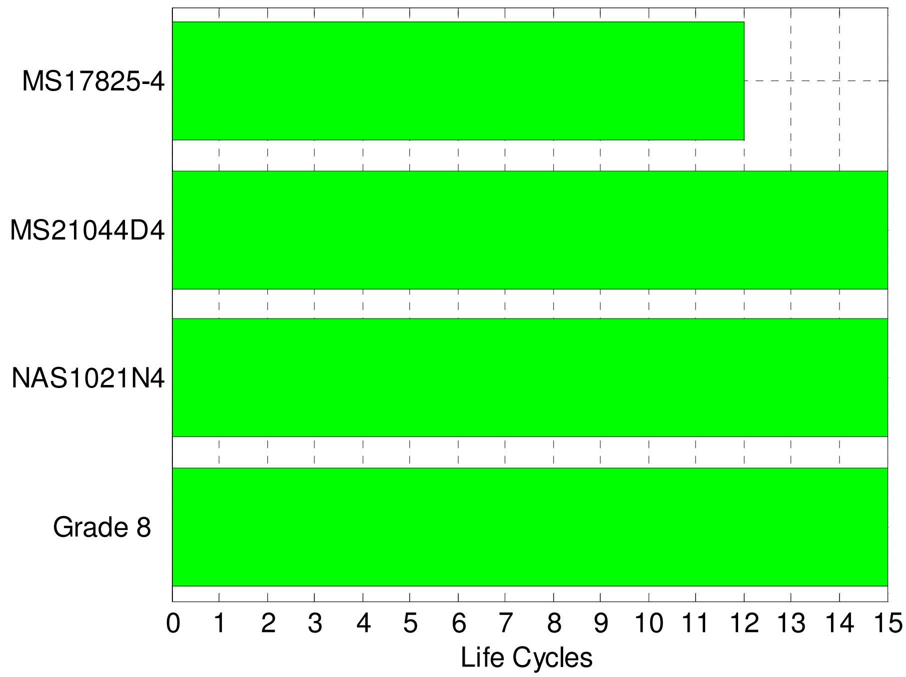

Figure 3-37: Nylon Life; 66% Y Preload

3.3.3 75% Y Preload

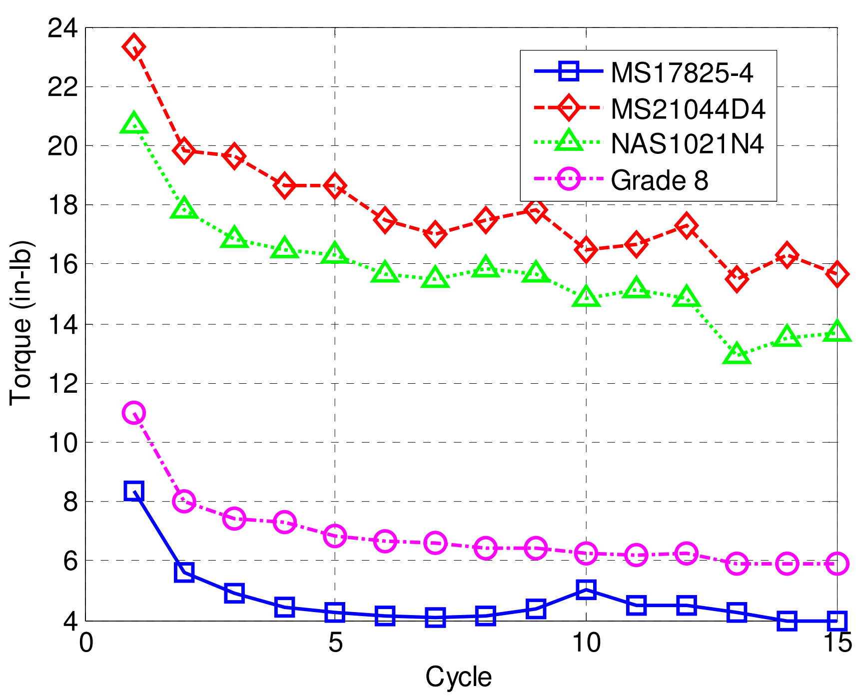

Figure 3-38: Nylon Assembly Prevailing Torque; 75% Y Preload

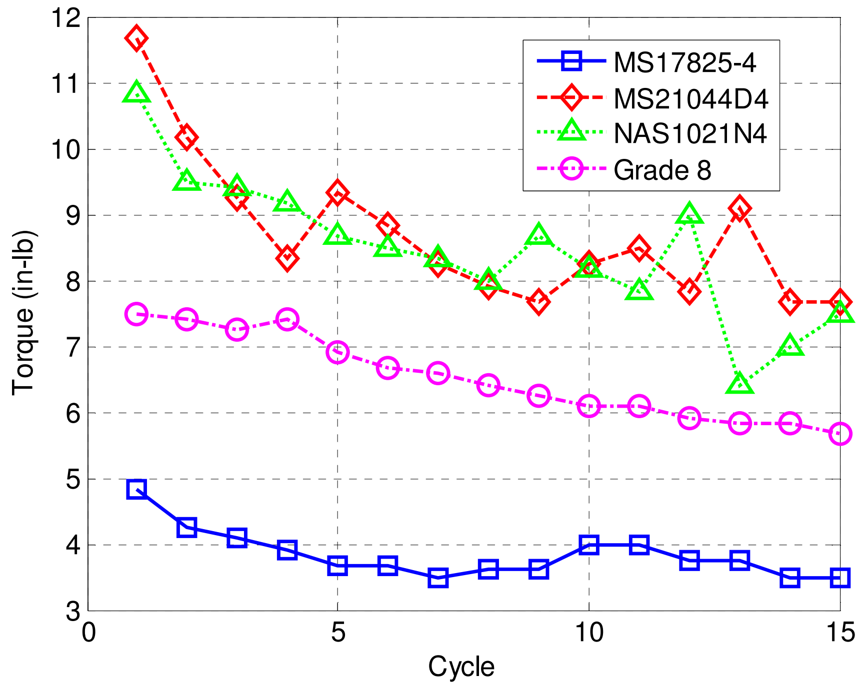

Figure 3-39: Nylon Removal Prevailing Torque; 75% Y Preload

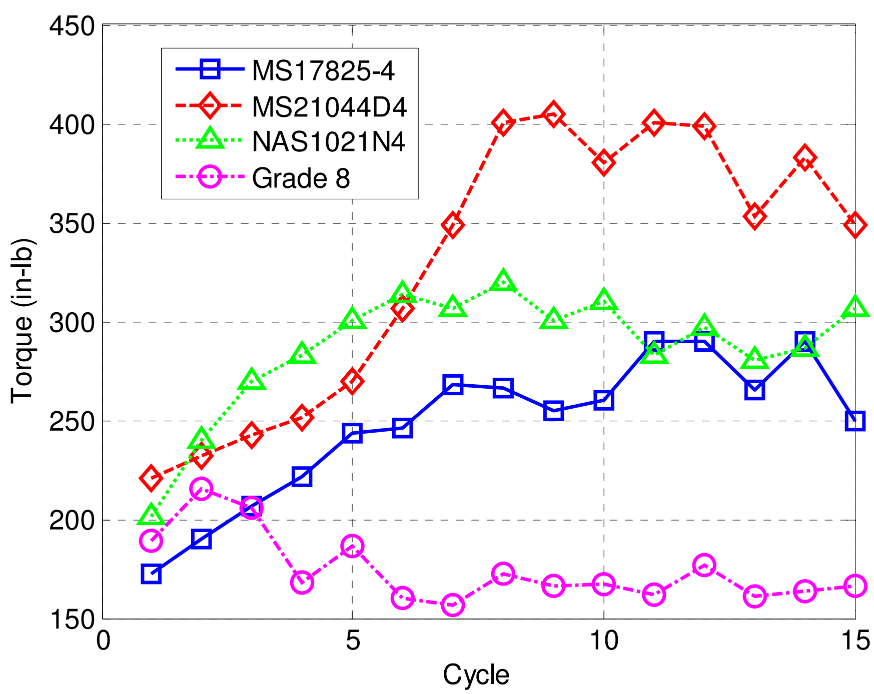

Figure 3-40: Nylon Tightening Torque; 75% Y Preload

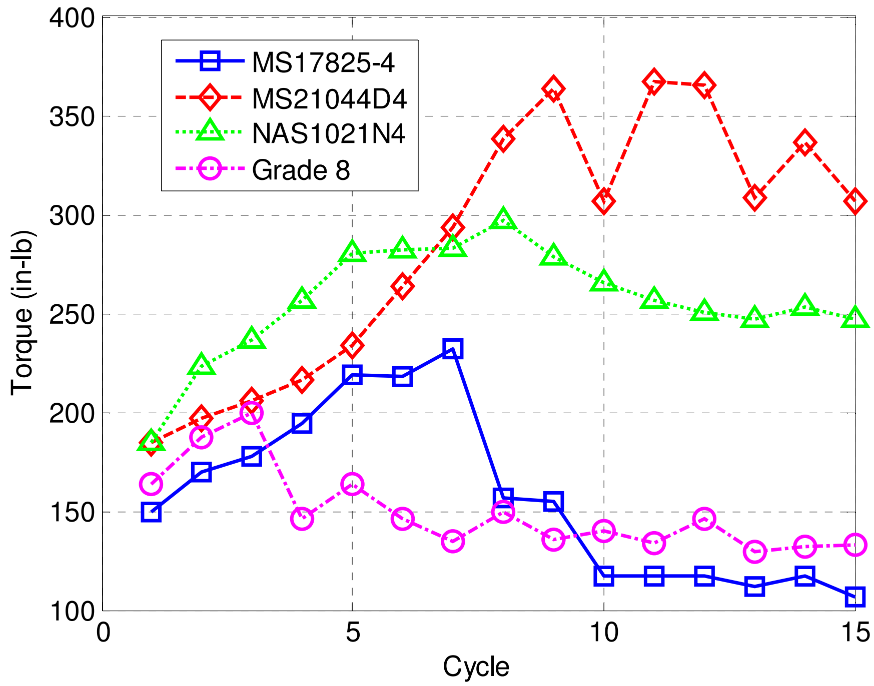

Figure 3-41: Nylon Breakloose Torque; 75% Y Preload

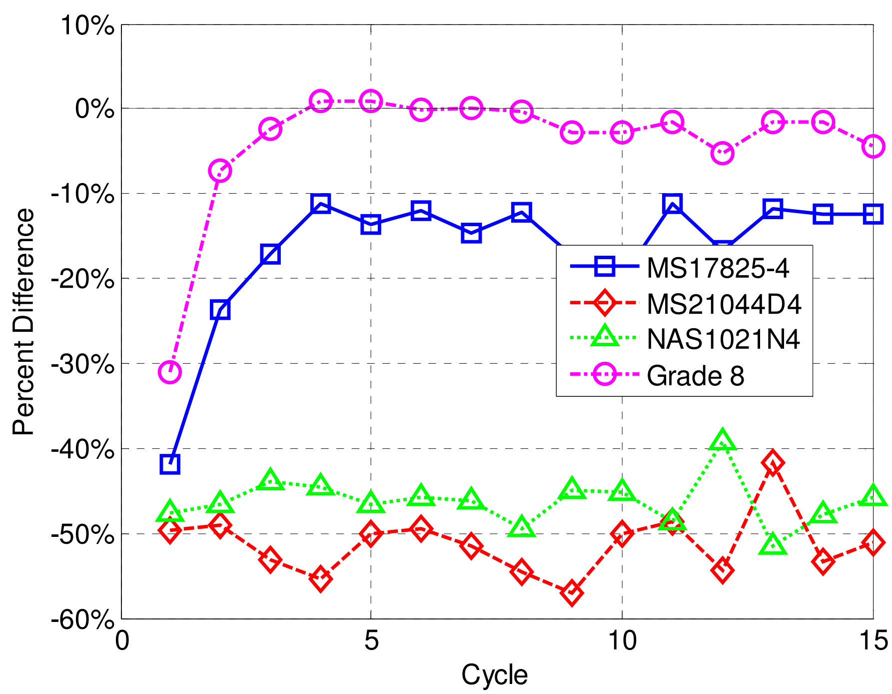

Figure 3-42: Nylon Percent Difference; 75% Y Preload

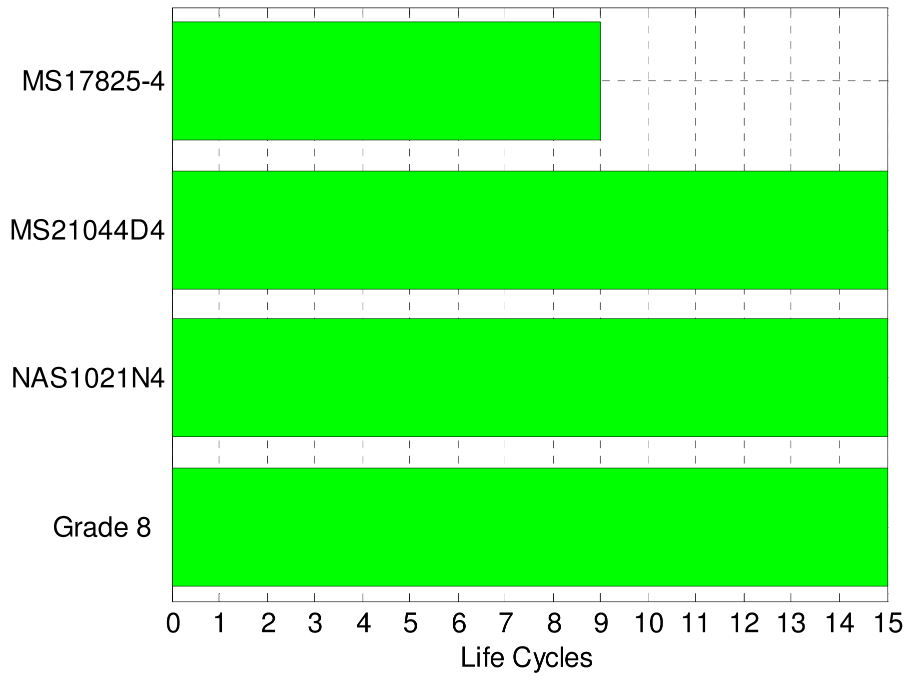

Figure 3-43: Nylon Life; 75% Y Preload

3.3.4 85% Y Preload

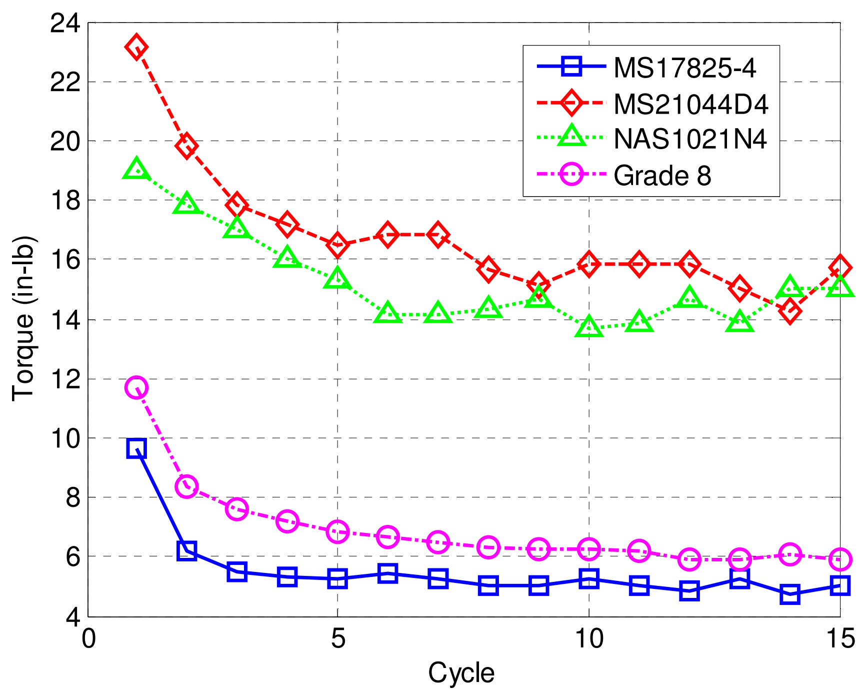

Figure 3-44: Nylon Assembly Prevailing Torque; 85% Y Preload

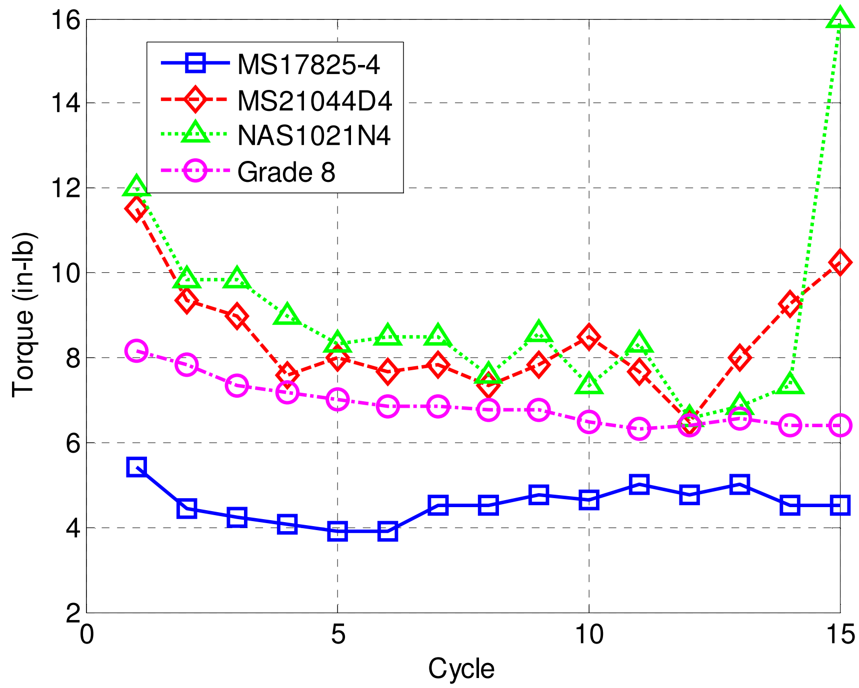

Figure 3-45: Nylon Removal Prevailing Torque; 85% Y Preload

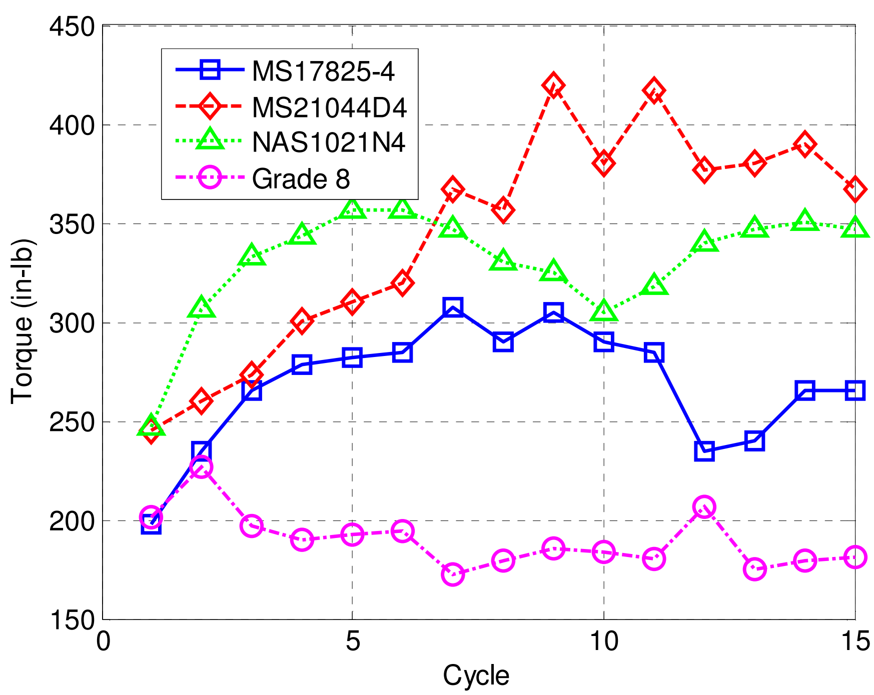

Figure 3-46: Nylon Tightening Torque; 85% Y Preload

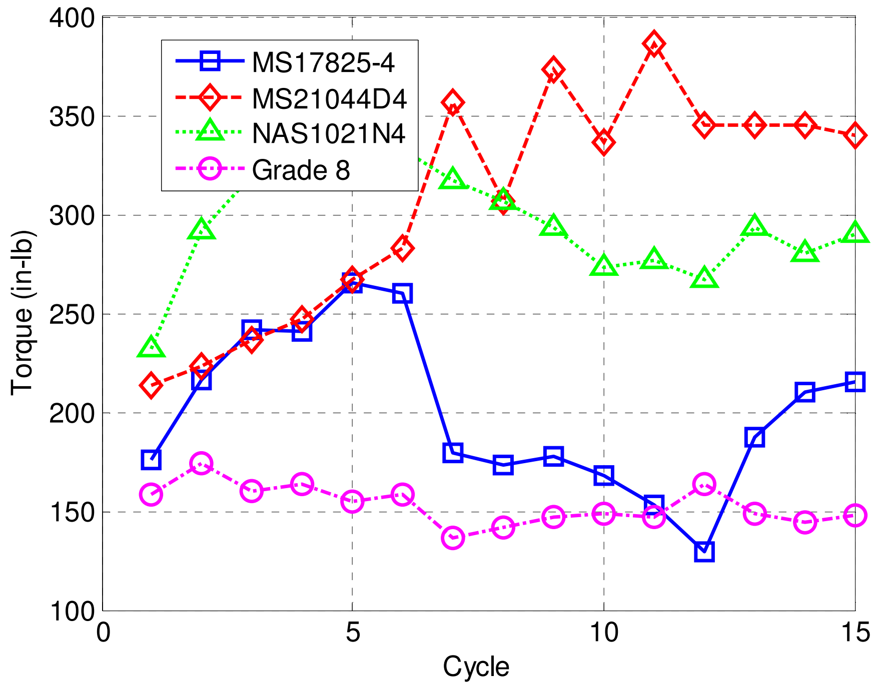

Figure 3-47: Nylon Breakloose Torque; 85% Y Preload

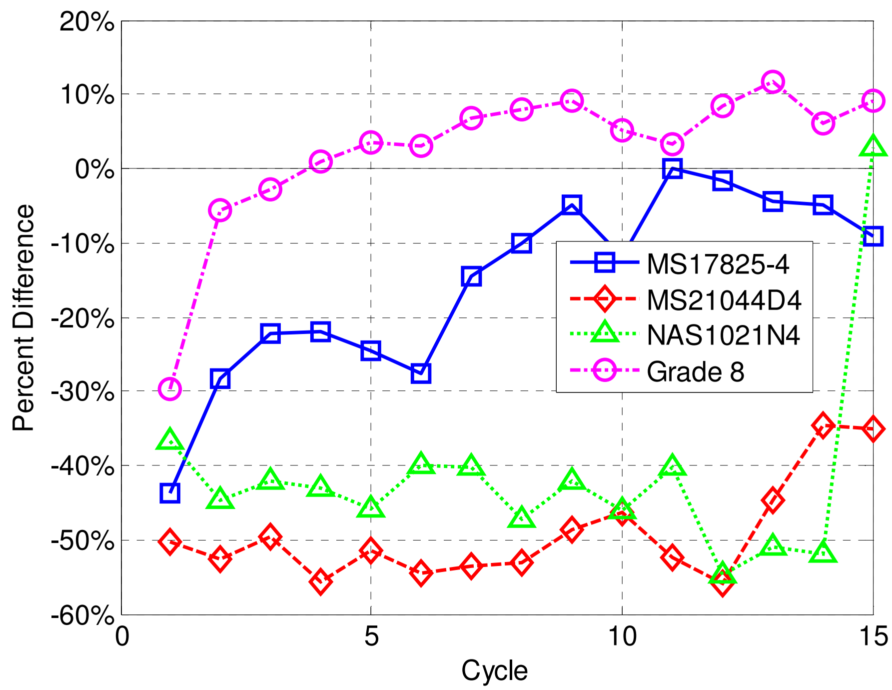

Figure 3-48: Nylon Percent Difference; 85% Y Preload

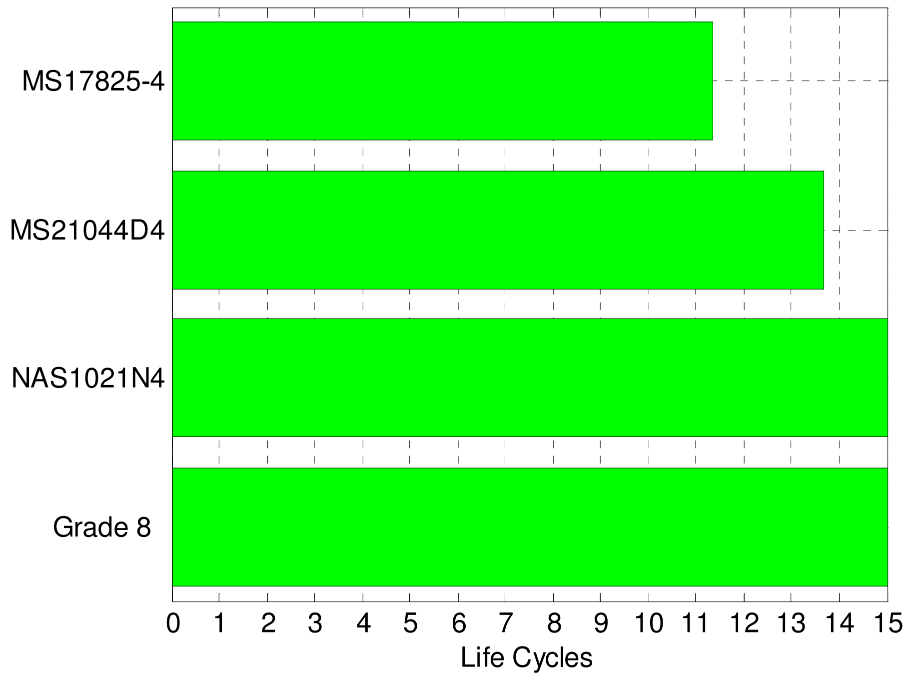

Figure 3-49: Nylon Life; 85% Y Preload

3.3.5 Averaged Preload Comparison

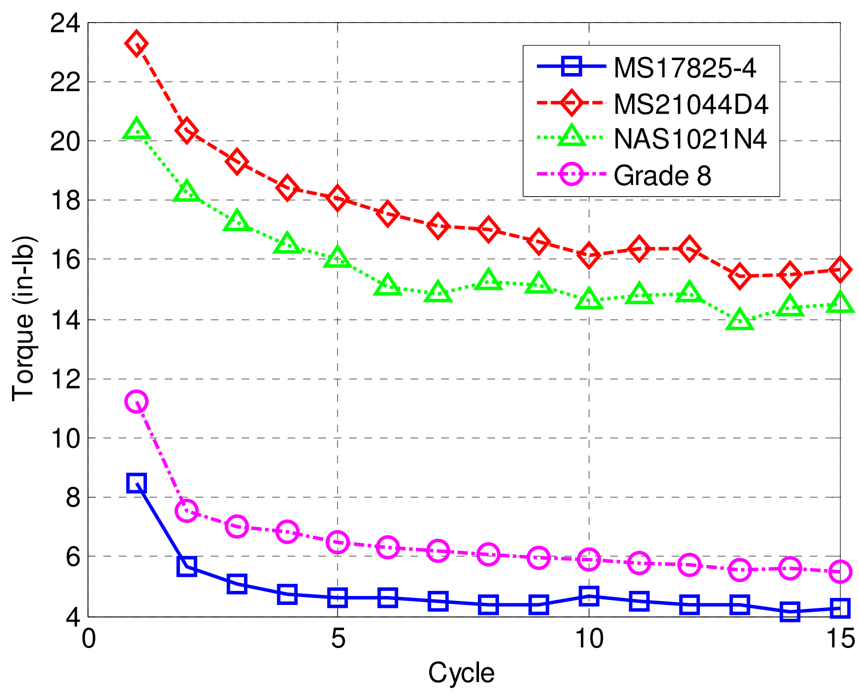

Figure 3-50: Nylon Assembly Prevailing Torque; Averaged

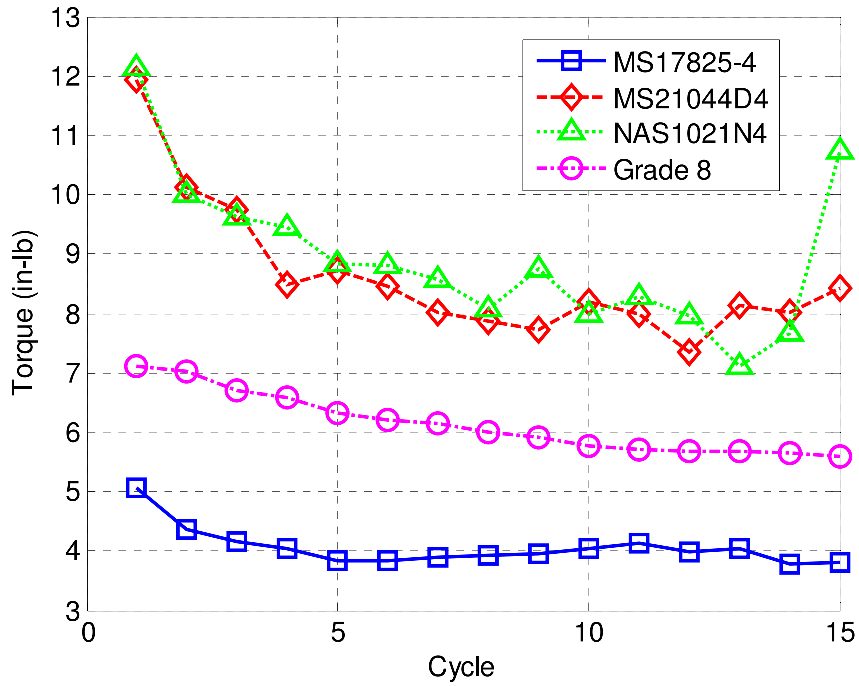

Figure 3-51: Nylon Removal Prevailing Torque; Averaged

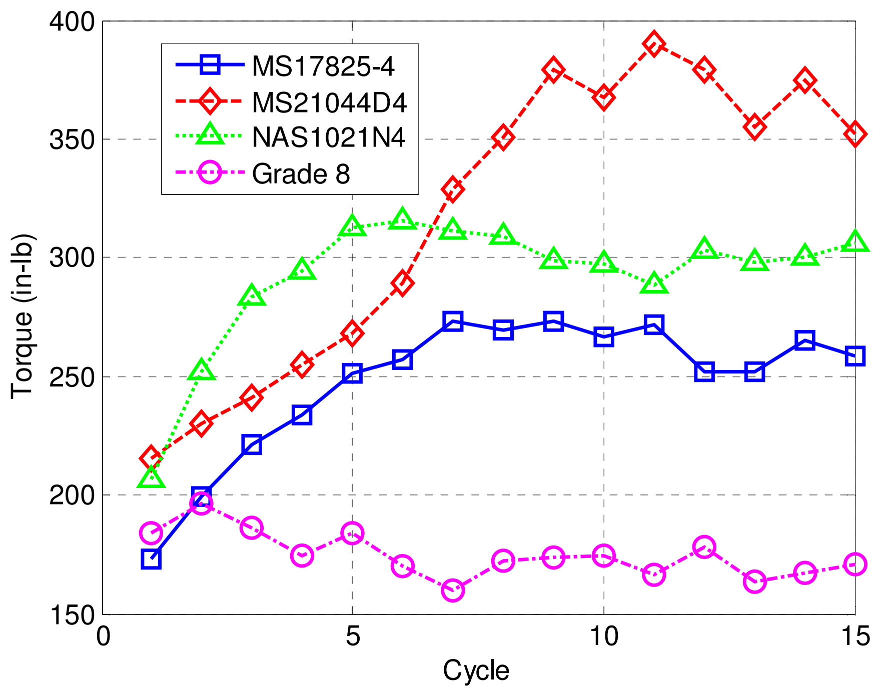

Figure 3-52: Nylon Tightening Torque; Averaged

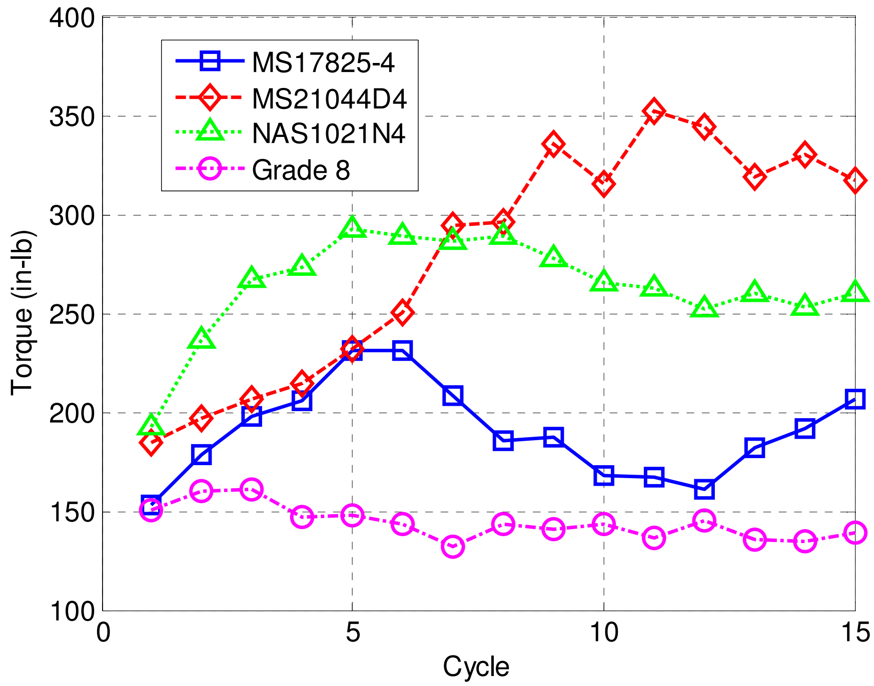

Figure 3-53: Nylon Breakloose Torque; Averaged

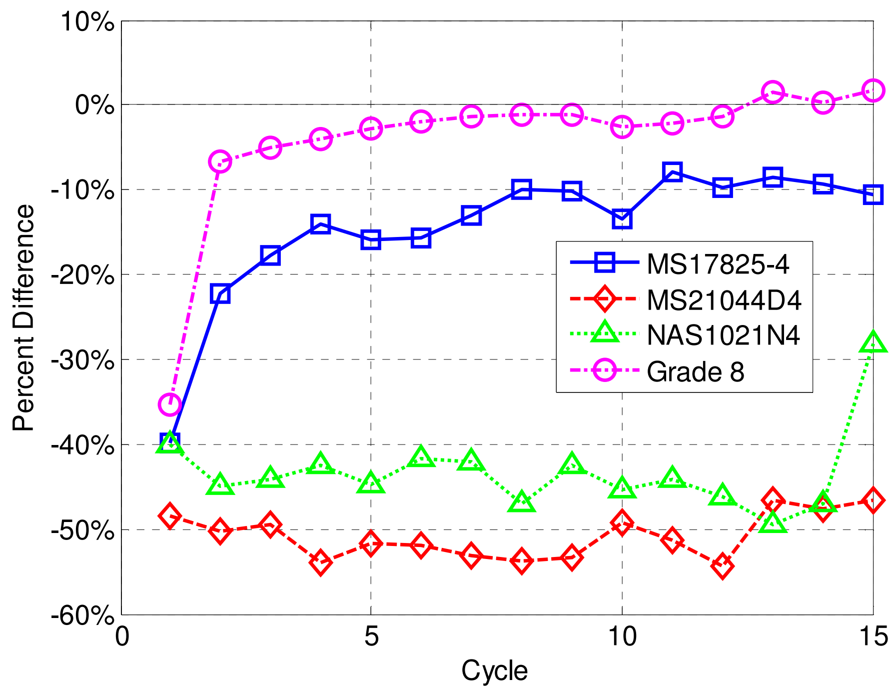

Figure 3-54: Nylon Percent Difference; Averaged

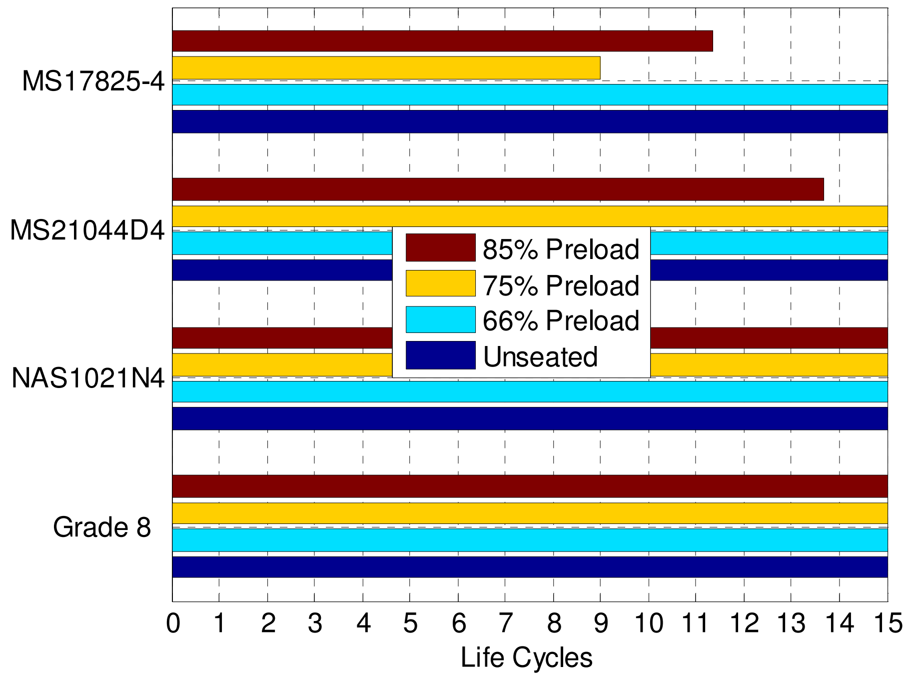

Figure 3-55: Nylon Life; Averaged

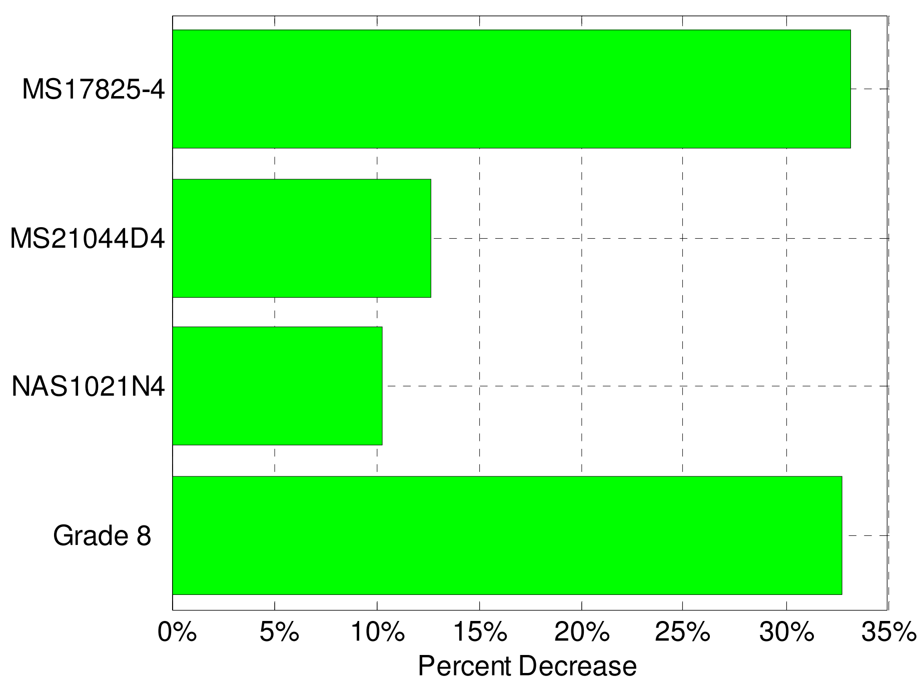

Figure 3-56: Nylon Percent Decrease; Averaged

3.4 Locknut Comparison

This section contains plots comparing all seven locknuts together, locknuts: MS21043-4, NAS1291-4, NAS1805-4, MS17825-4, MS21044D4, NAS1021N4, and Grade 8. Each point in the plots represents the average of trials 2, 3, and 4 of each preload test. Standard deviation calculations and spreads are provided in Appendix E.

3.4.1 Unseated

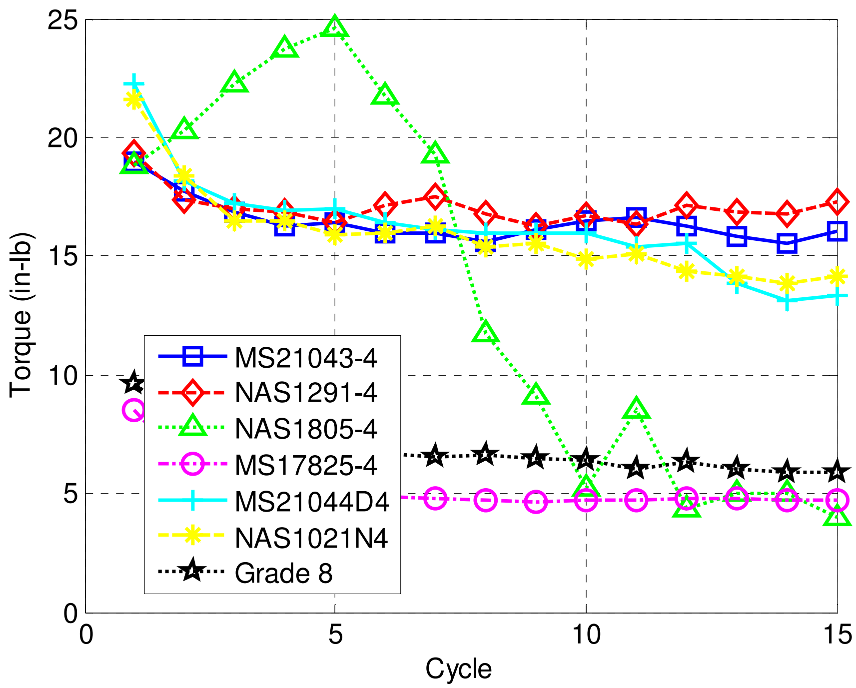

Figure 3-57: Assembly Prevailing Torque; Unseated

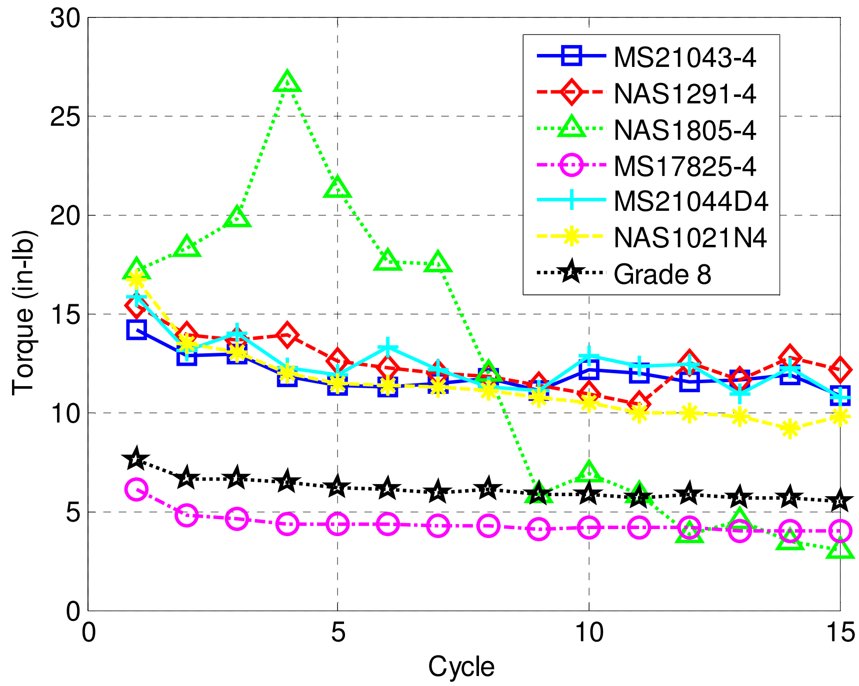

Figure 3-58: Removal Prevailing Torque; Unseated

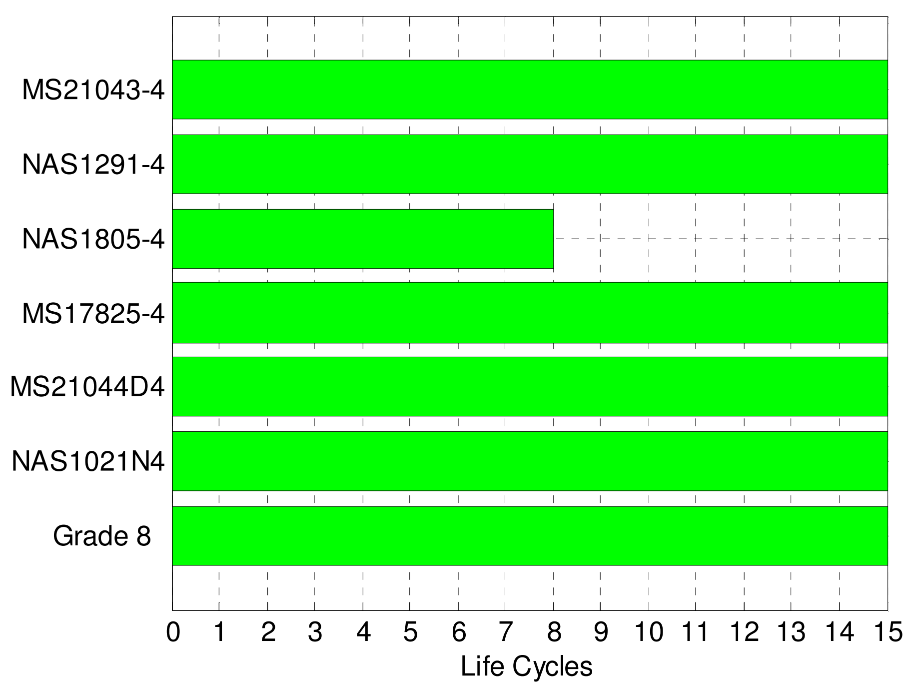

Figure 3-59: Life; Unseated

3.4.2 66% Y Preload

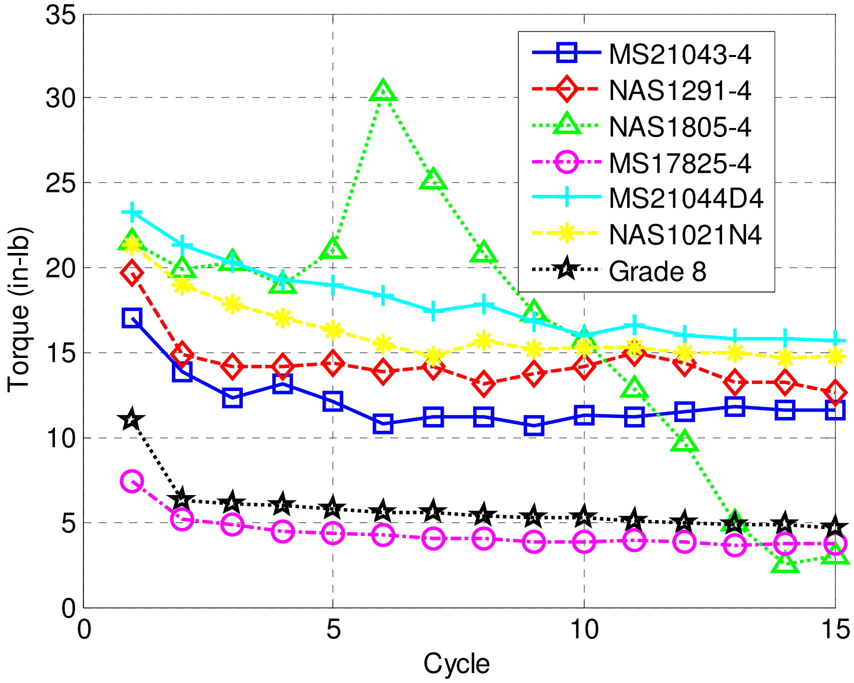

Figure 3-60: Assembly Prevailing Torque; 66% Y Preload

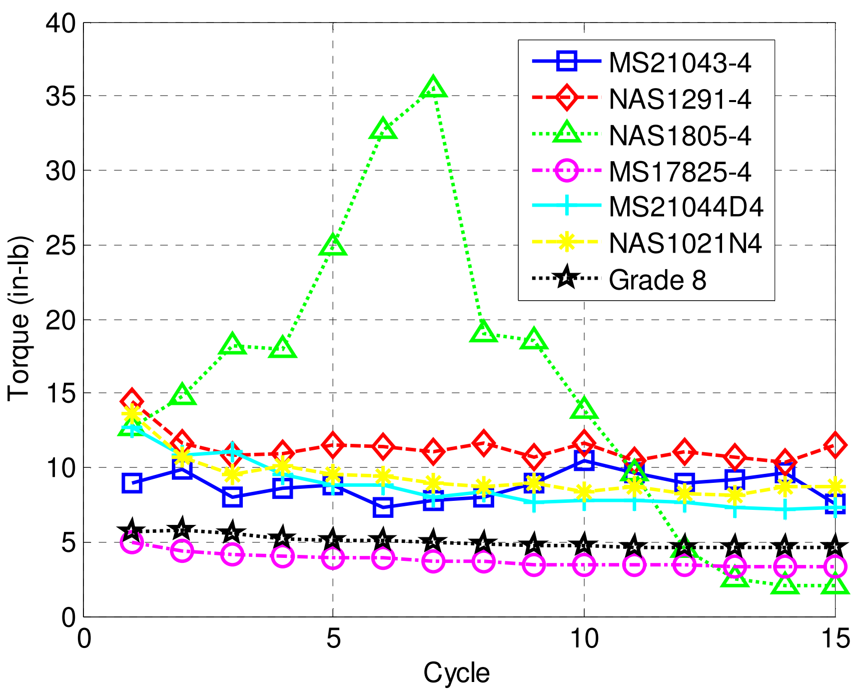

Figure 3-61: Removal Prevailing Torque; 66% Y Preload

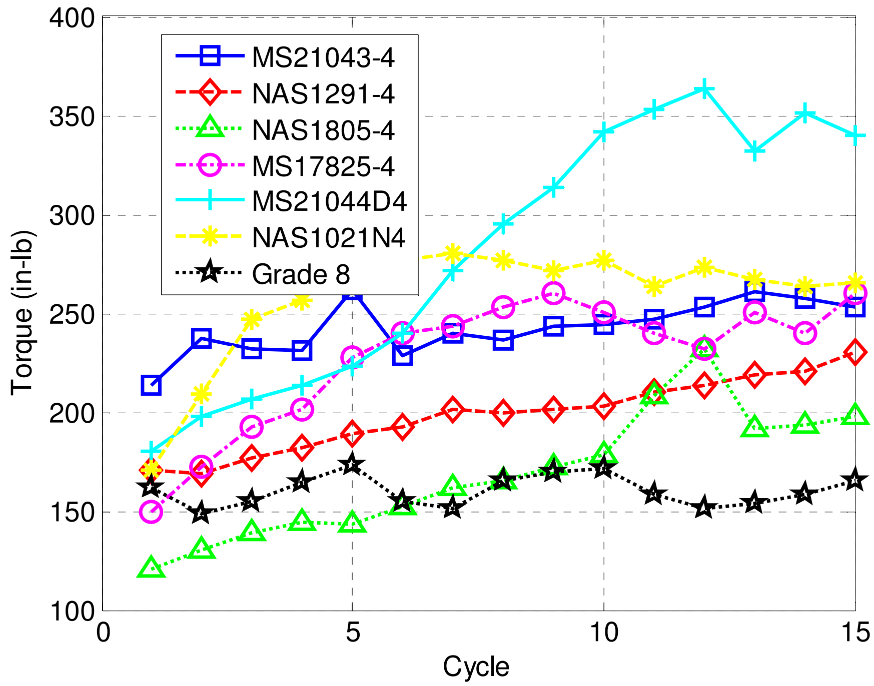

Figure 3-62: Tightening Torque; 66% Y Preload

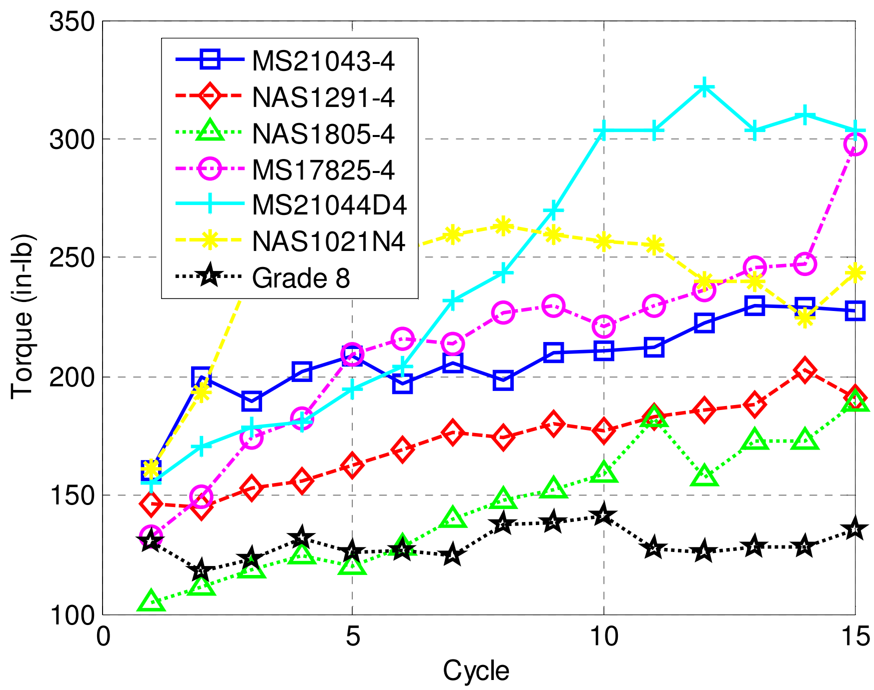

Figure 3-63: Breakloose Torque; 66% Y Preload

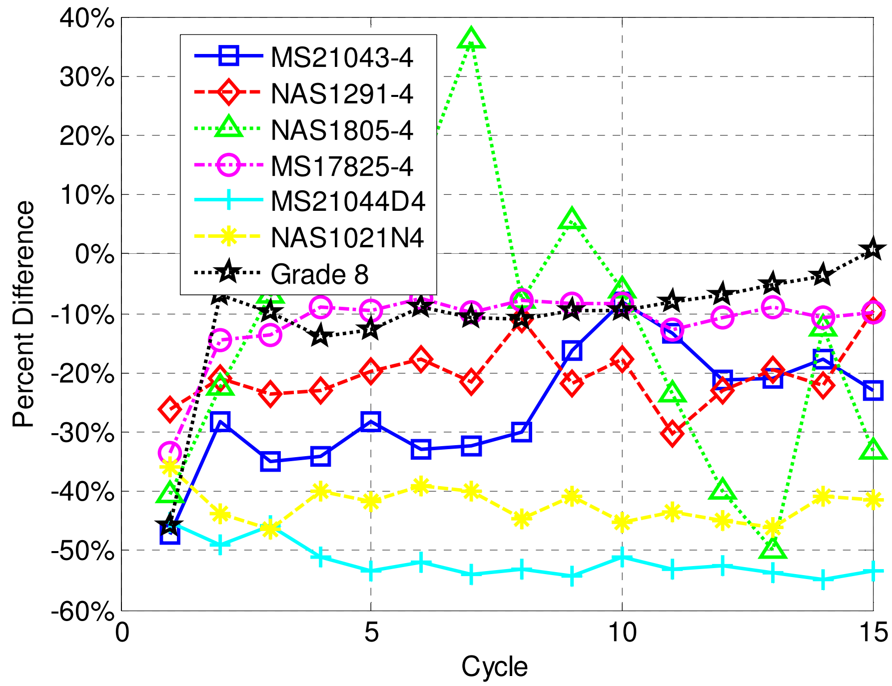

Figure 3-64: Percent Difference; 66% Y Preload

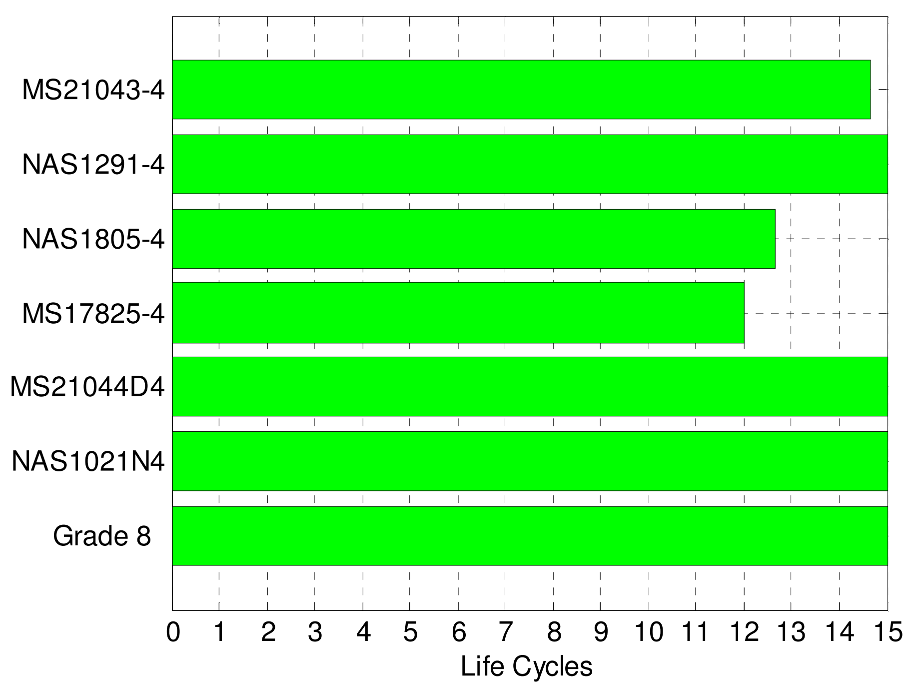

Figure 3-65: Life; 66% Y Preload

3.4.3 *75% Y Preload*

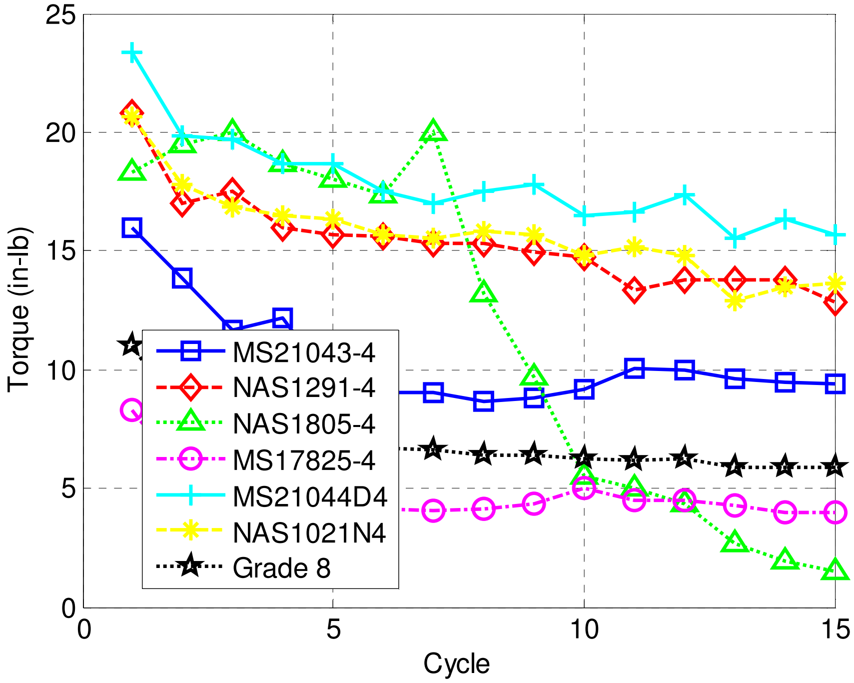

Figure 3-66: Assembly Prevailing Torque; 75% Y Preload

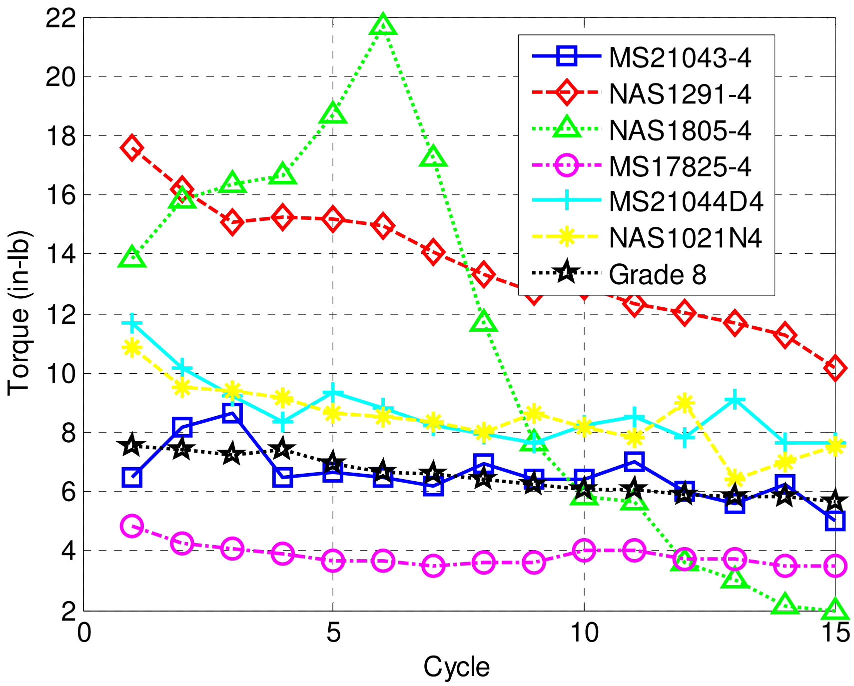

Figure 3-67: Removal Prevailing Torque; 75% Y Preload

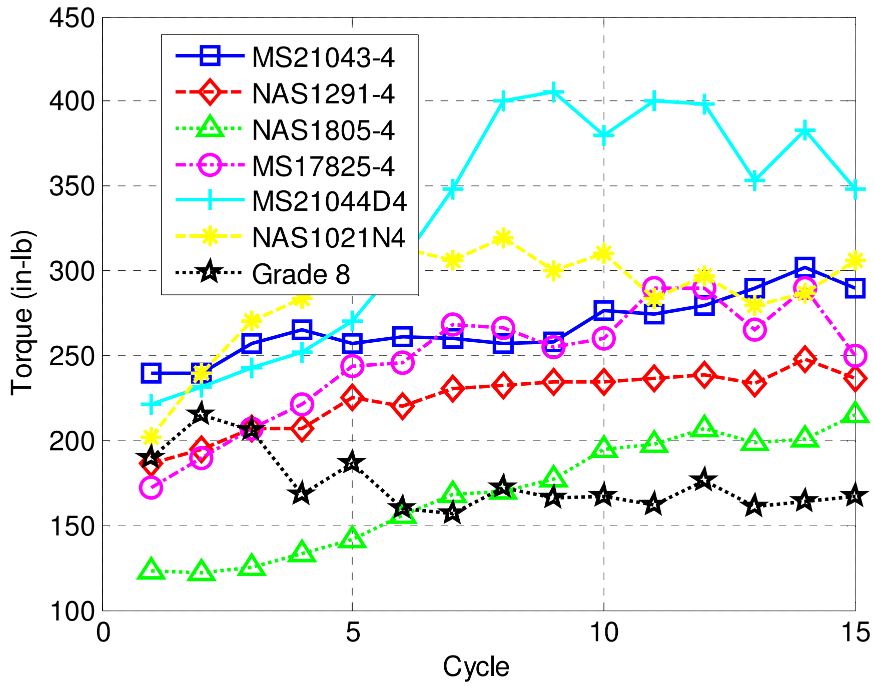

Figure 3-68: Tightening Torque; 75% Y Preload

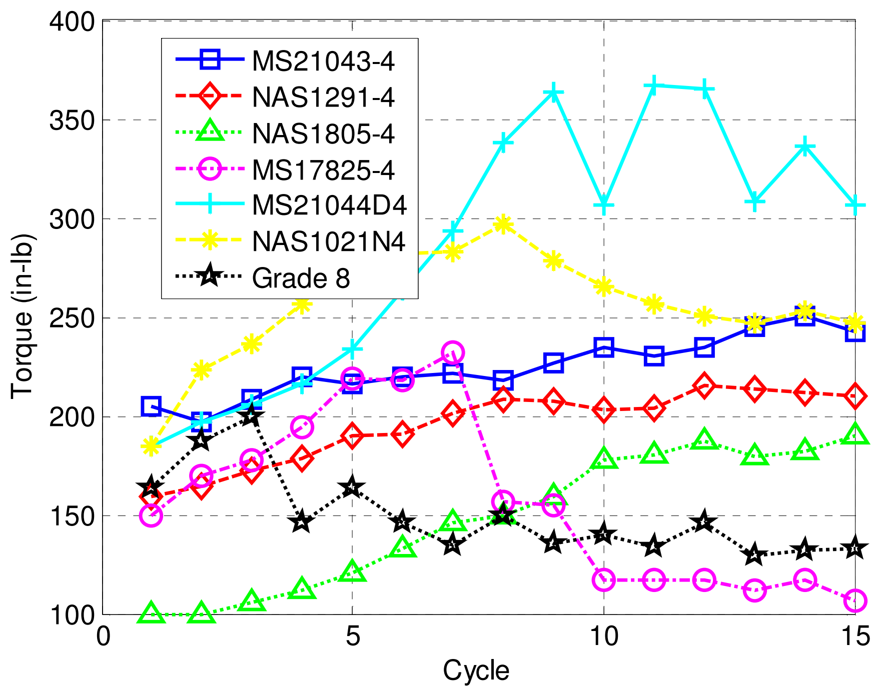

Figure 3-69: Breakloose Torque; 75% Y Preload

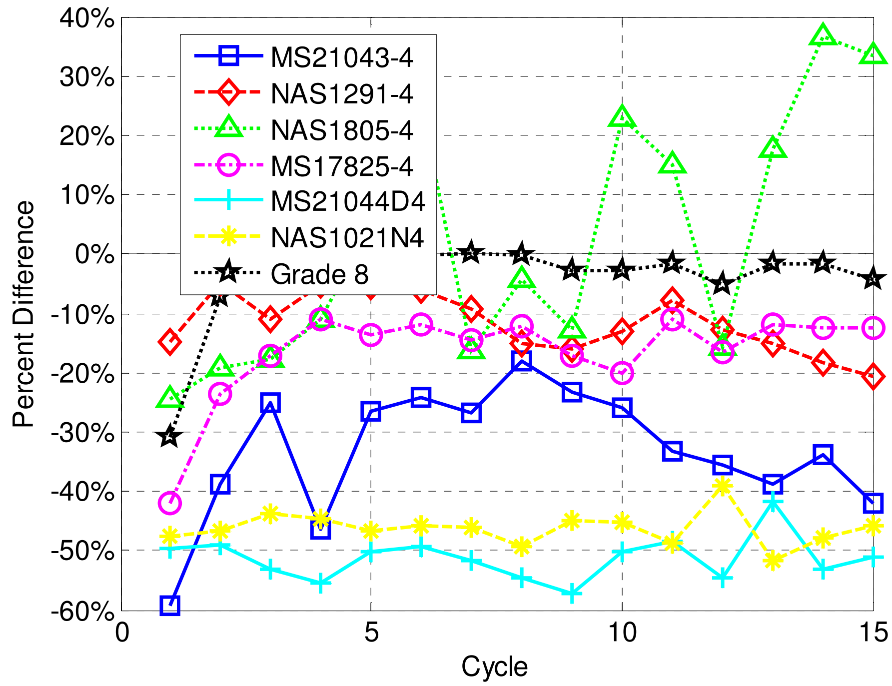

Figure 3-70: Percent Difference; 75% Y Preload

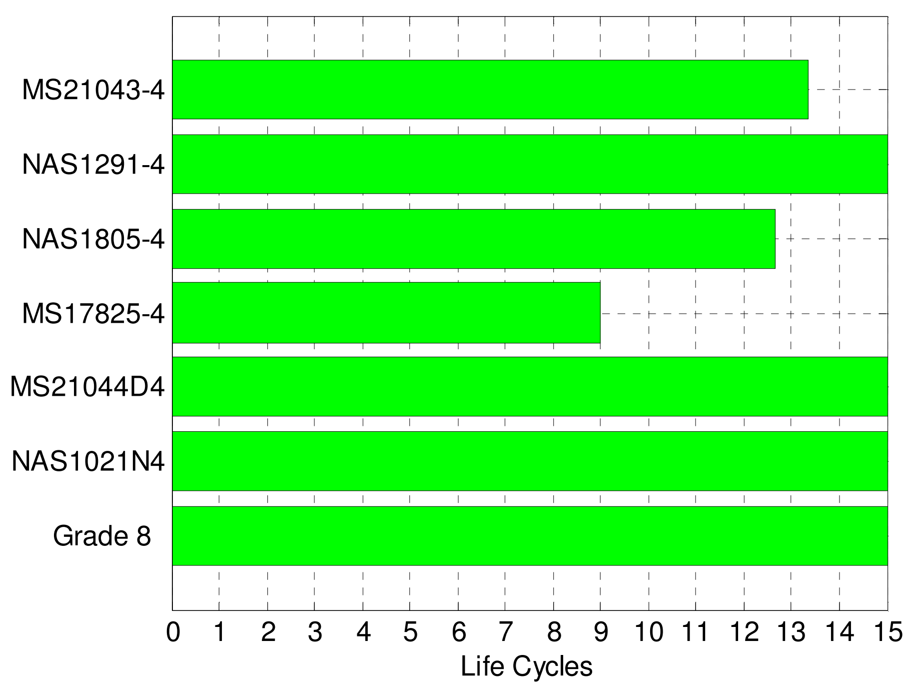

Figure 3-71: Life; 75% Y Preload

3.4.4 85% Y Preload

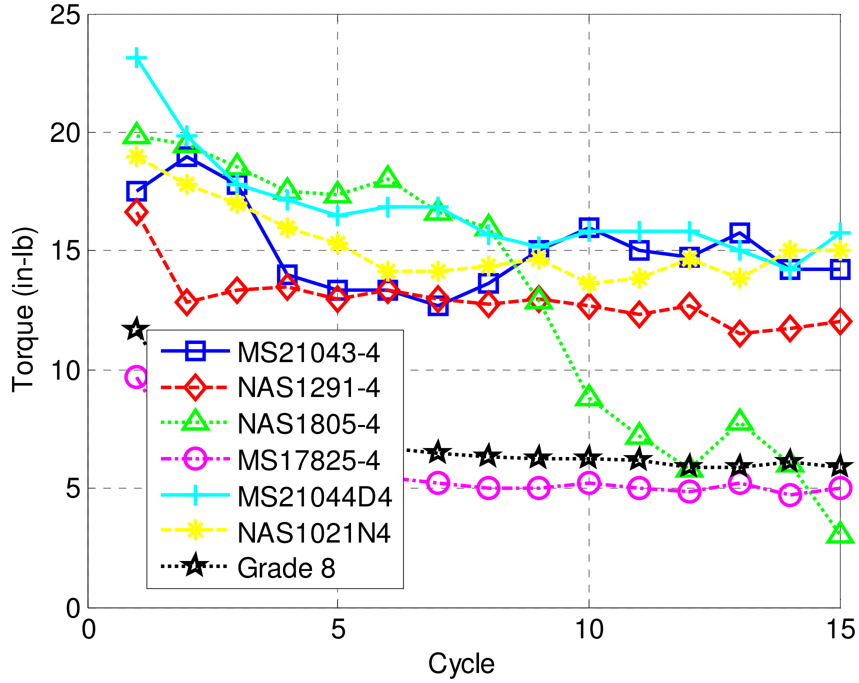

Figure 3-72: Assembly Prevailing Torque; 85% Y Preload

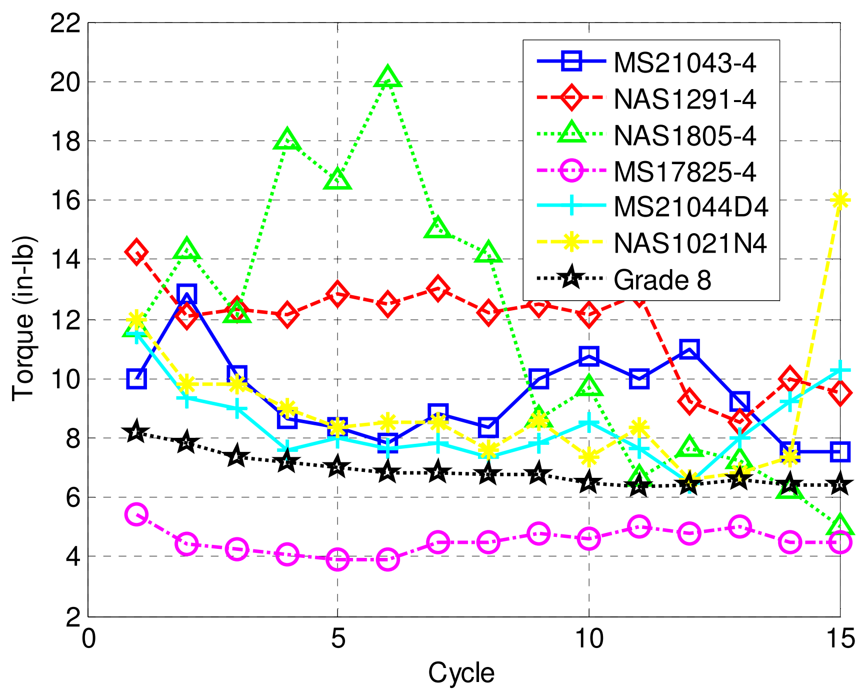

Figure 3-73: Removal Prevailing Torque; 85% Y Preload

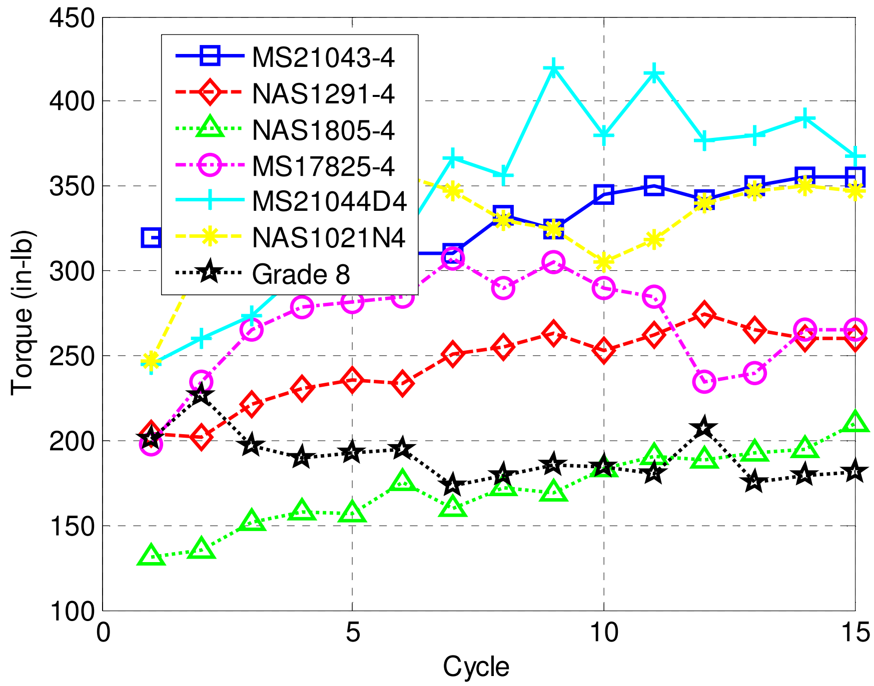

Figure 3-74: Tightening Torque; 85% Y Preload

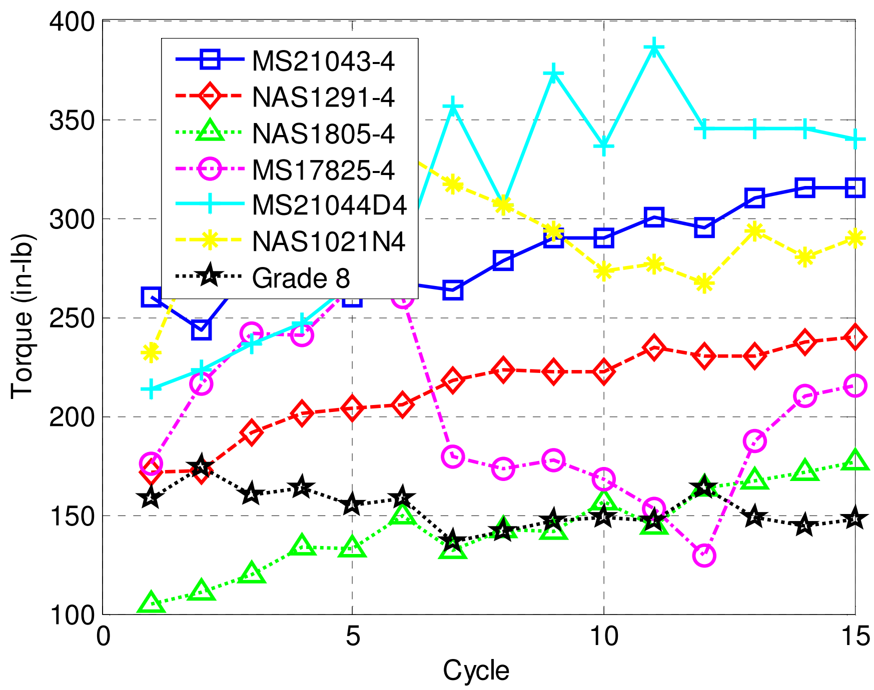

Figure 3-75: Breakloose Torque; 85% Y Preload

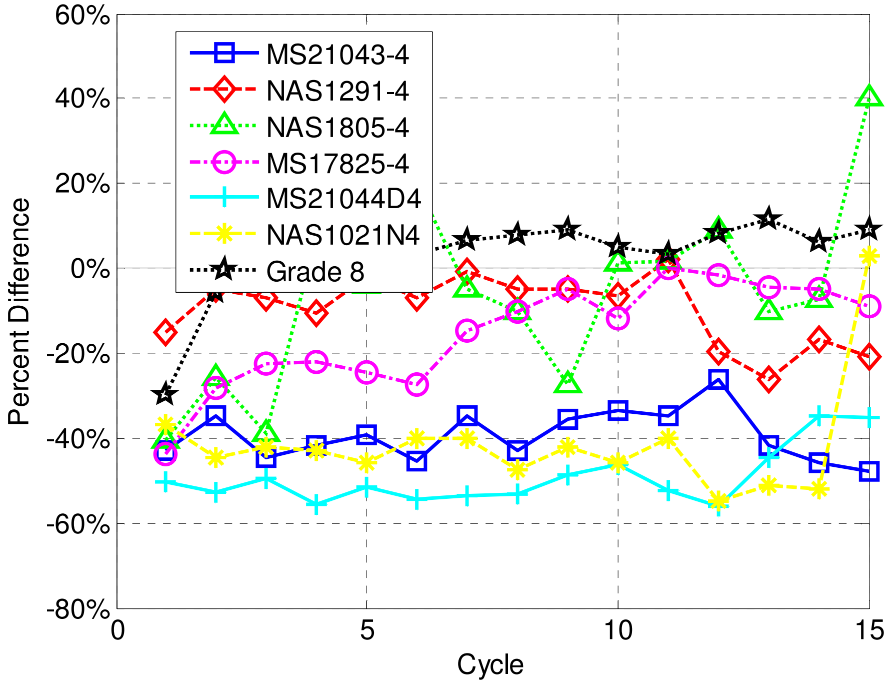

Figure 3-76: Percent Difference; 85% Y Preload

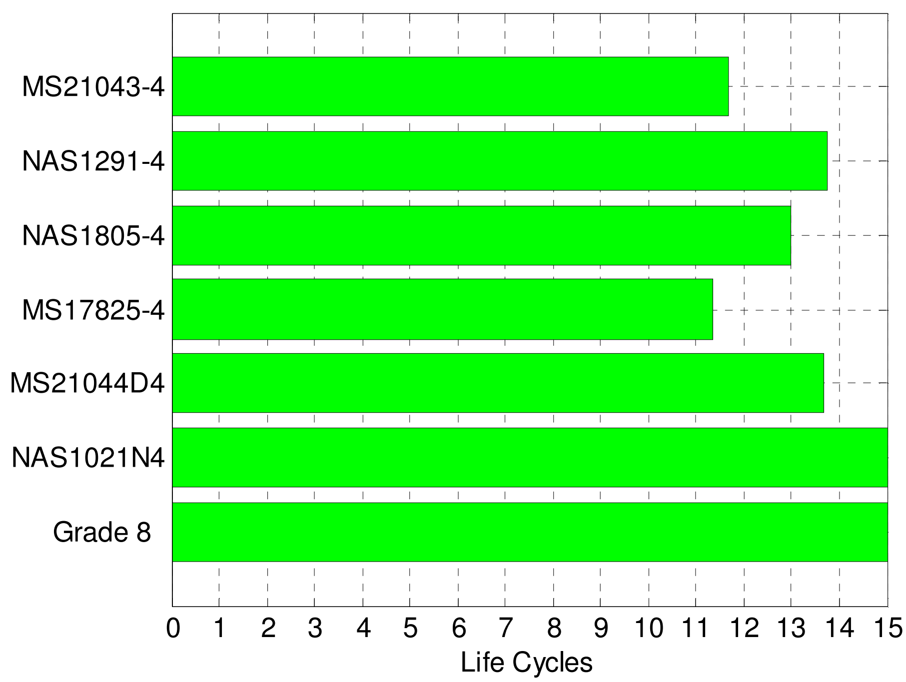

Figure 3-77: Life; 85% Y Preload

3.4.5 Averaged Preload Comparison

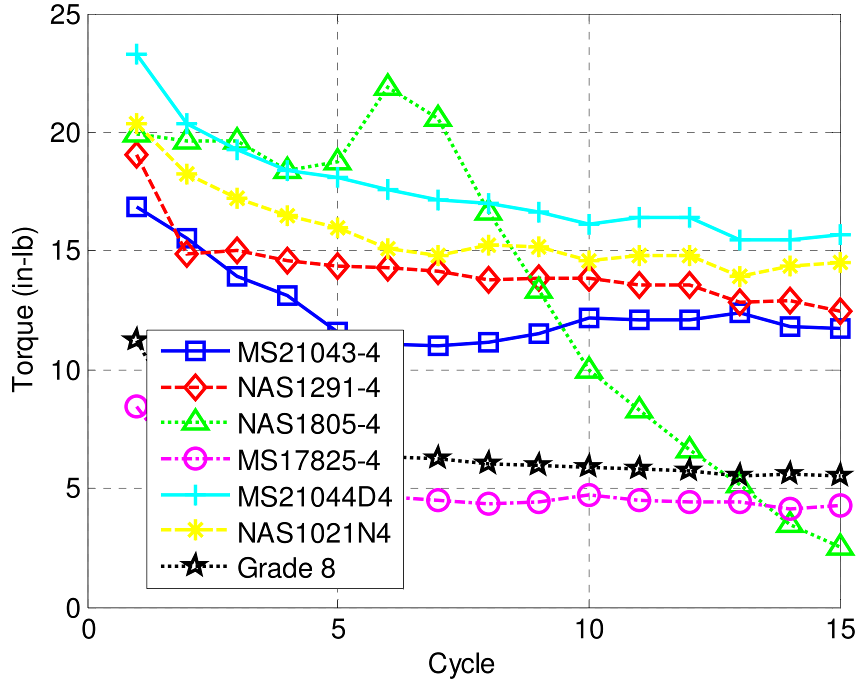

Figure 3-78: Assembly Prevailing Locknut; Averaged

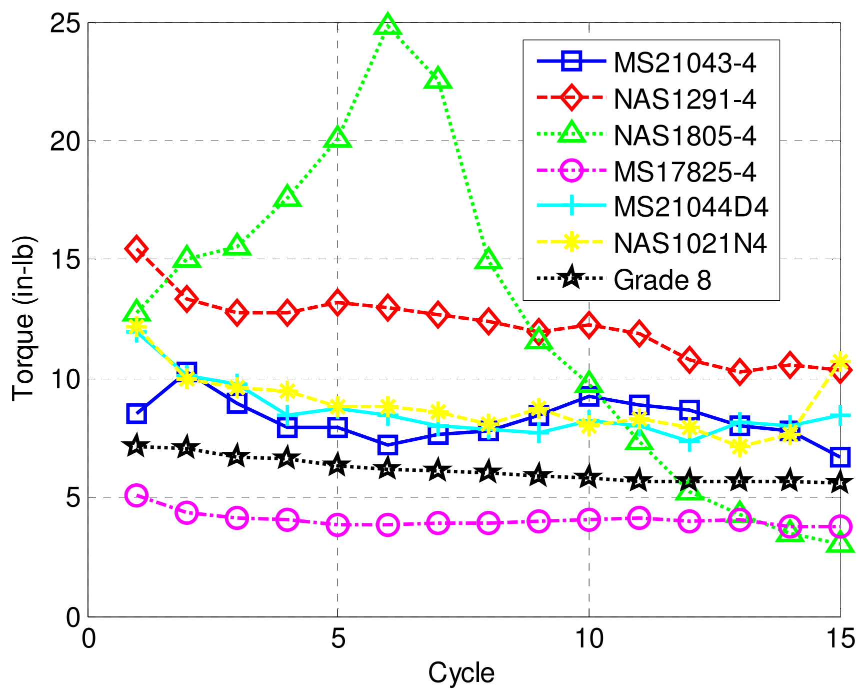

Figure 3-79: Removal Prevailing Locknut; Averaged

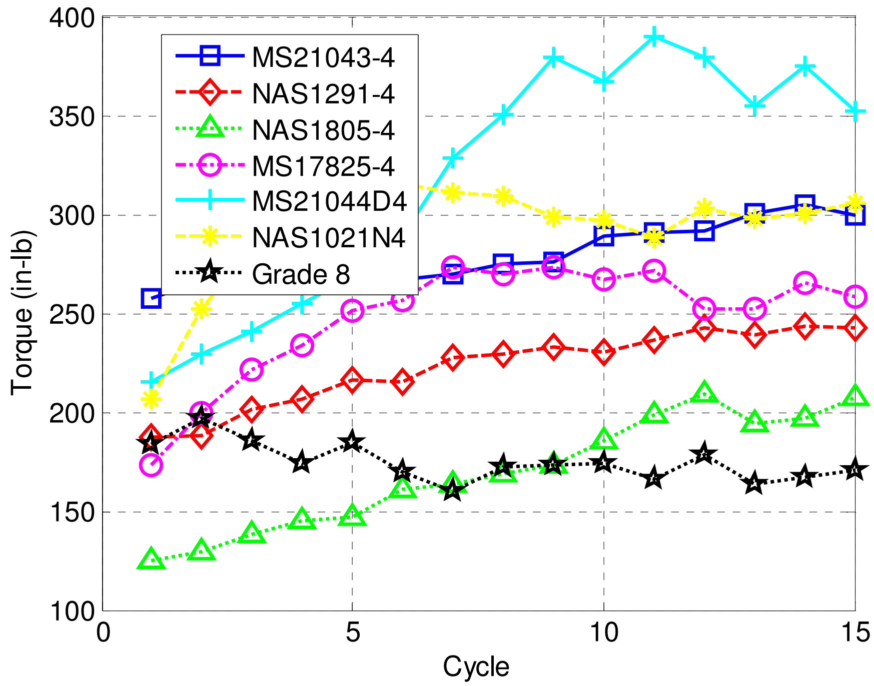

Figure 3-80: Tightening Torque Locknut; Averaged

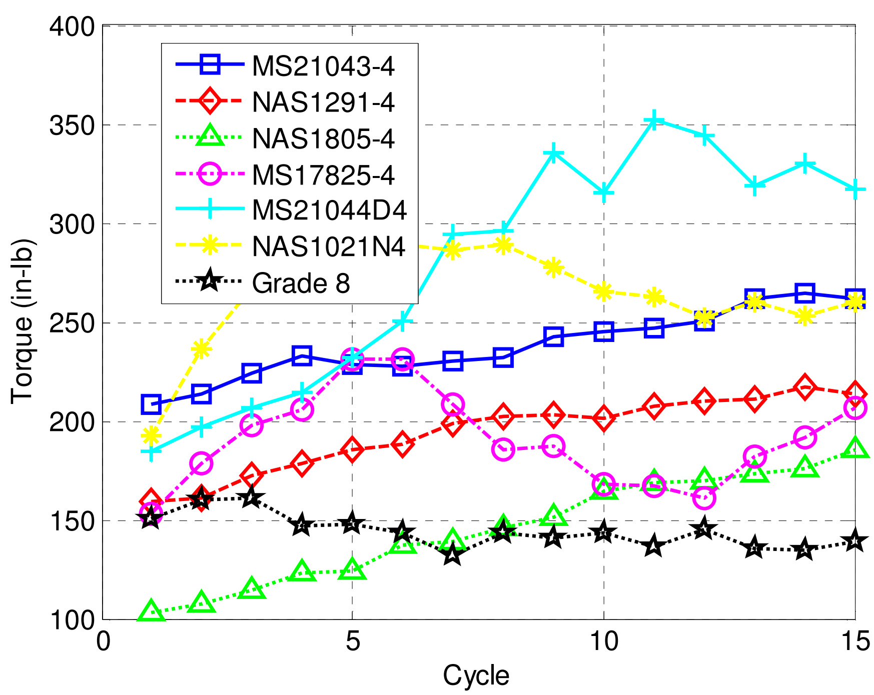

Figure 3-81: Breakloose Torque Locknut; Averaged

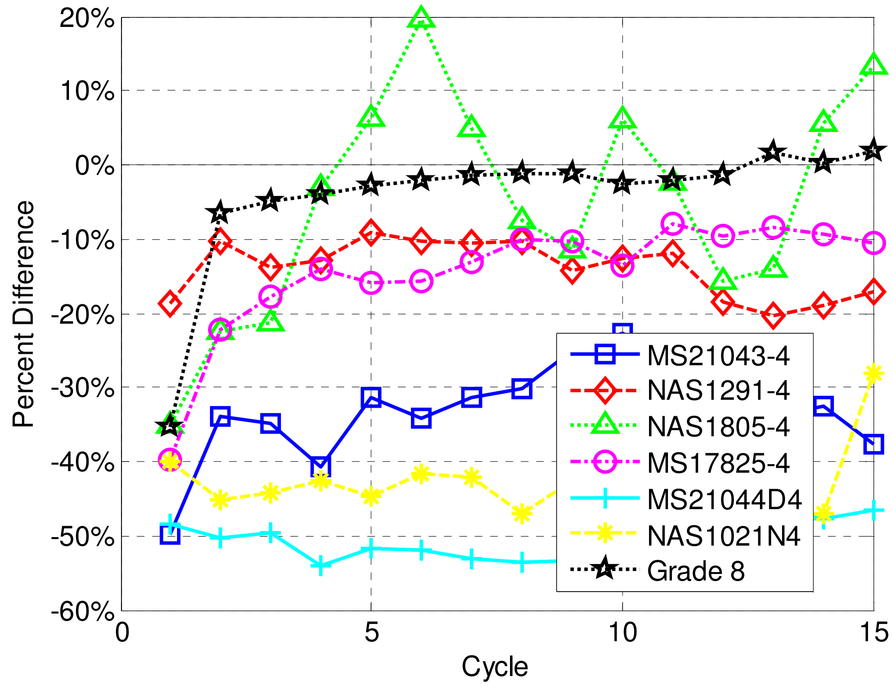

Figure 3-82: Percent Difference Locknut; Averaged

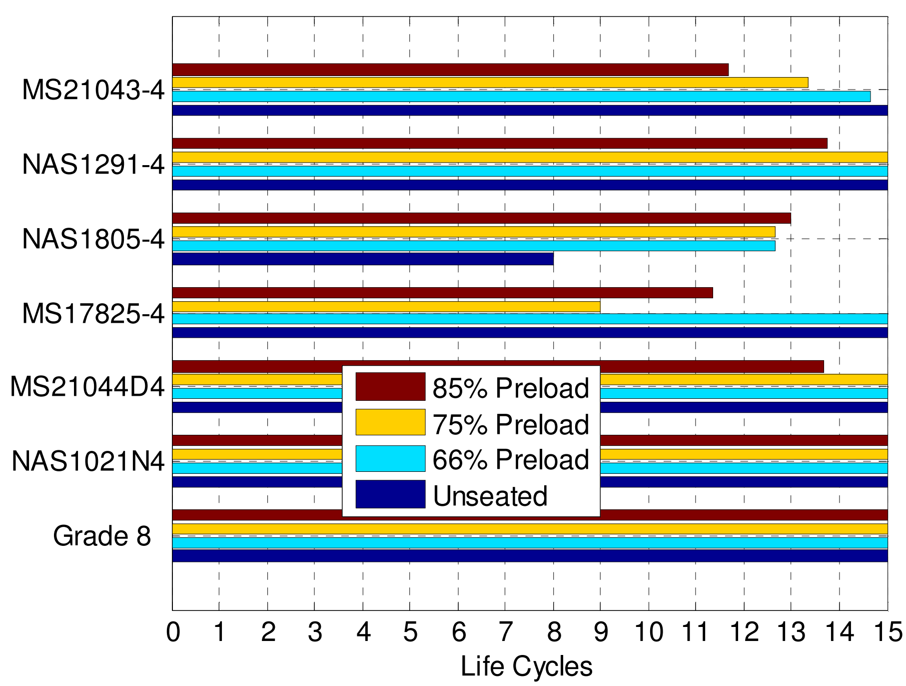

Figure 3-83: Life Locknut; Averaged

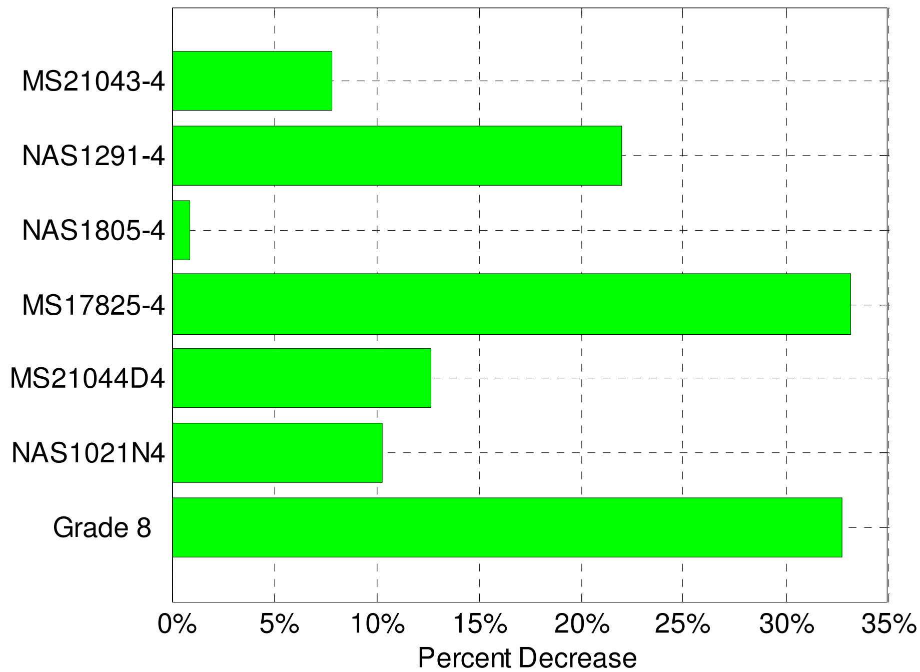

Figure 3-84: Percent Decrease Locknut; Averaged

3.5 MS21044D4 and NAS1021N4 Lubrication Comparison

Original tests performed with MS21044D4 and NAS2021N4 utilizing Castrol Braycote 601 EF lubrication, commonly used in aerospace applications. During testing it is noticed that the performance of the locknuts are lower than expected, so the tests are performed again without this lubrication. The tests without lubrication perform within the standard's requirements. This section includes figures of plotted data for MS21044D4 and NAS1021N4 without lubrication, as plotted previously, compared with plotted data with Braycote lubrication applied to the locknuts. Only figures showing the averaged preload comparison are provided in this chapter, figures with 66% Y, 75% Y, and 85% Y preload levels are available in Appendix D.7 and Appendix D.10.

3.5.1 MS21044D4 Averaged Preload Comparison

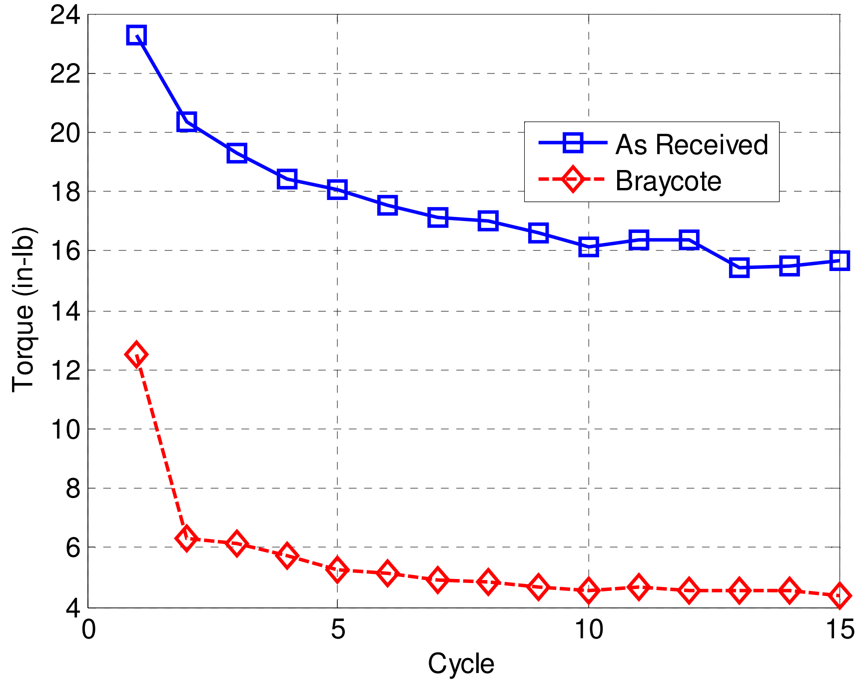

Figure 3-85: MS21044D4 Lubrication Comparison Assembly Prevailing; Averaged

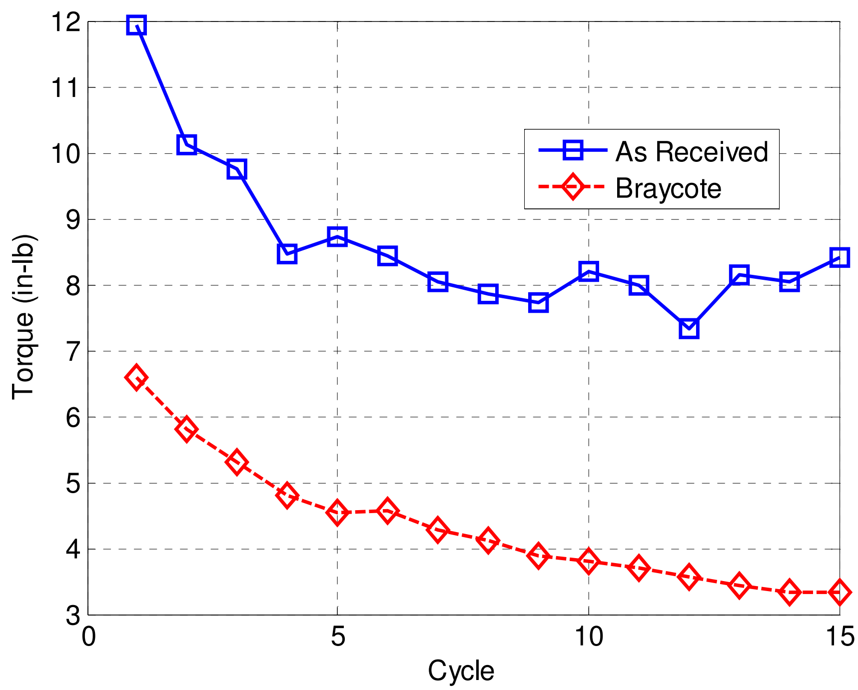

Figure 3-86: MS21044D4 Lubrication Comparison Removal Prevailing; Averaged

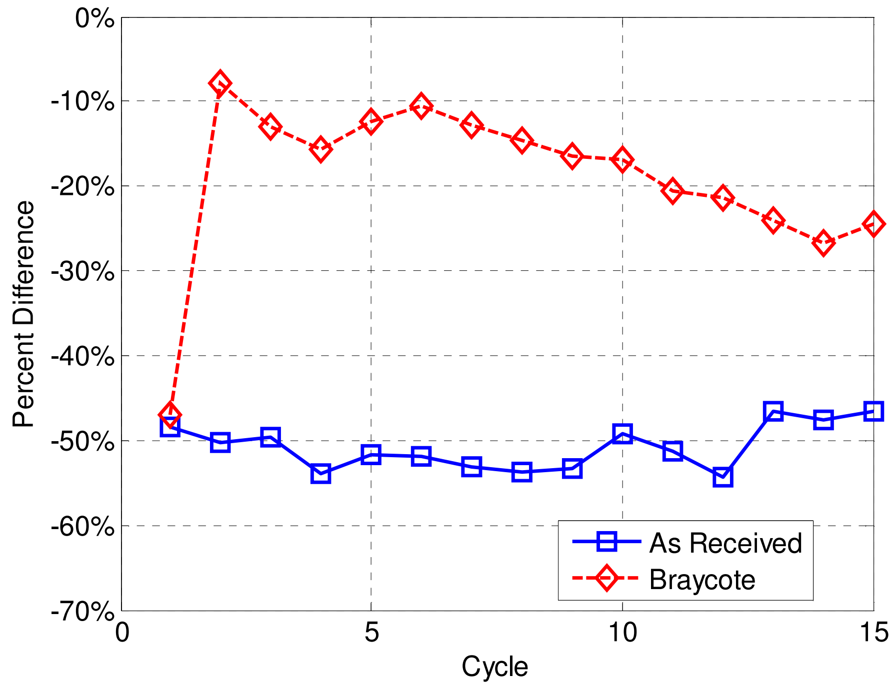

Figure 3-87: MS21044D4 Lubrication Comparison Percent Difference; Averaged

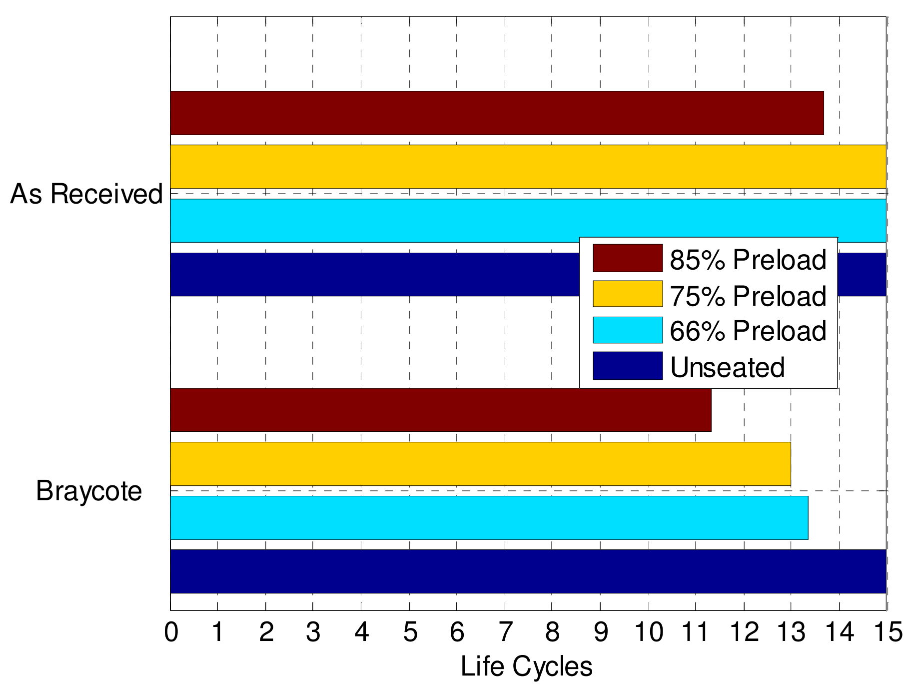

Figure 3-88: MS21044D4 Lubrication Comparison; Life Averaged

3.5.2 NAS1021N4 Averaged Preload Comparison

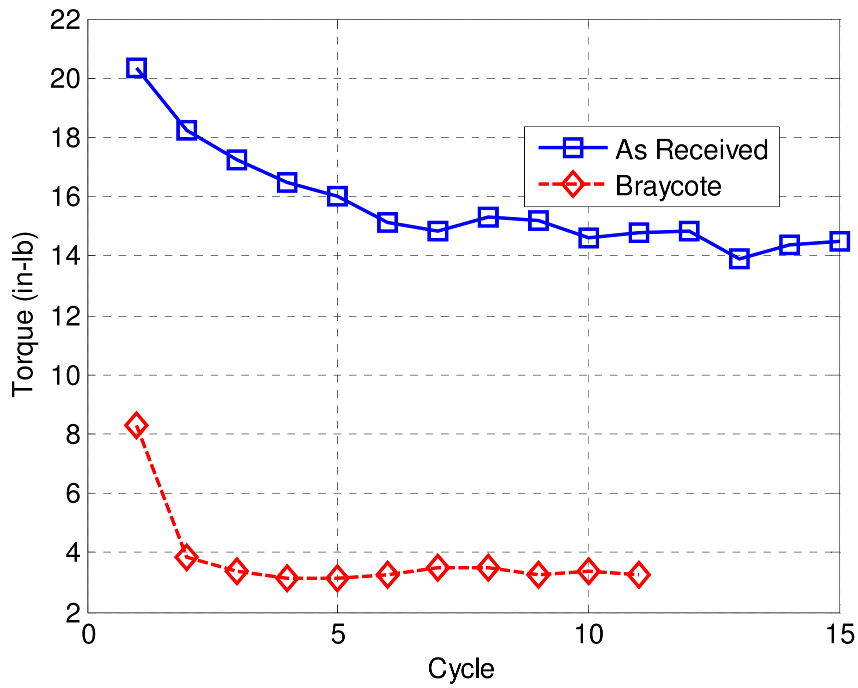

Figure 3-89: NAS1021N4 Lubrication Comparison Assembly Prevailing; Averaged

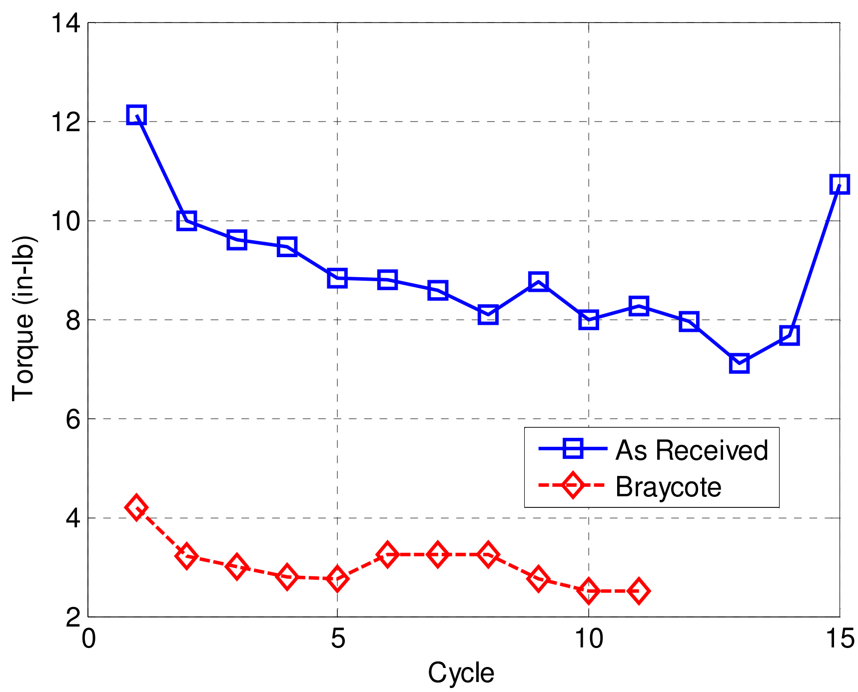

Figure 3-90: NAS1021N4 Lubrication Comparison Removal Prevailing; Averaged

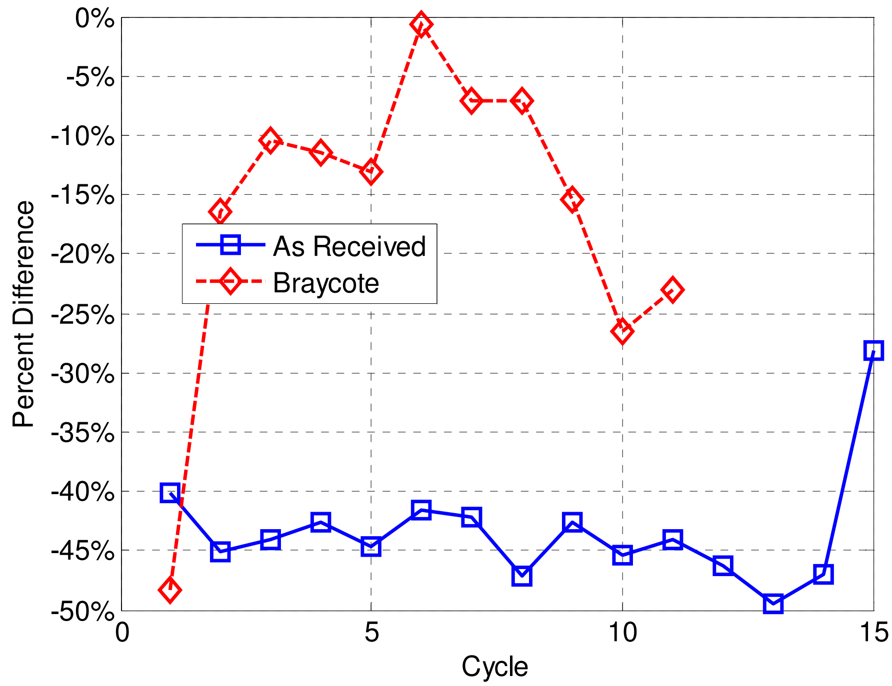

Figure 3-91: NAS1021N4 Lubrication Comparison Percent Difference; Averaged

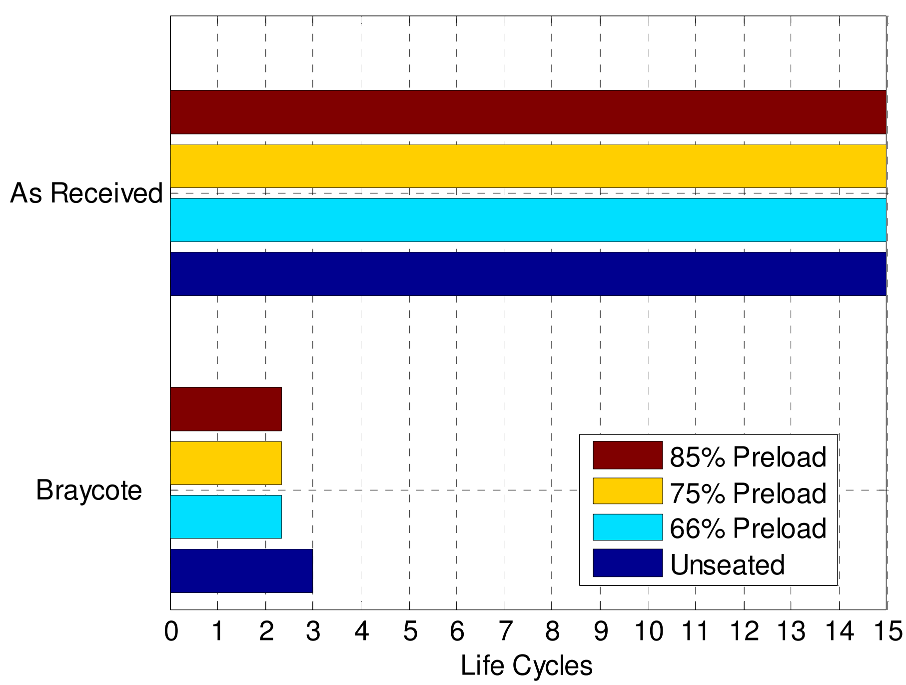

Figure 3-92: NAS1021N4 Lubrication Comparison Life; Averaged

4 Analysis and Discussion of Data

4.1 Overview

This chapter provides a detailed analysis and discussion of the data present in the previous chapter. Due to the large amount of data generated during the testing the analysis and discussion of the data is broken up into four sections in the order as the data was presented in the previous chapter. The sections are 4.2 Summary Tables, 4.3 All-Metal Locknuts, 4.4 Nylon Locknuts, 4.5 Locknut Comparison, 4.6 Nylon Locknut Lubrication Comparison, and 4.7 Torque Friction Equation. The locking feature type sections are further divided into sections describing the data plotted. Those sections are Assembly Prevailing Torque, Removal Prevailing Torque, Tightening Torque, Breakloose Torque, Percent Difference, and Reuse Life. Details of the individual locknuts without comparative description are provided in Appendix I.

For all locknuts and across all preloads the Assembly Prevailing Torque trend is a noticeable initial decrease between the first and second cycle, and then a slowly decreasing trend for the remainder of the trial. The only notable exception is NAS1805-4, where it increases rapidly and then decreases substantially over the course of the trial. This is possibly due to the locknut and test bolt both being A-286 steel, and galling may be occurring. The overall trends for the Removal Prevailing Torque were very similar to the trends for Assembly Prevailing, including for NAS1805-4. Tightening and Breakloose Torque for all aerospace grade locknuts steadily increase throughout the trial. The torques for the non-aerospace locknut, Grade 8, remain fairly constant for all cycles. The trends for percent difference differ between the locknuts. For all-metal locknuts MS21043-4 and NAS1291-4 and also nylon insert locknuts MS17825-4 and Grade 8 the overall trend is there is a large increase between the first and second cycles; followed by a plateauing of the values. Locknuts MS21044D4 and NAS1021N4 both indicate a fairly constant trend with minor oscillation through the trials. NAS1805-4 does not establish an overall trend; its values are erratic and unpredictable.

The reuse life for locknuts MS21043-4 and NAS1291-4 decreases as the applied preload level increases. For NAS1805-4 the trend is reversed, as preload increases as does its life. MS17825-4's life also decreases as preload increases, but except that life for 75% Y preload is lower than 85% Y preload. Nylon insert locknuts MS21044D4, NAS1021N4, and Grade 8 perform well regardless of preload. All three locknuts survive all 15 cycles for all preload levels, except MS21044D4 survives an average of 13.667 cycles at 85% Y preload.

The percent decrease of Assembly Prevailing Torque between cycles one and two shows no trends with respect to aerospace verses non-aerospace, all-metal verses nylon insert, etc. NAS1291-4, MS17825-4, and Grade 8 all have above a 20% decrease between the two cycles. MS21044D4 and NAS1021N4 both indicate above a 10% difference. MS21043-4 has a difference of about 7.5%, and NAS1805-4 about 1%.

4.2 Summary Tables

This section contains several summary tables of the locknuts. The data is presented in these tables to provide summary of results of the locknut's testing for all preloads. The separate summary tables are presented: locknut behavior, locknut life, and locknut damage.

The locknut behavior table, Table 4-1, is more general in nature than Tables 4-2 and 4-3, some of which is covered in more detail in the other tables. This table lists the assembly prevailing, removal prevailing, and assembly prevailing verification torques along with the trends for the tightening, Breakloose, and percent difference between the assembly and removal prevailing torques of a respective cycle. Also included in the locknut behavior table is the number of cycles the locknut survived, particles/filings present, and damage to locknut and bolt.

Locknut life table, Table 4-2, covers the life of the locknut in greater detail than the locknut behavior table provided. In this table the average number of cycles a locknut survived is presented. Also included are the median, maximum, and minimum number cycles the locknut survived.

The locknut damage table, Table 4-3, lists damage the locknuts, bolts, and washers sustained during testing. Items considered are: test bolt threads and shaft; locknut 6/12 points, threads, coating, exterior plating, and locking feature; test washer surface damage; and if any particles or chips were created during testing.

Table 4-1: Locknut Summary Table

Locknut	Preload %	Assembly Prevailing Torque Trend	Removal Prevailing Torque Trend	Assembly Prevailing Verification Torque Trend	Tightening Torque Trend	Breakloose Torque Trend	Percent Difference Trend	Number of Cycles Locknut Survived	Damage* to Locknut	Damage* to Bolt	Particles/ Filings Present
MS21043	66%	-18.63%	9.26%	-20.00%	Steady -> (+)	Steady -> (+)	-40.43%	14.66667	St & Ct	No	Yes
	75%	-13.54%	25.64%	-21.43%	Steady -> (+)	Steady -> (+)	-34.65%	13.33333	St & Ct	No	Yes
	85%	8.57%	28.33%	-9.09%	Steady -> (+)	Steady -> (+)	-18.46%	11.66667	St & Ct	No	Yes
NAS1291	66%	-24.41%	-19.54%	0.00%	(+)	(+)	-20.03%	15	St, Ct	No	Yes
	75%	-18.56%	-8.06%	-7.14%	(+) -> Steady	(+) -> Steady	-66.27%	15	St, Ct	No	Yes
	85%	-23.00%	-15.20%	-5.00%	(+)	(+) -> Steady	-68.02%	13.75	St, Ct	No	Yes
NAS1805	66%	-7.36%	17.11%	19.35%	(+)	(+)	-44.92%	12.66667	Ct, Sf	DL	Yes
	75%	6.36%	14.46%	72.00%	(+)	(+)	-20.97%	12.66667	Ct, Sf	DL	Yes
	85%	-1.68%	22.86%	-9.09%	(+)	(+)	-36.52%	13	Ct, Sf	DL	Yes
MS17825	66%	-30.34%	-10.17%	-11.54%	(+) -> (±)	(+)	-56.46%	12	St & Ct	No	No
	75%	-33.00%	-12.07%	-18.75%	(+) -> (±)	(+) -> (-) -> Steady	-43.47%	9	St & Ct	No	No
	85%	-36.21%	-18.46%	-15.38%	(+) -> Steady -> (-)	(+) -> (-) -> (+)	-35.60%	11.33333	St & Ct	No	No
MS21044D4	66%	-8.57%	-14.47%	-13.95%	(+) -> Steady	(+) -> Steady	8.49%	15	C, DL, Ct, Sn	No	No
	75%	-15.00%	-12.86%	-4.88%	(+) -> Steady	(+) -> Steady	-1.00%	15	C, DL, Ct, Sn	No	No
	85%	-14.39%	-18.84%	-13.58%	(+)	(+) -> Steady	4.59%	13.66667	C, DL, Ct, Sn	No	No
NAS1021N4	66%	-10.94%	-21.47%	-5.13%	(-) -> Steady	(-) -> Steady	22.27%	15	DL, Ct, Sn	No	No
	75%	-13.71%	-12.31%	-21.43%	Steady -> (-)	Steady -> (-)	-2.04%	15	DL, Ct, Sn	No	No
	85%	-6.14%	-18.06%	-11.90%	(-)	(-)	21.40%	15	DL, Ct, Sn	No	No
Grade 8	66%	-42.42%	2.94%	-35.00%	(±)	Steady	-84.66%	15	DL, Sn	No	No
	75%	-27.27%	-1.11%	0.00%	(±) -> Steady	(+) -> (-)	-76.43%	15	DL, Sn	No	No
	85%	-28.57%	-4.08%	20.00%	Steady	Steady	-81.20%	15	DL, Sn	No	No

* All damage determined through inspection by unassisted eyes
All Values are averages/estimates over Trials 2,3, and 4 performed
All Prevailing Torque values are for difference between Cycle 1 and 2 only
Assembly Prevailing Verification Torque Trend data from Trial 1

		Standard (St)	: Normal wear
(+)	Increasing	Cone (C)	: Locking feature created a conical deformation (/ \)
(-)	Decreasing	Delamination (DL	: Delamination resulting in chips of material (from Bolt or Locking Feature)
(±)	Oscillating	Coating (Ct)	: Locknut's thread's coating was damaged
Steady	Values Leveled Off	Scuffing (Sf)	: Scuffing occurred(metal transfer from Bolt to Locking Feature)
->	Then	Scoring (Sn)	: Scoring of nylon locking feature

Table 4-2: Locknut Life Summary

Locknut	Preload %	Average Number of Cycles Locknut Survived	Minimum Number of Cycles Locknut Survived	Maximum Number of Cycles Locknut Survived	Median Number of Cycles Locknut Survived
MS21043	**66% Y**	12.00	4	15	14.5
	75% Y	10.75	3	15	12.5
	85% Y	12.00	5	15	14
NAS1291	**66% Y**	15.00	15	15	15
	75% Y	15.00	15	15	15
	85% Y	13.75	11	15	14.5
NAS1805	**66% Y**	11.75	9	14	12
	75% Y	11.50	8	14	12
	85% Y	11.50	7	15	12
MS17825	**66% Y**	12.75	11	15	12.5
	75% Y	10.50	5	15	11
	85% Y	10.25	4	15	11
MS21044D4	**66% Y**	15.00	15	15	15
	75% Y	15.00	15	15	15
	85% Y	14.00	11	15	15
NAS1021N4	**66% Y**	15.00	15	15	15
	75% Y	15.00	15	15	15
	85% Y	15.00	15	15	15
Grade 8	**66% Y**	15.00	15	15	15
	75% Y	15.00	15	15	15
	85% Y	15.00	15	15	15

Locknut fails when prevailing torque value exceeds the range 3.5 - 30 in-lb
All Values are averages over all trials performed

Table 4-3: Locknut Damage Table

Locknut	Preload %	Bolt Threads Damage*	Bolt Shaft Damage*	Locknut 6/12 Points Damage*	Locknut Threads Damage*	Locknut Thread Coating Damage*	Locknut Exterior Plating Damage*	Locknut Locking Feature Damage*	Washer Damage*	Particles Present Damage*
MS21043	66%	No	No	Mw	No	w	B & P	wm	nw	Yes
	75%	No	No	Mw	No	w	B & P	wm	nw	Yes
	85%	No	No	Mw	No	w	B & P	wm	nw	Yes
NAS1291	66%	No	No	No	No	Sw	B & P	wm	minw	No
	75%	No	No	No	No	Sw	B & P	wm	nw	No
	85%	No	No	Mw	No	Sw	B & P	wm	nw	Yes
NAS1805	66%	w	No	No	No	Sw	B	wm & Sf	nw	Yes
	75%	w	No	Mw	No	Sw	B & P	wm & Sf	nw	Yes
	85%	w	No	Mw	No	Sw	B & P	wm & Sf	nw	Yes
MS17825	66%	No	No	No	No	Sw	B & P	Sn & DL	minw	No
	75%	No	No	No	No	Sw	B & P	Sn & DL	minw	No
	85%	No	No	No	No	Sw	B & P	Sn & DL	nw	No
MS21044D4	66%	No	No	No	No	Sw	S	Sn, DL, & C	minw	Yes
	75%	No	No	No	No	Sw	S	Sn, DL, & C	minw	Yes
	85%	No	No	No	No	Sw	S	Sn, DL, & C	nw	Yes
NAS1021N4	66%	No	No	No	No	Sw	B, P, & S	Sn & DL	minw	Yes
	75%	No	No	No	No	Sw	B & P	Sn & DL	minw	Yes
	85%	No	No	No	No	Sw	B & P	Sn & DL	nw	Yes
Grade 8	66%	No	No	No	No	Mw	P	Sn	nw	No
	75%	No	No	No	No	Mw	P	Sn	majw	No
	85%	No	No	No	No	Mw	P	Sn	majw	No

* All damage determined through inspection by unassisted eyes, across all trials

No -> Nothing noticable
Sw -> Severe wear
w -> wear
Mw -> mild wear

S -> Sides
B -> Bottom
P -> Points (6/12)
Sn -> Scoring of nylon
DL -> Delaminatin of nylon
C -> Conical (/ \) shape created in nylon

minw -> minor wear (almost unnotiable)
nw -> noticable wear (clearly seen, average wear)
majw -> major wear (significant)
wm -> wear of metal locking feature
Sf - > Scuffing (metal transfer)

4.3 All-Metal Locknuts

4.3.1 Overview

This section describes Figures 3-1 to 3-28 of the All-Metal type locknuts for all preload values. The all-metal locknuts are MS21043-4, NAS1291-4, and NAS1805-4. The sections describe the measured torque data for all preload levels together.

4.3.2 Assembly Prevailing Torque

The plots described in this section are Figures 3-1, 3-4, 3-10, 3-16, and 3-22. The Assembly Prevailing Torque indicates similar trends for all three locknuts throughout testing unseated, 66% Y Preload, and 75% Y Preload. During unseated 66% Y preload testing, MS2104304 and NAS1291-4 values decrease for the first three cycles then level off for the remaining cycles of the trials. The decrease is minor for both, remaining well above the minimum torque value of 3.5 in-lbs. It seems unseated and 66% Y preload only cause mild damage to the locking feature for the first three cycles and then any further damage is negligible. The trends for unseated and 66% Y preload are very similar to the trend for 75% Y preload for MS21043-4 and NAS1291-4. At 75% Y the decrease in torque occurs for the first five cycles, and then levels off above the required 3.5 in-lb.

With a preload of 85% Y, there is more scatter in prevailing torque. MS21043-4 at first experiences a minor increase in torque between cycles one and two, then decrease for cycles 3 and 4 where the torque levels offs. After cycle 7, the torque begins to increase until cycle ten where it plateaus for the remaining cycles. This erratic trend may be due to locking feature damage or particles contaminated the threads resulting in increased friction in the later cycles. NAS1291-4 behaved similar as previous preloads except the torque decrease was significantly larger for the 85% Y preload.

NAS1805-4 trends and behaviors indicate major differences for each of the loadings subjected to the locknut. In unseated testing, the torque rose for the first 5 cycles and then decreases very rapidly for the next 5 cycles, losing about 80% of measured torque. After the substantial decrease, the torque measurements stabilized. This behavior seems to be caused by the locknut damaging the test bolt's threads. Initially the damage cases increased friction, and then the threads are damaged to the point where they can no longer maintain substantial torque. The Rockwell C Scale rating for NAS1805-4 is 49, where the test bolt's rating was much lower at 32. This large difference in hardness of the metals of the locknut and test bolt possibly leads to the damage sustained by the bolt. It appears to be that the bolt damage caused thread interference. Initially the chips, from the test bolt threads, created by the locknut by damaging the bolt could be contaminating the threads causing increased friction and ultimately higher torque measurements. The substantial decrease appears to be caused by the continued removal of the test bolt's threads leaving little left to sustain torque measurement levels. Also since both the test bolt and locknut are A-286 steel galling occurred.

At 66% Y preload locknut NAS1805-4 torque values are stable for the first 5 cycles. Between cycle 5 and cycle 6 a large increase in torque occurs. After cycle 6 the torque decreases very rapidly until cycle 14 where it levels off. This behavior is also likely due to the test bolt damage as it was for the unseated testing. For the preload of 75% Y, the behavior is similar to that of the 66% Y preload testing. The torque is constant for the first 6 cycles, increases for one cycle then rapidly decreases. This continues until cycle ten, when the decrease slows considerably but the torque level is maintained for the remainder of the trial. The behavior at 85% Y preload starts off with a mild decreasing trend for eight cycles, then decreases significantly(losing almost half its torque quality) during cycles eight through ten. After cycle ten the decrease in torque lessens to a slower rate for the remaining of the trial with a minor increase at cycle 13. The damage the locknut subjects to the test bolt seems to be the primary driver to the initial increases in torque then the rapid decreases after the first several cycles.

4.3.3 Removal Prevailing Torque

The plots described in this section are Figures 3-2, 3-5, 3-11, 3-17, and 3-23. The Removal Prevailing Torque indicates similar behavior for the three locknuts across all preload variations. Changes in torque for MS21043-4 are fairly comparable throughout all four preloads. The torque measurements do not vary any great deal through a trial. Torque measurements are constant, only oscillating a minor amount during each cycle by less than 10%. As the preloads increase the oscillations in the previous preload become more exaggerated. The trends are more or less the same, simply the magnitude of the variations occurring increase. This increase in the magnitude remains relatively small, never growing larger than 25%.

NAS1291-4 indicates a constant torque for the unseated and 66% Y preload testing. The torque decreases only slightly between the first and second cycle then levels off for the remainder of the trial. For 75% Y preload indicates a slow decreasing torque throughout the trial, losing about 45% of the original torque measurement from cycle one to fifteen. At 85% Y preload, the torque decreases between the first and second cycle and levels off, matching the trends for the unseated and 66% Y preloads until cycle 11. The torque decreases noticeably between cycle 11 and 12, and fluctuates for the remainder of the trial.

NAS1805-4 shows the most resemblance between preload levels. Each plot has a slight increasing trend for the first few cycles, and then a significant increase occurs for the next two to four cycles. After the large increase a very significant decrease occurs through about the next ten cycles, causing the loss of around 70% of its peak torque value. The last few cycles either level off or decrease at a substantially slower rate. As mentioned in the discussion of the Assembly Prevailing Torque, this large increase then significant decrease in torque is likely due to the locknut damaging the test bolt.

4.3.4 Tightening Torque

The plots described in this section are Figures 3-6, 3-12, 3-18, and 3-24. Tightening Torque for all three locknuts is very similar not only throughout each preload level, but also with each other. Each locknut's torque during tightening slowly increase line. The slope is near parallel for each locknut with respect to each other over all the preload levels. During 66% Y preload locknuts MS21043-4 and NAS1805-4 experienced a sudden increase at cycle 5 and cycles 11 and 12 respectively. After the increase at the mentioned cycles, the tightening torque returned to its previous trend. The tightening torque increasing slowly over the trials is to be expected. As the locknut experiences reuse the threads of both the locknut and test bolt experience wear, caused by the presence of particles after each cycle. Also the lubrication from the locknuts is worn away. Both these factors are increasing the friction between the locknut and the test bolt, causing the increase in torque required to achieve a desired preload.

4.3.5 Breakloose Torque

The plots described in this section are Figures 3-7, 3-13, 3-19, and 3-25. The Breakloose Torque for each locknut is analogous to each other as well as each preload. These trends are also very similar to the trends indicated in the Tightening Torque. The Breakloose Torque follows a slowly increasing path for the entirety of the trial. There is more oscillation in the torque for Breakloose than Tightening, though it is minimal. This is possibly due to the increase static friction the locknut experiences under preload. As in the Tightening Torque NAS1805-4 has a sudden increase in torque at cycle 11 and then returns to the established trend. MS21043-4 Breakloose Torque increased significantly between cycles 1 and 2. It also has an increase at cycle 5 as it did with the Tightening Torque, though the magnitude is far less.

4.3.6 Percent Difference

The plots described in this section are Figures 3-8, 3-14, 3-20, and 3-26. Plots of the percent difference between the assembly prevailing and removal prevailing torques is not always easy to interpret. Some locknuts percent difference simply has too much fluctuation to be of much use. The percent difference for NAS1805-4 is particularly noisy for all preloads. The fluctuations of the percentage make it difficult to pull any useful information from the plot. On the other hand, the percent difference plots for MS21043-4 and NAS1291-4 are stable enough to interpret.

For MS21043-4 the percentage difference between the assembly and removal prevailing torques loitered around -20 to -30% for 66% Y preload and around -30 to -40% for 75% Y and 85% Y preloads. This indicates that the removal prevailing torque was most often proportionally 20-40% less than the assembly prevailing torque.   The percent difference for NAS1291-4 remained around -20% for 66% Y preload and -10% for 75% Y and 85% Y preloads; indicating that the removal prevailing torque was generally 10 to 20% less than the assembly prevailing torque.

4.3.7 Reuse Life

The plots described in this section are Figures 3-3, 3-9, 3-15, 3-21, and 3-27. The unseated tested life for locknuts MS21043-4 and NAS1291-4 is 15 cycles as set by their respective standards. The life for NAS1805-4 is only 8 cycles; this is far below the minimum of 15 cycles for unseated life. The failures occurred either due to the prevailing torque increasing beyond the maximum of 30 in-lb or decreasing below the minimum of 3.5 in-lb. Inspection of the locknut and test bolt indicates the failure seems to be occurring in the test bolt and not in the locknut’s locking feature itself. As mentioned previously the hardness of the locknut is significantly larger than that of the test bolt. This is likely causing the locknut to damage the test bolt's threads beyond the point of maintaining preload within ranges set by the standards.

As the preload increased the life of locknuts MS21043-4 and NAS1291-4 decreased.   This behavior is to be expected due the increase in force applied causing further damage to the locking feature and limiting its ability to maintain preload. Interestingly, as preload increased, the life for NAS1805-4 also increased. The increase is marginal between the seated trials, but much more pronounced when comparing the unseated life verses the seated. The seated locknuts survived on average an additional 4.7 cycles longer than the unseated locknuts. This could be due to the increased preload causes the thread's surface to smooth during damage, while under lower preloads any containment in the threads could have increase the roughness of the thread's surface.

4.4 Nylon Locknuts

4.4.1 Assembly Prevailing Torque

The plots described in this section are Figures 3-29, 3-32, 3-38, 3-44, and 3-50. The Assembly Prevailing Torque for the four nylon insert locknuts all follow a similar path. The trend is also maintained through each preload level. There is a noticeable decrease in the torque between the first and second cycle, then the torque is a slower decreasing slope through the remaining cycles. The decrease in torque between the first and second cycle increases as the preload increases. Other than this magnitude the prevailing torque remains fairly constant with regards to locknut and preload. Locknuts

MS17825-4 and Grade 8 torques have a very slight decreasing slope after cycle 2. The torque measurements do not decrease by a significant amount after the initial decrease between cycle one and two. For locknuts MS21044D4 and NAS1021N4 the decreasing slope is more pronounced, but also not very substantial.

4.4.2 Removal Prevailing Torque

The plots described in this section are Figures 3-30, 3-33, 3-39, 3-45, and 3-51. The Removal Prevailing Torque indicates noticeable differences between the locknuts. The torque for MS21044D4 and NAS1021N4 indicate a decrease in the first two cycles. In the following cycles, torque oscillates within an overall decreasing trend. This decrease occurs at a slow rate, falling by around 25% over 13 cycles. During 85% Y preload testing there is a sudden large increase in torque at cycle 15 for NAS1021N4, an increase of more than 100%. It is likely due to particles or some contaminate in the threads causing the increase in torque. For locknuts MS17825-4 and Grade 8, their trends resemble their trends in the Assembly Prevailing Torque. There is a noticeable decrease between cycle 1 and 2, then the decrease for the remainder of the trial is very slow. The torque does not reduce more than 15% for the last 14 cycles.

4.4.3 Tightening Torque

The plots described in this section are Figures 3-34, 3-40, 3-46, and 3-52. The Tightening Torque differs noticeably between each locknut, but remains fairly constant between preload levels. MS17825-4's torque measurement increases quickly for the first 5 cycles and then plateaus for the remainder of the trial, with some minor oscillation. During 85% Y preload there is a significant decrease in torque at cycle 12, and the torque does not reestablish torque value it held prior to the decrease. For MS21044D4, the tightening torque behaves similar to MS17825-4's tightening torque. The torque increases for the first five cycles and plateaus for the remaining cycles. At 75% Y preload, the torque values oscillate noticeably during the constant state after cycle 5. During 85% Y preload, the torque decreases between cycle 6 and 10 then increases back to the level it was at cycle five between cycles 10 and 13, this results in a small valley in the plot. NAS1021N4 indicates a significant increase through the first 9 cycles. This increase the torque gains around 150% during those cycles. The remaining cycles oscillate around a constant torque value. Torque for the Grade 8 locknut is steady through the entire trial. There is some minor oscillation, but overall the torque remains fairly constant for all 15 cycles.

4.4.4 Breakloose Torque

The plots described in this section are Figures 3-35, 3-41, 3-47, and 3-53. The Breakloose Torque for the locknuts indicate a very similar to the Tightening Torque previously exhibited. At 66% Y preload MS17825-4's torque increases for the first 5 cycles and plateaus until cycle 15 where the torque increases significantly. The increase at cycle 15 could be due to contaminants in the threads increasing the friction. For 75% Y and 85% Y preloads the torque increases for the first 5 cycles like in 66% Y preload and the tightening torque, but at cycle 7 (75% Y preload) and 6 (85% Y preload) the torque decreases substantially. The decrease in torque is about 40% of the peak value over the next few cycles. During 85% Y preload the torque indicates a sharp increase at cycle 12, almost regaining all the lost torque from the decrease by cycle 15.

The other three locknuts all perform analogous to their Tightening Torque. MS21044D4's torque increases for the first 9 cycles and then plateaus, with some oscillation. NAS1021N4's torque increases for the first 5 cycles and then levels off for the remainder of the trial. During both 75% Y and 85% Y preloads there is a moderate decrease in the torque after the peak value is achieved. This decrease lasts for only 5 cycles and then levels off for the remaining cycles. Grade 8 shows a stable torque with slight oscillation. In 75% Y preload the torque increases for the first 3 cycles then decreases at cycle 4, from cycle 5 to 15 the torque is fairly constant with only minor oscillation.

4.4.5 Percent Difference

The plots described in this section are Figures 3-36, 3-42, 3-48, and 3-54. The percent difference for all 4 nylon insert locknuts provides very useable information. For locknuts MS17825-4 and Grade 8 at preloads of 66% Y and 75% Y, their cycle 1 value was about -35% and -45%, respectively. Then then by cycle 2 both had values around -10%, and the percent difference would remain around -10% for the remainder of the trial. This shows that, generally, the removal prevailing torque is 10% less than the assembly prevailing torque. At 85% Y, MS17925-4 would increase and the value would plateau, and then increase again and plateau, this would happen for a total of three times. Grade 8 at 85% Y percent difference increased like it did in 66% Y and 75% Y preloads, but it increased to a range of 5% to 10% after cycle 5. In this case, the removal prevailing torque is actually larger than the assembly prevailing torque.

Both MS21044D4's and NAS1021N4's percent difference values mostly remained within the range of -40% and -55%. The values of assembly prevailing and removal prevailing torque remained fairly proportional to one another throughout their trials. This trend could possibly lend itself to a direct verification test for the locknuts, if the assembly prevailing is know so is a fairly good estimate of the removal prevailing torque.

4.4.6 Reuse Life

The plots described in this section are Figures 3-31, 3-37, 3-43, 3-49, and 3-55. For the unseated testing all four nylon insert locknuts survived the standard NASM25027's minimum requirements. At 66% Y preload only MS17825-4 did not survive all 15 cycles, lasting 12. Again at 75% Y preload it was only MS17825-4 that did not survive all fifteen cycles, this time only lasting 9 cycles. For 85% Y preload MS17825-4 averaged just over 11 cycles of life, MS21044D4 survived for about an average of 13.667 cycles. Both NAS1021N4 and Grade 8 locknuts survived all 15 cycles. It should be noted that the non-aerospace locknut, Grade 8, and performed better life than two of the aerospace grade locknuts, MS17825-4 and MS21044D4.

4.5 Locknut Comparison

4.5.1 Assembly Prevailing Torque

The plots described in this section are Figures 3-57, 3-60, 3-66, 3-72, and 3-78. By looking at the figures, there is a clear grouping of locknuts through all preload levels.

Two main groups of locknuts appear, plus one locknut, NAS1805-4, that falls well outside these two groups. There is a lower and an upper group, beginning defined by their magnitude of torque respective of the other group. The lower group includes two nylon insert locknuts MS17825-4 and Grade8. The upper group contains all-metal locknuts MS21043-4 and NAS1291-4 and also nylon insert locknuts MS21044D4 and NAS1021N4. NAS1805-4 starts out with a higher level of torque near the upper group and increases quickly to well above the upper group, but then decreases about half way through the trial to level out around the lower group. During 75% Y preload MS21043-4 switches from the upper group to the lower group, and then returns the upper group during 85% Y preload.

4.5.2 Removal Prevailing Torque

The plots described in this section are Figures 3-58, 3-61, 3-67, 3-73, and 3-79. For unseated and 66% Y preload the torque indicated is similar to the Assembly Prevailing Torque's path. Lower and upper groups exist with the same locknuts within each; also NAS1805-4 holds the same trend as in assembly prevailing. For 75% Y preload there is only one grouping, including MS21043-4, MS21044D4, NAS1021N4, and Grade 8. Torques for NAS1805-4, NAS1291-4, and MS17825-4 are dissimilar. NAS1291-4 is noticeably higher than the grouping, though it has a decreasing torque causing it to become closer and closer the group as the trial continues. NAS1805-4 follows the same path as it has been previously, starting above the group then increasing quickly and ultimately decreasing rapidly by the middle of the trial. MS17825-4 is only slightly below the grouping and remains almost parallel to the group. For 85% Y no real grouping occurs. All the locknuts are dispersed similar to 75% Y but the differences for the outliers are much smaller.

4.5.3 Tightening Torque

The plots described in this section are Figures 3-62, 3-68, 3-74, and 3-80. The locknuts all indicate a moderate increasing torque throughout the trial. There is a fairly decent spread between the locknuts, and as such no clustering of groups occurs. The locknuts for the most part remain in the same order of higher torque values with respect to each other. From highest to lowest is: MS21044D4, NAS1021N4, MS21043-4, MS17825-4, NAS1291-4, NAS1805-4, and Grade 8. While this order is not perfectly maintained throughout the trial, overall the locknuts remain in that order. NAS1805-4 and Grade 8 switch places in order, for the first 7 cycles Grade 8 is higher than NAS1805-4, and for the last 7 cycles the opposite occurs.

4.5.4 Breakloose Torque

The plots described in this section are Figures 3-63, 3-69, 3-75, and 3-81. The torque's path established in the Tightening Torque also occurs in the Breakloose Torque. The only difference with the torque is for MS17825-4 at preloads of 75% Y and 85% Y. Half way through the trial it indicates a large decrease in torque, losing about 50% of its peak value and then leveling out for the remaining cycles. This loss in torque could be due to the locking feature being worn out and not creating sufficient friction to continue.

4.5.5 Percent Difference

The plots described in this section are Figures 3-64, 3-70, 3-76, and 3-82. Comparing the percent difference between the assembly and removal prevailing torques for all the locknuts together only offers limited usable information. What does occur, occurs through all preloads. NAS2191-4, MS17825-4, and Grade 8 all increase for the first three cycles and then plateau around -10%. No usable information can be derived from NAS1805-4 plots. MS21044D4 and NAS1021N4 both remain near constant around -50%, with only minor oscillation. MS21043-4 increases for the first 3 cycles and plateaus for the next five cycles, by cycle 7 the values begin to diverge by preload. For 66% Y preload it increasing again and plateaus after three cycles for the remainder of the trial. At 75% Y it slowly decreases for the remaining cycles, and for 85% Y it does not alter from the stable state it reached initially.

4.5.6 Reuse Life

The plots described in this section are Figures 3-59, 3-65, 3-71, 3-77, and 3-3. The life of each locknut decreases when the preload increases, as to be expected. This however does not hold true for NAS1805-4. As the preload increases, so does its life. This is possibly due to increased galling during higher preloads causing an increase in friction. The nylon insert locknuts all outperform the all-metal locknuts. This is possibly due to the nylon insert not damaging the test bolt as an all-metal locking feature would. Also the nylon tends to deform to the shape of the test bolt threads, and possibly allowing for increased surface area to maintain the friction needed to allow for the necessary prevailing torque.

4.6 Nylon Locknut Lubrication Comparison

4.6.1 MS21044D4

The plots described in this section are Figures 3-85, 3-86, 3-87, and 3-88. During Assembly Prevailing Torque testing, the Braycote lubricated locknut has considerably less prevailing torque than the locknut without lubrication. This is clearly due to the fact the Braycote lubrication is reducing the friction between the locknut and test bolt. The Braycote measurements are generally between 50% and 70% lower than the non-lubricated locknut measurements. The prevailing torque for the Braycote locknut is dangerously near failure (below 3.5 in-lb) for much of the trial with around 4.25 in-lbs of prevailing torque.

The results are not much different for Removal Prevailing Torque. The primary difference is that the prevailing torque does fall below the minimum of 3.5 in-lb required by the standards at cycle 13.

Both variations indicate intelligible percent difference results. After cycle 1, the Braycote locknut difference jumps from about -50% to -10% and slowly decreases to about -25% during the trial. This indicates the assembly and removal prevailing torque measurements are fairly close to one another, and with this a possible direct verification may be possible. The locknut without lubrication remains around -50% for the entirety of the trial. While the difference is predicable, it is significantly worse than that of the Braycote lubricated locknut.

The life for the non-lubricated locknut outperformed the life of the Braycote lubricated locknut. While the life lost with the Braycote applied was only about 25% at maximum preload, it seems the better choice between the two is no lubrication.

With the significant differences between the measurements without lubrication and with Braycote applied, a single trial at 85% Y preload is performed with another lubrication, 3-IN-ONE(Naphthenic Oil). The results are very different than the other two tests. The Assembly Prevailing Torque starts at around where it does for the Braycote locknut, but as the trial continues the prevailing torque does not decrease as quickly or as significantly. This also occurs to the Removal Prevailing Torque. Both the Tightening and Breakloose Torque measurements remain fairly constant throughout the trial, with no lubrication and Braycote locknuts the torques increased through the trial. The life with 3-IN-ONE is also significant, surviving all 15 cycles. The raw data is provided in MS21044D4 85% Y Preload Trial 5 in Appendix C.6.4 Table C-124.

4.6.2 NAS1021N4

The plots described in this section are Figures 3-89, 3-90, 3-91, and 3-92. The torque for NAS1021N4 are near identical to those of MS21044D4. The only significant difference between the trends of the two locknut varieties is the life. The Braycote lubricated NAS1021N4 locknuts indicated substantially less life than the non-lubricated NAS1021N4 locknuts. While the non-lubricated locknuts survived all 15 cycles for all preloads the Braycote lubricated locknuts only survived 3 cycles during unseated testing and an average of 2.33 cycles for 66% Y, 75% Y, and 85% Y preloads. It is possible the

Braycote is somehow chemically damaging the nylon insert, though no such indications of incompatibilities were found in references. It is also interesting the Braycote did not have as such a severe effect of the nylon of the MS21044D4 locknuts.

Testing with 3-IN-ONE at 85% Y preload is performed with NAS1021N4 like it was on MS21044D4. The locknut tested with 3-IN-ONE far outperformed the testing with Braycote. The Assembly and Removal Prevailing Torques start out higher, decrease slower, and maintain a torque above the minimum of 3.5 in-lb. The Tightening and Breakloose Torques decrease by about 20% between cycle one and two, and then level off for the remaining cycles. The life with 3-IN-ONE significantly surpassed the life with Braycote. Where the life at 85% Y for the Braycote testing averaged around 2.33 cycles, with 3-IN-ONE the locknut survived all 15 cycles. The raw data is provided in NAS1021N4 85% Y Preload Trial 5 in Appendix C.8.4 Table C-167.

4.6.3 MS17825-4

MS17825-4 is also tested without lubrication as MS21044D4 and NAS1021N4. Initially applied with Braycote for 66% Y preload testing, Assembly Prevailing Torque is always below the minimum measurement of 3.5 in-lb. Since this first value does not meet the minimum set forth by the standard no further testing is done with Braycote applied. 3-IN-ONE lubrication is used during a trial and the locknut is subjected to 85% Y preload. The results are the locknut fails during the first cycle, but during the removal prevailing torque. Even though it did not last an entire cycle, it did outlast the locknut lubricated with Braycote.

4.6.4 Grade 8

Testing for Grade 8 is performed with Naphthenic Oil, 3-IN-ONE, for the main body of the thesis. To compare with the other nylon locknuts it is also tested at 85% Y preload without lubrication and with Braycote applied. Without lubrication applied all torque values are noticeably higher than with 3-IN-ONE applied. Most importantly the Tightening and Breakloose Torques are significantly higher, by about 45%. This was caused by the significant more friction between the threads of the locknut and test bolt. The test bolt fractured in two during the second cycle Tightening Torque. Without lubrication the Grade 8 system has considerably less life. This data can be seen in Grade 8 85% Y Preload Trial 5 in Appendix C.9.6 Table C-191.

Testing with Braycote provided interesting results. The Assembly and Removal Prevailing Torques are both remarkably below those of the locknut lubricated with 3-IN-ONE, by about 50%. The Tightening and Breakloose Torques are noticeably larger with Braycote applied instead of the Naphthenic Oil, by an amount between 15% and 20% higher. The locknut did survive all 15 cycles, though the IFI 100/107 standards only specify life up to 5 cycles. The prevailing torque never dropped below the minimum of 1.5 in-lb for cycle 5 through the trial. This data can be seen in Grade 8 85% Y Preload Trial 6 in Appendix C.9.6 Table C-192.

4.7 Torque Friction Equation

A torque friction equation described by Bickford [9] relates the torque applied to a nut to the friction and elastic reactions from the torque.

$$T_{on} = F_p\left(\frac{P}{2\pi} + \frac{\mu_t r_t}{cos\beta} + \mu_n r_n\right) + T_p \qquad \text{Equation 4.1}$$

$$T_{off} = F_p\left(\frac{P}{2\pi} - \frac{\mu_t r_t}{cos\beta} - \mu_n r_n\right) - T_p \qquad \text{Equation 4.2}$$

where:

T_{on} = torque applied to tighten nut (in-lb)

T_{off} = torque applied to loosen nut (in-lb)

F_p = preload in bolt (lb)

P = thread pitch

μ_t = coefficient of friction in thread surface

μ_n = coefficient of friction in nut face

r_t = effective contact radii of thread surface (in)

r_n = effective contact radii of nut face (in)

β = half-angle of thread tooth (usually 30°)

T_p = prevailing torque (in-lb)

The testing performed appears to add support to this equation. The Tightening Torque and the Breakloose Torque both more often than not, seem to follow the same trends. When the Tightening Torque increases or decreases the Breakloose Torque increase and decreases with it. The negatives in T_{off} are because Breakloose Torque is defined as positive. The makeup of the torque is about 50% due to thread friction, 40%

due to other friction, and 10% due to bolt stretch. Two examples of this are Figure 4-1 and 4-2. There is a percent difference between Tightening and Breakloose Torques of about 10%, which is expected since bolt stretch works against, increasing, Tightening Torque and with, reducing, Breakloose Torque.

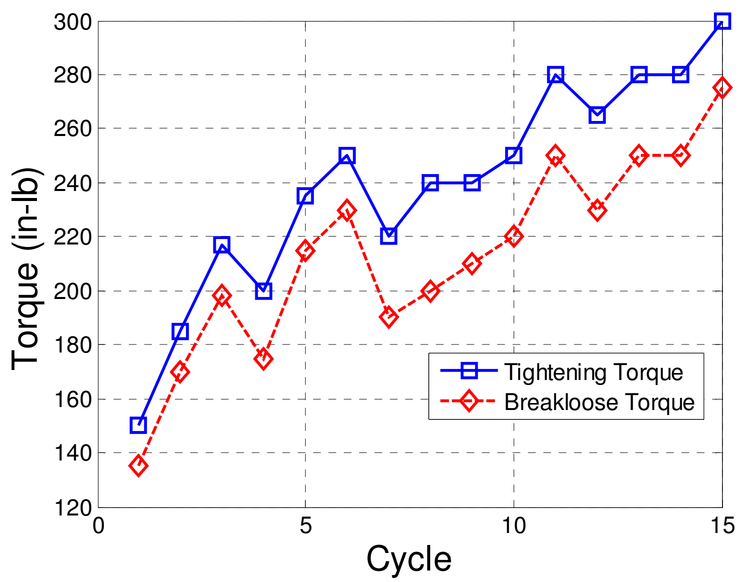

Figure 4-1: MS17825-4 Trial 3; 66% Y Preload, Tightening and Breakloose Comparison

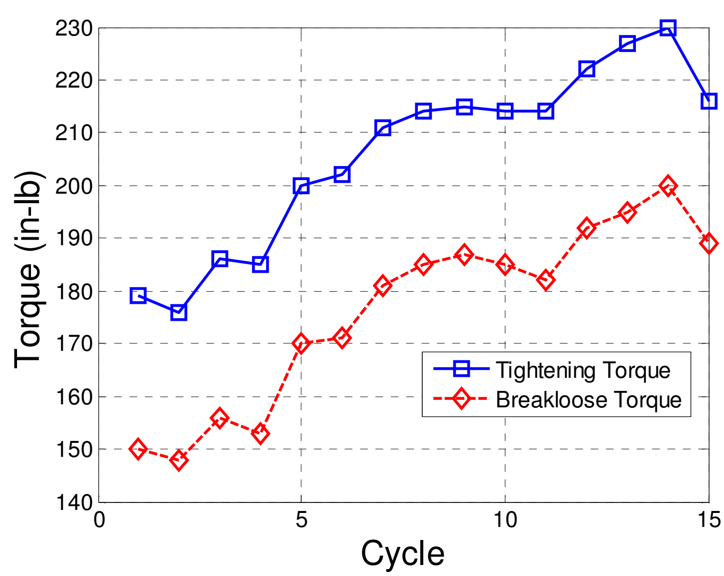

Figure 4-2: NAS1291-4 Trial 2; 75% Y Preload, Tightening and Breakloose Comparison

4.8 Summary Discussion

All four nylon locknuts MS17825-4, MS21044D4, NAS1021N4, and Grade 8 survived all 15 cycles during unseated and 66% Y preload tests. Nylon locknuts MS21044D4, NAS1021N4, and Grade 8 also survive all 15 cycles at 75% Y preload. NAS1021N4 and Grade 8 are the only locknuts of the seven tested to survive all 15 cycles at 85% Y preload. Of the all-metal locknuts only MS21043-4 and NAS1291-4 survive the required 15 cycles of unseated testing. NAS1291-4 is the only all-metal locknut to survive 15 reuse cycles at 66% Y and 75% Y preload. Not a single all-metal locknut survives 15 reuse cycles at 85% Y preload. No locknut is destroyed in the first cycle.

Torque-tension is a direct relationship between the two measurements. In the tests in this thesis, with reuse an increase in torque is required for each reuse cycle to achieve a given preload on the locknut. With many in industry using a torque measurement to apply a desired preload without directly measuring the preload; if a locknut is reused and a torque measurement utilized to apply a given preload, the preload actually applied to the locknut is less than the intended preload. This effect worsens as the number of reuse cycles for the locknut increases, and could lead to a failure of the bolted system.

Lubrication has a significant effect on the performance of the nylon locknuts. It is likely to play an import role in the all-metal locknuts as well, but none were tested with lubrication other than what was applied by the manufacturer. The locknuts with no lubrication provided the best performance, followed by those applied with Naphthenic Oil, and the worst performers with respect to prevailing torque life were the locknuts with Braycote applied. It is possible the nylon could be either absorbing or its surface retains the lubrication providing noticeably less friction, by extension less prevailing torque is achieved. Another possibility, especially with the Braycote, could be a chemical incompatibility between the locknut's nylon insert and the lubrication.

Only the NAS1805-4 all-metal locknut performance does not meet the requirements set forth by the standard. The standard states the locknut must remain above 3.5 in-lb and below 30 in-lb during 15 unseated cycles. NAS1805 only survives an average 8 of the required 15 unseated cycles. Most of the failures are due to the prevailing torque falling below the minimum 3.5 in-lb, but a few of the failures occur when the prevailing torque increases beyond the maximum 30 in-lb. This was also the only locknut to indicate a failure by increasing above the maximum torque. Also the reuse life for NAS1805 increases with the increase of preload. This could be due to the galling between the locknut and test bolt. It should be noted that the locking feature of NAS1805 itself does not seem to be damaged. The test bolt sustained significant wear to its threads. The threads which came into contact with the locking feature are worn away as reuse tests are performed, during testing straight continuous chips are created during removal of locknut. It is the test bolt that failed, not the locknut, mostly likely due to galling from material compatibility issues.

For many trials, there is a noticeable difference in Assembly Prevailing Torque measurements between cycles one and two. Each locknut indicates a different percent decrease. Assembly Prevailing for MS21043-4 on average decreases 7.5% after one use. NAS1291-4 has a decrease of about an average of 22% after a single reuse. NAS1805-4 has the lowest decrease, with an average around 1%. MS17825-4 indicates the largest decrease at an average of about 33%. MS21044D4's average decrease is near 12.5%. NAS1021N4 on average decreased 10% after one use. Grade 8 has a decrease of about an average of 32%. After this initial decrease between cycles one and two, the assembly prevailing torque either levels off or continues to decrease at a much slower rate.

Only NAS1805-4 defies the trends followed by the other locknuts. For Assembly and Removal Prevailing Torques, the torque increases quickly for the first few cycles; then the torque decreases significantly and quickly. Strangely the Tightening and Breakloose torques indicate almost perfect steadily increases. The percent difference is erratic, and no usable information can be ascertained from the data. The reuse life for NAS1805 is also opposite than the life of the other locknuts. As the preload increases as did its reuse life, the other locknuts indicate a decrease in reuse life with an increase in preload. It is also the only locknut to fail causing significant damage to the test bolt. Since the test bolt and locknut are A-286 steel galling is occurring, causing the differences between NAS1805 torque and the other locknut's torques.

The difference between the manner in which trial 1 is performed verse how trials 2, 3 and 4 are, impacted the results. When the preload is removed from the locknut without loosening it, the removal prevailing torque is up to 50% higher. In many cases it is only slightly less than the assembly prevailing torque. Also the removal torque decreases at a much slower rate during trial1 than it does during trials 2, 3, and 4. With the difference of prevailing torques between the trial types, it is difficult for a direct verification to be plausible. If preload is lost during use, the removal prevailing torque will not be near enough of the assembly prevailing torque measurement.

The fixture allows for this removal of preload without loosening of the locknut. This ability allows for testing to determine that more damage to the locking feature occurs in the removal of the preload on the locknut than in the application of the preload.

The standard IFI 100/107 mentions in its definition for Breakloose Torque that for most lock fasteners Breakloose torque is larger than Tightening torque. The testing done for this thesis indicates the opposite. During testing Tightening torque is always greater than Breakloose torque. This is consistent with the Torque Friction equation.

The top performing with respect to reuse life all-metal locknut is NAS1291-4; with the worst performing all-metal locknut is MS21043-4. The top performing with respect to reuse life nylon insert, and locknuts overall, locknuts are NAS1021N4, an aerospace grade locknut, and Grade 8, a non-aerospace grade locknut. The worst performing nylon insert locknut is MS17825-4.

5 Conclusions

This thesis addressed voids in literature and specifications currently existing for aerospace locknuts with respect to seated and torqued reuse life, while providing additional data and warnings for torque-tension and lubrication problems. There is very little published data and the many standards specify prevailing torque minimum and maximum for only unseated reuse life. The reuse of seven locknuts was performed and will be published. By collecting torque and preload data concurrently, the information gathered from the tests will more reliably relate between torque and preload. This was achieved by use of a special test fixture, which allowed for the application of preload to the locknut then for the removal of the preload without loosening the locknut. Wear-out as a function of seated reuse cycles was performed by testing each locknut up to 15 cycles or failure while being seated. Two different trial types were performed; one where the preload was removed from the locknut without loosening the locknut, and the other where the preload was removed by loosening the locknut. Wear-out as a function of preload was performed by testing each locknut with preloads of 66% Y, 75% Y, and 85% Y of total preload.

There are four main points found from the testing. The first is the number of reuse cycles is greater for the nylon locknuts tested than the all-metal locknuts tested. Another key point is the all-metal type locknuts initially have a prevailing torque near the standard's maximum. Torque-tension relationship in reuse may provide a bigger issue than decrease in prevailing torque with reuse. Industry uses the torque-tension relationship to tighten fasteners to desired preloads, since tightening torque increases with reuse the preload applied with a particular torque will decrease with reuse. Lubrication is important in the performance of the nylon locknuts, all-metal locknuts typically have lubrication applied from manufacture so none were tested. The prevailing torque and reuse life can be reduced up to 400% depending on lubricant.

Five trends were indicated by all seven locknuts. Assembly Prevailing and Removal Prevailing torques both decrease with reuse. Tightening and Breakloose torques to achieve a given preload increase with reuse. All torque value's initial measurements increase with an increase in preload. The percent difference between Assembly Prevailing and Removal Prevailing within a cycle levels off after the first reuse, with only NAS1805-4 having erratic results. Reuse life decreases with reuse and with preload increase.

It appears behavior of prevailing torque with reuse of locknuts is not simple. For unseated and 66% Y preload all locknuts but NAS1805-4 performed very well allowing for up to 14 or 15 reuses. The all-metal locknuts seem to perform very well with reuse, achieving ten reuse cycles does not seem to be any problem. Nylon insert locknuts perform the best with reuse all but MS17825-4 can be used for 15 reuse cycles up to 75% Y preload without any issues. So it seems many locknuts are able to maintain required performance with reuse. Though with reuse inspection of the locknut for any significant damage between reuse cycles is recommended, and be cautious of bolt damage and lubrication complications. It is recommended if prevailing feature locking fasteners are to be reused a sample testing of the fastener should be performed for the preload, joint conditions, and applied lubrications to be used. NAS1805 did not meet the standard of 15 cycles for unseated, most likely due to the locknut's Rockwell hardness is 49 and the test bolt's Rockwell hardness is 32. With such a large difference, and also both are A-286 steel, in hardness locknut NAS1805, the hardness and material compatibilities lead to test bolt failure. Locknut NAS1805-4 does not appear to fail; the test bolt is damaged to failure.

The data collected from testing agrees with the torque friction equation provided by Bickford [9]. This showing that the Tightening and Breakloose torques are dependent on primarily friction, around 90% of the torque, and also bolt stretch, 10% of the torque measurement.

References

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4. MIL-I-45914A, 1991, *Insert, screw thread – locked in, key locked*, Department of Defense Military Specification.

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Appendices

Appendix A: Test Fasteners Information

A.1 Locknuts

Table A-1: MS21043 Locknut

MS21043	
Part #:	MS21043-4 Rev. 2
Alternate #:	NASM21043-4
Lot #:	M007427-000
Qualification Spec:	NASM25027
Thread Size:	0.2500 in
Thread Pitch:	28 – Fine, UNJF
Aerospace:	Yes
Material:	AMS 5731-L Steel
Locking Feature Material:	AMS 5731-L Steel
Coating/Plating:	AMS 2410 Silver
Lubricant:	Dry Film
Description:	Feature 0.25”-28, Nut, Self-locking, Hexagon, Silver Finish

Table A-2: NAS1291 Locknut

NAS1291	
Part #:	NAS1291-4 Rev. 12
Alternate #:	MS21042L4
Lot #:	SK274
Qualification Spec:	NASM25027
Thread Size:	0.2500 in
Thread Pitch:	28 – Fine, UNJF
Aerospace:	Yes
Material:	QQ-P-416C Carbon Steel
Locking Feature Material:	QQ-P-416C Carbon Steel
Coating/Plating:	Cadmium
Lubricant:	Dry Film
Description:	0.25”-28, Nut, Self-locking, Hexagon, Color - Dark Gray, Cadmium Finish

Appendix A (Continued)

Table A-3: NAS1805 Locknut

NAS1805	
Part #:	NAS1805-4
Alternate #:	
Lot #:	am816
Qualification Spec:	NAS3350
Thread Size:	0.2500 in
Thread Pitch:	28 – Fine, UNJF
Aerospace:	Yes
Material:	A – 286 Stainless Steel
Locking Feature Material:	A – 286 Stainless Steel
Coating/Plating:	AMS 2700 Type 2 Rev. C
Lubricant:	Solid Film
Description:	0.25”-28, Nut, Self-locking, Hexagon, 12-Point, Dark Gray Color

Table A-4: MS17825 Locknut

MS17825	
Part #:	MS17825-4 Rev. H
Alternate #:	F12NEC-0428
Lot #:	0501930-420
Qualification Spec:	NASM25027; ASTM D4066-94B, 96A, 99, 01A Group 1 Class 1
Thread Size:	0.2500 in
Thread Pitch:	28 – Fine, UNJF
Aerospace:	Yes
Material:	1137 Steel
Coating/Plating:	Cadmium and Yellow Chromate
Locking Feature Material:	Nylon
Lubricant:	None
Description:	0.25”-28, Nut, Self-locking, Hexagon, Slotted, Color – Yellow, Cadmium and Yellow Chromate Finish, Black Nylon Locking Feature

Appendix A (Continued)

Table A-5: MS21044 Locknut

MS21044	
Part #:	MS21044D4 Rev. H
Alternate #:	NAS1021H4
Lot #:	0501960-080
Qualification Spec:	NASM25027; ASTM D4066-94B, 96A, 99, 01A Group 1 Class 1
Thread Size:	0.2500 in
Thread Pitch:	28 – Fine, UNJF
Aerospace:	Yes
Material:	2024 T4 Aluminum
Coating/Plating:	Anodized and Blue Dye
Locking Feature Material:	Nylon
Lubricant:	None
Description:	0.25”-28, Nut, Self-locking, Hexagon, Color – Blue, Anodized and Blue Dye Finish, Green Nylon Locking Feature

Table A-6: NAS1021 Locknut

NAS1021	
Part #:	NAS1021N4 Rev. 10
Alternate #:	MS21044N4
Lot #:	40157-000
Qualification Spec:	NASM25027; ASTM D4066-00
Thread Size:	0.2500 in
Thread Pitch:	28 – Fine, UNJF
Aerospace:	Yes
Material:	AMS 5040 Carbon Steel
Coating/Plating:	Cadmium
Locking Feature Material:	Nylon
Lubricant:	None
Description:	0.25”-28, Nut, Self-locking, Hexagon, Color – Yellow, Cadmium Finish, Red Nylon Locking

Appendix A (Continued)

Table A-7: Grade 8 Locknut

Grade 8 Locknut	
Grainger Part #:	1EY89
Alternate #:	
Lot #:	59NE8-048 6D
Qualification Spec:	IFI 100/107
Thread Size:	0.2500 in
Thread Pitch:	28 – Fine, UNF
Aerospace:	No
Material:	Grade 8 Steel
Coating/Plating:	Plain Finish
Locking Feature Material:	Nylon
Lubricant:	3-IN-ONE, (Naphthenic Oil)
Description:	0.25”-28, Nut, Self-locking, Hexagon, 6-Point, Dark Gray Color, Dark Purple Nylon

A.2 Bolts

Table A-8: NAS1004 Bolt

NAS1004	
Part #:	NAS1004-29A
Lot #:	26306
Qualification Spec:	AMS 7477
Thread Size:	0.2500 in
Thread Pitch:	28 – Fine, UNJF
Aerospace	Yes
Material:	A-286
Coating/Plating:	QQP35C
Lubrication:	No
Cleaner:	MEK
0.2% Yield:	100,000 psi
66% Y Preload:	2400 lb
75% Y Preload:	2730 lb
85% Y Preload:	3100 lb
Description:	0.25”-28, Bolt

Appendix A (Continued)

Table A-9: Grade 8 Bolt

Grade 8	
Part #:	Grade 8
Lot #:	251328A
Qualification Spec:	SAE J429 and ASME B18.2.1
Thread Size:	0.2500 in
Thread Pitch:	28 – Fine, UNJF
Aerospace	No
Material:	Alloy Steel
Coating/Plating:	Yellow Zinc
Lubrication:	No
Cleaner:	MEK
0.2% Yield:	130,000 psi
66% Y Preload:	3120 lb
75% Y Preload:	3550 lb
85% Y Preload:	4020 lb
Description:	0.25”-28, Bolt

A.3 Washers

Table A-10: NAS1149 Washer

NAS1149	
Part #:	NAS1149C0463R
Lot #:	65603/391629-01
Qualification Spec:	MIL-S-5059; UNSPSC 31161807
Nominal Diameter:	0.25 in
Outer Diameter:	0.50 in
Inner Diameter:	0.265 in
Thickness:	0.063 in
Aerospace:	Yes
Material:	CRES
Coating/Plating:	QQ-P-35
Description:	0.25” Washer

Appendix A (Continued)

Table A-11: Grade 8 Washer

Grade 8	
Part #:	Grade 8
Lot #:	47142-01
Qualification Spec:	ASME/ANSI B 18.22 and ASTM F436
Nominal Diameter:	0.25 in
Outer Diameter:	0.75 in
Inner Diameter:	0.31 in
Thickness:	0.051 in – 0.080 in
Aerospace:	No
Material:	Through Hardened Steel
Coating/Plating:	Yellow Zinc
Description:	0.25” Washer

Appendix B: Fixture Dimensioned Drawings

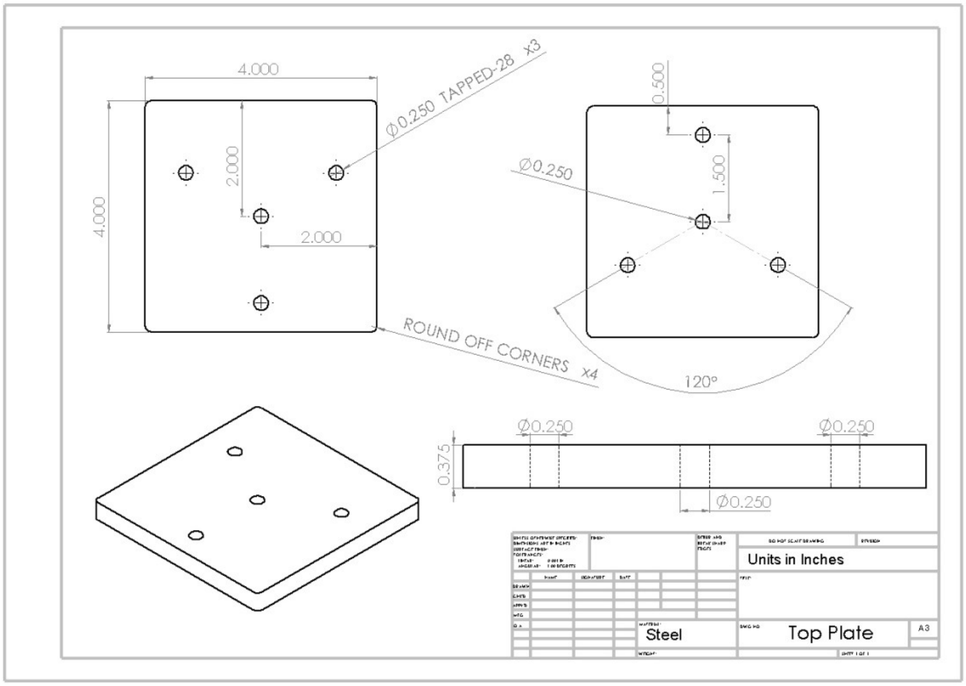

Figure B-1: Bottom Plate

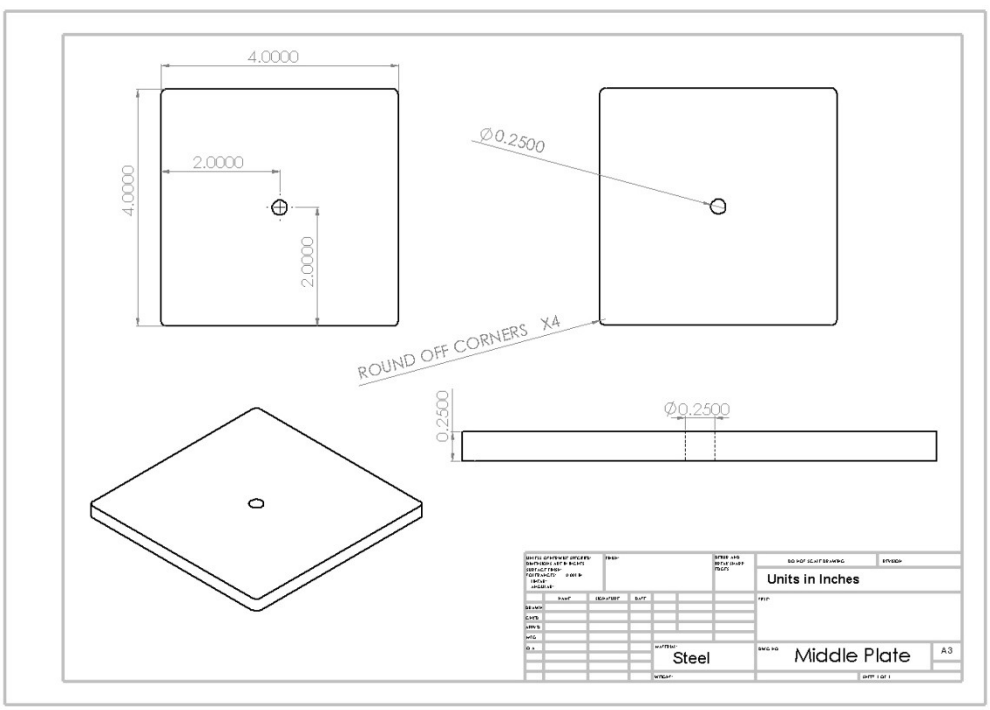

Figure B-2: Middle Plate

Appendix B (Continued)

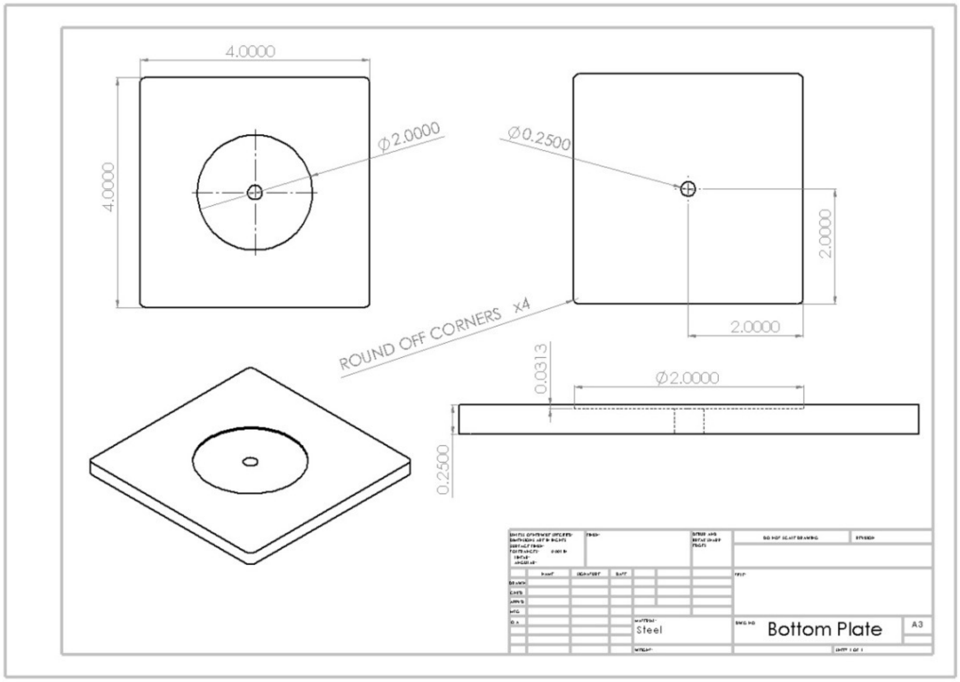

Figure B-3: Top Plate

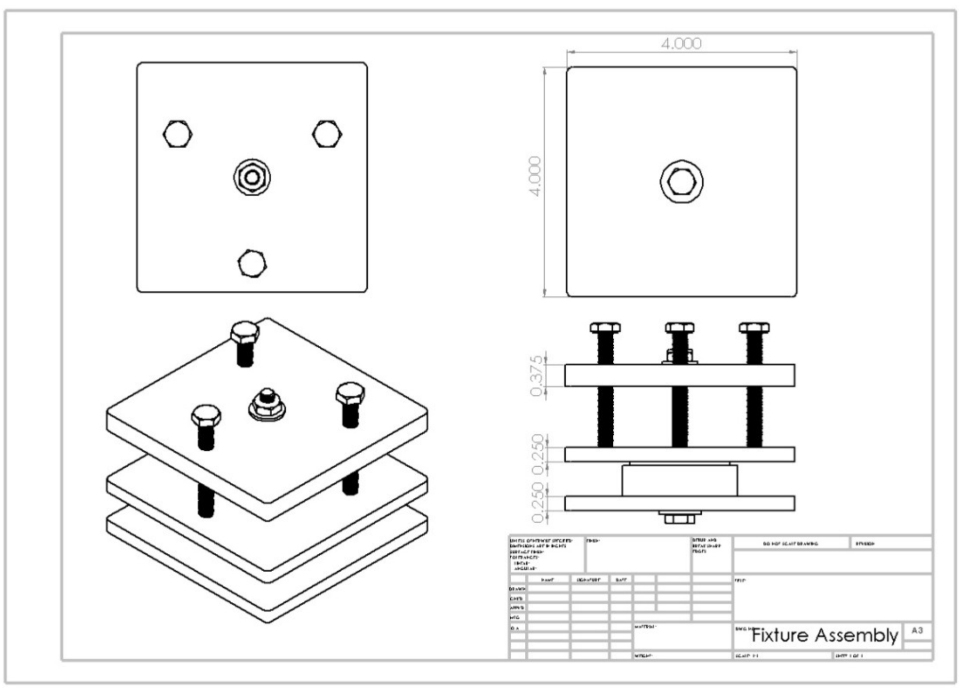

Figure B-4: Fixture Assembly

Appendix C: Raw Data Tables

C.1 MS21043-4

C.1.1 Unseated

Table C-1: MS21043-4; Unseated - Trial 1

Trial 1					
Cycle	**Assembly Prevailing (in-lbs)**	**Removal Prevailing (in-lbs)**	**Assem. Prevailing Ver. (in-lbs)***	**Percent Difference Removal**	**Percent Difference Assem. Ver.**
1	20	14.5	20	-27.50%	0.00%
2	18.5	12.75	18.25	-31.08%	-1.35%
3	18	13.5	18	-25.00%	0.00%
4	16.5	11.25	18	-31.82%	9.09%
5	17.5	11.5	16.5	-34.29%	-5.71%
6	16.75	11	16.5	-34.33%	-1.49%
7	17	10.5	16.5	-38.24%	-2.94%
8	17.5	14.5	17.5	-17.14%	0.00%
9	18.5	12.5	17	-32.43%	-8.11%
10	20	16.5	19.5	-17.50%	-2.50%
11	18.5	14.5	19.5	-21.62%	5.41%
12	19.5	14.75	18	-24.36%	-7.69%
13	17.5	13	17.5	-25.71%	0.00%
14	17.5	13	17.5	-25.71%	0.00%
15	16.25	10.5	15.5	-35.38%	-4.62%
				Life (Cycles):	**15**

Appendix C (Continued)

Table C-2: MS21043-4; Unseated - Trial 2

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	20.5	16.5	21	-19.51%	2.44%
2	17.5	17	17.5	-2.86%	0.00%
3	18	16.25	18	-9.72%	0.00%
4	17.5	15.5	18.5	-11.43%	5.71%
5	18	15	18	-16.67%	0.00%
6	17	15.5	18	-8.82%	5.88%
7	17.5	15.25	18.5	-12.86%	5.71%
8	17.5	14	18	-20.00%	2.86%
9	16.5	13.5	18	-18.18%	9.09%
10	18.5	15	18	-18.92%	-2.70%
11	19	15.5	18	-18.42%	-5.26%
12	18	13.5	18	-25.00%	0.00%
13	17.5	15	18.5	-14.29%	5.71%
14	18.25	16.5	18.5	-9.59%	1.37%
15	19	15	19	-21.05%	0.00%
				Life (Cycles):	**15**

Table C-3: MS21043-4; Unseated - Trial 3

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	12.5	8	14.25	-36.00%	14.00%
2	13	6	12.5	-53.85% Y	-3.85% Y
3	13	7	13.25	-46.15%	1.92%
4	13	7	13	-46.15%	0.00%
5	12	6	12	-50.00%	0.00%
6	12	5.5	12	-54.17%	0.00%
7	12.5	5	11	-60.00%	-12.00%
8	10	4.5	10	-55.00%	0.00%
9	12	4.5	11	-62.50%	-8.33%
10	10	4	11	-60.00%	10.00%
11	11	4.5	11	-59.09%	0.00%
12	10	5.5	8.5	-45.00%	-15.00%
13	10.25	4	11	-60.98%	7.32%
14	10	4.5	11.5	-55.00%	15.00%
15	11.5	5	11.5	-56.52%	0.00%
				Life (Cycles):	**15**

Appendix C (Continued)

Table C-4: MS21043-4; Unseated - Trial 4

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	23	17.5	22	-23.91%	-4.35%
2	22	15.5	20	-29.55%	-9.09%
3	18.5	15	18.5	-18.92%	0.00%
4	18	13.5	18.5	-25.00%	2.78%
5	18	13	18.25	-27.78%	1.39%
6	18.25	13	16.5	-28.77%	-9.59%
7	17	15	17.5	-11.76%	2.94%
8	17.5	14	17.5	-20.00%	0.00%
9	17.5	14	16	-20.00%	-8.57%
10	17.5	13	16.5	-25.71%	-5.71%
11	18	13.25	17.5	-26.39%	-2.78%
12	17.5	12.5	16	-28.57%	-8.57%
13	18	14.5	16.5	-19.44%	-8.33%
14	16.5	13.5	16	-18.18%	-3.03%
15	17.5	13	17.5	-25.71%	0.00%
				Life (Cycles):	**15**

Table C-5: MS21043-4; Unseated - Trial Average

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	19	14.12	19.31	-26.73%	3.02%
2	17.75	12.81	17.06	-29.33%	-3.57%
3	16.87	12.93	16.93	-24.95%	0.48%
4	16.25	11.812	17	-28.60%	4.40%
5	16.37	11.37	16.18	-32.18%	-1.08%
6	16	11.25	15.75	-31.52%	-1.30%
7	16	11.43	15.8	-30.71%	-1.57%
8	15.62	11.75	15.75	-28.04%	0.71%
9	16.12	11.12	15.5	-33.28%	-3.98%
10	16.5	12.12	16.25	-30.53%	-0.23%
11	16.62	11.93	16.5	-31.38%	-0.66% Y
12	16.25	11.56	15.12	-30.73%	-7.82%
13	15.81	11.63	15.87	-30.11%	1.17%
14	15.56	11.87	15.87	-27.12%	3.33%
15	16.06	10.88	15.88	-34.67%	-1.15%
				Life (Cycles):	15

Appendix C (Continued)

C.1.2 66% Y Preload

Table C-6: MS21043-4; 66% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	8.5	223	5.0	5.0	-41.18%
2	4.0	218	3.5	4.0	0.00%
3	3.5	214	3.8	4.0	14.29%
4	4.0	231	2.0	3.0	-25.00%
5	3.5	221	3.0	2.0	-42.86%
6	3.0	208	3.0	3.5	16.67%
7	3.0	219	2.5	3.5	16.67%
8	3.5	217	3.0	4.0	14.29%
9	3.5	214	2.8	3.0	-14.29%
10	3.0	219	2.0	2.0	-33.33%
11	3.0	205	2.0	2.0	-33.33%
12	3.0	197	1.8	2.0	-33.33%
13	2.8	187	2.0	3.0	9.09%
14	3.2	193	2.0	2.2	-31.25%
15	3.5	184	2.0	2.3	-35.71%
				Life (Cycles):	**4**

Table C-7: MS21043-4; 66% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	16.5	216	170	10	-39.39%
2	12.5	233	192	10	-20.00%
3	11.5	227	184	9.1	-20.87%
4	12.5	234	200	10.2	-18.40%
5	12	286	196	10.5	-12.50%
6	11	225	196	9	-18.18%
7	11.25	216	187	8	-28.89%
8	11.5	216	181	9.5	-17.39%
9	10.6	221	189	9.9	-6.60%
10	12	224	193	12	0.00%
11	12.5	216	196	10	-20.00%
12	13	229	202	11	-15.38%

Appendix C (Continued)

Table C-7 (Continued)

13	14.5	233	219	10.5	-27.59%
14	13	233	221	12	-7.69%
15	15	240*			
		*Locknut 6-Point Hex Damaged		**Life (Cycles):**	**14**

Table C-8: MS21043-4; 66% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	19.5	200	125	10.5	-46.15%
2	17.5	245	212	11.5	-34.29%
3	16.5	250	200	10	-39.39%
4	16.5	210	195	9	-45.45%
5	15	235	200	10.5	-30.00%
6	12	205	175	8	-33.33%
7	13	230	200	11	-15.38%
8	12.5	242	205	10	-20.00%
9	12.5	240	210	10	-20.00%
10	13	250	220	12	-7.69%
11	12.5	245	210	11.5	-8.00%
12	12.5	250	225	8.5	-32.00%
13	13	260	230	10	-23.08%
14	13	260	225	10	-23.08%
15	12	240	225	8	-33.33%
				Life (Cycles):	**15**

Table C-9: MS21043-4; 66% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	15	225	185	6.5	-56.67%
2	11.5	235	195	8	-30.43%
3	9	220	185	5	-44.44%
4	10.5	250	210	6.5	-38.10%
5	9.5	265	230	5.5	-42.11%
6	9.5	255	220	5	-47.37%
7	9.5	275	230	4.5	-52.63%
8	9.5	250	210	4.5	-52.63%

Appendix C (Continued)

Table C-9 (Continued)

9	9	270	230	7	-22.22%
10	9	260	220	7.5	-16.67%
11	8.5	280	230	7.5	-11.76%
12	9	280	240	7.5	-16.67%
13	8	290	240	7	-12.50%
14	9	280	240	7	-22.22%
15	8	280	230	7	-12.50%
				Life (Cycles):	**15**

Table C-10: MS21043-4; 66% Y - Trial Average

Trial Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	17.0	213.7	160.0	9.0	-47.40%
2	13.8	237.7	199.7	9.8	-28.24%
3	12.3	232.3	189.7	8.0	-34.90%
4	13.2	231.3	201.7	8.6	-33.98%
5	12.2	262.0	208.7	8.8	-28.20%
6	10.8	228.3	197.0	7.3	-32.96%
7	11.3	240.3	205.7	7.8	-32.30%
8	11.2	236.0	198.7	8.0	-30.01%
9	10.7	243.7	209.7	9.0	-16.28%
10	11.3	244.7	211.0	10.5	-8.12%
11	11.2	247.0	212.0	9.7	-13.25%
12	11.5	253.0	222.3	9.0	-21.35%
13	11.8	261.0	229.7	9.2	-21.05%
14	11.7	257.7	228.7	9.7	-17.66%
15	11.7	260.0	227.5	7.5	-22.92%
				Life (Cycles):	**14.67**

Appendix C (Continued)

C.1.3 75% Y Preload

Table C-11: MS21043-4; 75% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	7.5	189	5	7	-6.67%
2	6.5	208	4.5	5.5	-15.38%
3	5.5	216	3	3.75	-31.82%
4	3.5	200	3	3.5	0.00%
5	3	227	2.5	3	0.00%
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
				Life (Cycles):	**3**

Table C-12: MS21043-4; 75% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	16	240	205	6.5	-59.38%
2	8	230	200	6	-25.00%
3	8	260	205	7	-12.50%
4	10	280	230	6.5	-35.00%
5	7.5	280	240	6	-20.00%
6	7	290	250	6	-14.29%
7	7.5	270	230	6	-20.00%
8	7.5	275	230	6	-20.00%
9	7.5	270	230	6.25	-16.67%
10	7.5	280	240	5.75	-23.33%
11	7.25	280	230	5	-31.03%

Appendix C (Continued)

Table C-12 (Continued)

12	6.5	290	240	5	-23.08%
13	6.75	300	250	4.75	-29.63%
14	6	320	250	4	-33.33%
15	5.75	290	230	4	-30.43%
				Life (Cycles):	**15**

Table C-13: MS21043-4; 75% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	18	260	200	12	-33.33%
2	14.5	260	210	13.5	-6.90%
3	14.5	265	220	8.5	-41.38%
4	12	240	200	7	-41.67%
5	12	240	190	6.5	-45.83%
6	12	250	215	5.5	-54.17%
7	11.5	255	210	8	-30.43%
8	12	235	210	6.5	-45.83%
9	12.5	270	230	6.5	-48.00%
10	14	270	230	9	-35.71%
11	13.5	270	230	7	-48.15%
12	12.5	280	240	6.5	-48.00%
13	13	285	250	8.5	-34.62%
14	13	290	255	6	-53.85% Y
15	12	280	245	5.25	-56.25%
				Life (Cycles):	**15**

Table C-14: MS21043-4 75% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	15.5	230	190	6.5	-58.06%
2	12.5	250	210	5.5	-56.00%
3	12	250	210	4.5	-62.50%
4	8.5	250	210	7	-17.65%
5	8	255	220	7	-12.50%
6	7.5	260	220	7	-6.67%

Appendix C (Continued)

Table C-14 (Continued)

7	7	240	215	6.75	-3.57%
8	7	270	240	6.5	-7.14%
9	7.5	280	250	7	-6.67%
10	9	235*			
11					
12					
13					
14					
15					
		*Locknut 6-Point Hex Damage		**Life (Cycles):**	**10**

Table C-15: MS21043-4; 75% Y - Trial Average

Trial Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	16.0	240.0	205.0	6.5	-59.38%
2	13.8	240.0	196.7	8.2	-38.80%
3	11.7	256.7	208.3	8.7	-25.13%
4	12.2	265.0	220.0	6.5	-46.29%
5	9.3	256.7	216.7	6.7	-26.44%
6	9.0	261.7	220.0	6.5	-24.21%
7	9.0	260.0	221.7	6.2	-26.94%
8	8.7	256.7	218.3	6.9	-18.00%
9	8.8	258.3	226.7	6.4	-23.21%
10	9.2	276.7	235.0	6.4	-26.00%
11	10.1	183.3	230.0	7.0	-33.37%
12	10.0	280.0	235.0	6.0	-35.61%
13	9.6	290.0	245.0	5.6	-38.81%
14	9.5	302.5	250.0	6.3	-33.97%
15	9.4	290.0	242.5	5.0	-42.14%
				Life (Cycles):	**13.33**

Appendix C (Continued)

C.1.4 85% Y Preload

Table C-16: MS21043-4; 85% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Removal Prevailing (in-lbs)**	**Assem. Prevailing Ver. (in-lbs)***	**Percent Difference Assem. Ver.**
1	15	250	8	8.25	-45.00%
2	9.5	260	7	7.5	-21.05%
3	7.5	290	7	7	-6.67%
4	6.5	320	5.5	6	-7.69%
5	6	310	6	6	0.00%
6	5.75	290	5.5	5	-13.04%
7	5	330	5	5	0.00%
8	4.75	330	4.75	4.5	-5.26%
9	4.5	320	4	4.25	-5.56%
10	4.5	340	4	4	-11.11%
11	5	300	4	4.5	-10.00%
12	5	310	4	4.25	-15.00%
13	4	340	3.75	3.5	-12.50%
14	4	330*			
15					
		*Locknut 6-Point Hex Damage		**Life (Cycles):**	**13**

Table C-17: MS21043-4; 85% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	17.5	320	260	10	-42.86%
2	12	330	270	6.5	-45.83%
3	11	320	275	5.25	-52.27%
4	9	340	280	3.5	-61.11%
5	9	290	250	3	-66.67%
6	9	310	260	2.5	-72.22%
7	8.5	320	270	3	-64.71%
8	9.5	340	280	2.5	-73.68%
9					
10					
11					

Appendix C (Continued)

Table C-17 (Continued)

12					
13					
14					
15					
				Life (Cycles):	**5**

Table C-18: MS21043-4; 85% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	25	320	210	19	-24.00%
2	25	340	280	14	-44.00%
3	18	320	280	12.5	-30.56%
4	18.5	320	280	10.5	-43.24%
5	16.5	310	280	10.5	-36.36%
6	15.5	290	250	11	-29.03%
7	18	330	280	11.5	-36.11%
8	18	340	300	13.5	-25.00%
9	19	350	300	13.5	-28.95%
10	18	370	320	13	-27.78%
11	17.5	350	310	13.5	-22.86%
12	17.5	360	320	11	-37.14%
13	18.5	370	330	9	-51.35%
14	16	370	330	9	-43.75% Y
15	15	380	340	8	-46.67%
				Life (Cycles):	**15**

Table C-19: MS21043-4; 85% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	20	310	250	13	-35.00%
2	17.5	330	270	11	-37.14%
3	15	320	270	10	-33.33%
4	12.5	300	250	11.5	-8.00%
5	14.5	310	260	10.5	-27.59%
6	14	320	270	12.5	-10.71%

Appendix C (Continued)

Table C-19 (Continued)

7	13.5	330	275	11	-18.52%
8	12	310	280	6.5	-45.83%
9	13	340	280	8	-38.46%
10	12	330	280	7	-41.67%
11	12	335	280	8.5	-29.17%
12	14	340	300	7.5	-46.43%
13	10	340	300	6	-40.00%
14	12.5	340	300	6	-52.00%
15	11	340	290	4	-63.64%
				Life (Cycles):	**15**

Table C-20: MS21043-4; 85% Y - Trial Average

Trial Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	17.5	320.0	260.0	10.0	-42.86%
2	19.0	320.0	243.3	12.8	-34.94%
3	17.8	330.0	275.0	10.1	-44.47%
4	14.0	326.7	276.7	8.7	-41.67%
5	13.3	303.3	260.0	8.3	-39.30%
6	13.3	310.0	266.7	7.8	-45.39%
7	12.7	310.0	263.3	8.8	-34.82%
8	13.7	333.3	278.3	8.3	-42.77%
9	15.0	325.0	290.0	10.0	-35.42%
10	16.0	345.0	290.0	10.8	-33.70%
11	15.0	350.0	300.0	10.0	-34.72%
12	14.8	342.5	295.0	11.0	-26.01%
13	15.8	350.0	310.0	9.3	-41.79%
14	14.3	355.0	315.0	7.5	-45.68%
15	14.3	355.0	315.0	7.5	-47.88%
				Life (Cycles):	**11.67**

Appendix C (Continued)

C.1.5 Locknut Average

Table C-21: MS21043-4; Locknut Average

Locknut Average					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	16.8	257.9	208.3	8.5	-49.88%
2	15.6	265.9	213.2	10.3	-33.99%
3	13.9	273.0	224.3	8.9	-34.84%
4	13.1	274.3	232.8	7.9	-40.65%
5	11.6	274.0	228.4	7.9	-31.31%
6	11.1	266.7	227.9	7.2	-34.19%
7	11.0	270.1	230.2	7.6	-31.35%
8	11.2	275.3	231.8	7.8	-30.26%
9	11.5	275.7	242.1	8.5	-24.97%
10	12.2	288.8	245.3	9.2	-22.61%
11	12.1	260.1	247.3	8.9	-27.12%
12	12.1	291.8	250.8	8.7	-27.66% Y
13	12.4	300.3	261.6	8.0	-33.88%
14	11.8	305.1	264.6	7.8	-32.44%
15	11.8	301.7	261.7	6.7	-37.64%
				Life (Cycles):	**13.2**

C.2 NAS1291-4

C.2.1 Unseated

Table C-22: NAS1291-4; Unseated - Trial 1

Trial 1					
Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	28	27.5	29	-1.79%	3.57%
2	25	27.5	28	10.00%	12.00%
3	25	27	25	8.00%	0.00%
4	25	27.5	27.5	10.00%	10.00%
5	23	24	24	4.35%	4.35%
6	26	22	27	-15.38%	3.85% Y

Appendix C (Continued)

Table C-22 (Continued)

7	25.5	21	26	-17.65%	1.96%
8	24.5	20.75	25	-15.31%	2.04%
9	22.5	18.5	22.5	-17.78%	0.00%
10	24	18	24	-25.00%	0.00%
11	20.5	15	22	-26.83%	7.32%
12	23	19	25	-17.39%	8.70%
13	23	16	23.5	-30.43%	2.17%
14	23	19.5	23.5	-15.22%	2.17%
15	23.5	17.5	25	-25.53%	6.38%
				Life (Cycles):	**15**

Table C-23: NAS1291-4; Unseated - Trial 2

Trial 2					
Cycle	**Assembly Prevailing (in-lbs)**	**Removal Prevailing (in-lbs)**	**Assem. Prevailing Ver. (in-lbs)***	**Percent Difference Removal**	**Percent Difference Assem. Ver.**
1	13.25	8	13.5	-39.62%	1.89%
2	12	6.5	11.5	-45.83%	-4.17%
3	12.5	5.5	12	-56.00%	-4.00%
4	12.5	6.5	12	-48.00%	-4.00%
5	11	5	10.75	-54.55%	-2.27%
6	11.5	6.5	12	-43.48%	4.35%
7	11.5	5.5	11	-52.17%	-4.35%
8	12	6	12	-50.00%	0.00%
9	11.5	6.5	11	-43.48%	-4.35%
10	11.5	5.75	11.5	-50.00%	0.00%
11	12.5	6.5	12	-48.00%	-4.00%
12	13	7	12.5	-46.15%	-3.85% Y
13	11.5	8	13	-30.43%	13.04%
14	11	7	12.5	-36.36%	13.64%
15	11.5	7	13.5	-39.13%	17.39%
				Life (Cycles):	**15**

Appendix C (Continued)

Table C-24: NAS1291-4; Unseated - Trial 3

Trial 3					
Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	19.5	15	17.5	-23.08%	-10.26%
2	17.5	11.5	17.5	-34.29%	0.00%
3	15.5	13	18.5	-16.13%	19.35%
4	16	13	18.25	-18.75% Y	14.06%
5	17	13.5	17.5	-20.59%	2.94%
6	16	12	18	-25.00%	12.50%
7	17	11.5	17.5	-32.35%	2.94%
8	16.25	11	17.5	-32.31%	7.69%
9	16	10.75	17.5	-32.81%	9.38%
10	16.25	10	17	-38.46%	4.62%
11	16.25	10	17.25	-38.46%	6.15%
12	16	12	18.25	-25.00%	14.06%
13	16.5	11.5	18	-30.30%	9.09%
14	17	13	17.5	-23.53%	2.94%
15	17.25	11.5	18	-33.33%	4.35%
				Life (Cycles):	**15**

Table C-25: NAS1291-4; Unseated - Trial 4

Trial 4					
Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	16.5	11.25	15	-31.82%	-9.09%
2	15	10	15	-33.33%	0.00%
3	15	9	15.5	-40.00%	3.33%
4	14	8.75	15	-37.50%	7.14%
5	14.5	8	15	-44.83%	3.45%
6	15	8.5	15	-43.33%	0.00%
7	16	10	16.25	-37.50%	1.56%
8	14.25	9.5	16.5	-33.33%	15.79%
9	15	9.75	15.5	-35.00%	3.33%
10	15	10	16	-33.33%	6.67%
11	16	10	17	-37.50%	6.25%

Appendix C (Continued)

Table C-25 (Continued)

12	16.5	12	16	-27.27%	-3.03%
13	16.5	11	16	-33.33%	-3.03%
14	16	11.5	15	-28.13%	-6.25%
15	17	12.5	16.5	-26.47%	-2.94%
				Life (Cycles):	**15**

Table C-26: NAS1291-4; Unseated - Trial Average

Trial Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Removal Prevailing (in-lbs)**	**Assem. Prevailing Ver. (in-lbs)***	**Percent Difference Removal**	**Percent Difference Assem. Ver.**
1	19.31	15.43	18.75	-24.08%	-3.47%
2	17.37	13.87	18	-25.86%	1.96%
3	17	13.62	17.75	-26.03%	4.67%
4	16.87	13.93	18.18	-23.56%	6.80%
5	16.37	12.62	16.81	-28.90%	2.12%
6	17.12	12.25	18	-31.80%	5.17%
7	17.5	12	17.68	-34.92%	0.53%
8	16.75	11.81	17.75	-32.74%	6.38%
9	16.25	11.37	16.62	-32.27%	2.09%
10	16.68	10.93	17.12	-36.70%	2.82%
11	16.31	10.37	17.06	-37.70%	3.93%
12	17.12	12.5	17.93	-28.95%	3.97%
13	16.87	11.62	17.62	-31.13%	5.32%
14	16.75	12.75	17.12	-25.81%	3.13%
15	17.31	12.12	18.25	-31.12%	6.30%
				Life (Cycles):	15

Appendix C (Continued)

C.2.2 66% Y Preload

Table C-27: NAS1291-4; 66% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	17.5	158	14.9	13	-25.71%
2	14	158	12.5	13	-7.14%
3	11.5	166	10.7	12.5	8.70%
4	11.6	170	14.5	12.5	7.76%
5	12.2	176	12	13	6.56%
6	11	164	13	10.5	-4.55%
7	10.5	180	12	11	4.76%
8	10	179	10.5	12.5	25.00%
9	12.25	175	8.6	11.5	-6.12%
10	10.5	186	9	10	-4.76%
11	12	190	10	11	-8.33%
12	10	190	12	12	20.00%
13	12	200	8	11.5	-4.17%
14	10.5	200	13.5	13.5	28.57%
15	10	211	12.5	13	30.00%
				Life (Cycles):	15

Table C-28: NAS1291-4; 66% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	20	163	136	16	-20.00%
2	16.1	159	134	11	-31.68%
3	15.5	170	143	12	-22.58%
4	15	185	154	11.5	-23.33%
5	15.5	192	157	12.4	-20.00%
6	15	197	168	12	-20.00%
7	15	205	170	11.25	-25.00%
8	14.5	198	174	12	-17.24%
9	14.5	194	170	8.5	-41.38%
10	14	195	166	10.25	-26.79%
11	13.5	200	173	9	-33.33%

Appendix C (Continued)

Table C-28 (Continued)

12	14.5	205	177	9	-37.93%
13	12.7	210	180	9	-29.13%
14	13	214	203	10	-23.08%
15	12.5	215	187	10.9	-12.80%
				Life (Cycles):	**15**

Table C-29: NAS1291-4; 66% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	19.5	165	140	14.5	-25.64%
2	13.5	168	145	11.5	-14.81%
3	13.5	175	150	10.5	-22.22%
4	13.5	180	157	9.75	-27.78%
5	13.5	190	166	11.5	-14.81%
6	14.5	190	170	11.75	-18.97%
7	14.5	200	180	11	-24.14%
8	14.25	205	180	13	-8.77%
9	13.5	205	185	13	-3.70%
10	15	190	165	13.5	-10.00%
11	16.5	205	180	12	-27.27%
12	14	210	185	12	-14.29%
13	14	210	195	12	-14.29%
14	13.5	212	195	11	-18.52%
15	13	215	190	11.5	-11.54%
				Life (Cycles):	**15**

Table C-30: NAS1291-4; 66% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	19.5	185	163	13	-33.33%
2	15	180	155	12.5	-16.67%
3	13.5	185	165	10	-25.93%
4	14	180	156	11.5	-17.86%
5	14	185	165	10.5	-25.00%
6	12.25	190	170	10.5	-14.29%

Appendix C (Continued)

Table C-30 (Continued)

7	13	200	180	11	-15.38%
8	10.75	195	168	10	-6.98%
9	13.25	205	185	10.5	-20.75% Y
10	13.5	225	200	11.25	-16.67%
11	15	225	195	10.5	-30.00%
12	14.5	227	195	12	-17.24%
13	13	237	190	11	-15.38%
14	13.25	236	210	10	-24.53%
15	12.5	260	195	12	-4.00%
				Life (Cycles):	**15**

Table C-31: NAS1291-4; 66% Y - Trial Average

Trial Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	19.67	171	146.33	14.5	-26.32%
2	14.87	169	144.67	11.67	-21.05%
3	14.17	176.67	152.67	10.83	-23.58%
4	14.17	181.67	155.67	10.91	-22.99%
5	14.33	189	162.67	11.47	-19.94%
6	13.92	192.33	169.33	11.42	-17.75% Y
7	14.17	201.67	176.67	11.08	-21.51%
8	13.17	199.33	174	11.67	-11.00%
9	13.75	201.33	180	10.67	-21.95%
10	14.17	203.33	177	11.67	-17.82%
11	15	210	182.67	10.5	-30.20%
12	14.33	214	185.67	11	-23.15%
13	13.23	219	188.33	10.67	-19.60%
14	13.25	220.67	202.67	10.33	-22.04%
15	12.67	230	190.67	11.47	-9.45%
				Life: (Cycles)	**15**

Appendix C (Continued)

C.2.3 75% Y Preload

Table C-32: NAS1291-4; 75% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	21.5	185	15.5	14	-34.88%
2	14.5	202	12.5	13	-10.34%
3	14.5	200	11.5	14	-3.45%
4	14.25	201	9.9	12.5	-12.28%
5	13.5	204	10.5	12.5	-7.41%
6	13.25	206	11	13.5	1.89%
7	12	206	10	13	8.33%
8	13.5	204	10.5	12.5	-7.41%
9	12.5	205	9.5	12.5	0.00%
10	12	209	9	12.5	4.17%
11	12.5	210	9	12	-4.00%
12	13	204	8.5	11	-15.38%
13	13	211	8.5	12	-7.69%
14	13	210	8.4	11	-15.38%
15	13	210	7.5	11.5	-11.54%
				Life (Cycles):	**15**

Table C-33: NAS1291-4; 75% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	20	179	150	15	-25.00%
2	14.9	176	148	13	-12.75% Y
3	13	186	156	12	-7.69%
4	13	185	153	11.2	-13.85% Y
5	13	200	170	10.6	-18.46%
6	13.25	202	171	9.4	-29.06%
7	14	211	181	11	-21.43%
8	14	214	185	10	-28.57%
9	13.5	215	187	10.5	-22.22%
10	13.5	214	185	10	-25.93%
11	13	214	182	10	-23.08%

Appendix C (Continued)

Table C-33 (Continued)

12	13	222	192	9.4	-27.69%
13	13.5	227	195	10	-25.93%
14	13.4	230	200	10.75	-19.78%
15	12.5	216	189	10	-20.00%
				Life (Cycles):	**15**

Table C-34: NAS1291-4; 75% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	15	190	165	14.25	-5.00%
2	14	200	170	14	0.00%
3	14	209	170	13.75	-1.79%
4	13.75	210	183	14	1.82%
5	14	240	195	12.5	-10.71%
6	14	220	194	14.5	3.57%
7	14.5	240	205	13	-10.34%
8	13.75	235	215	10.5	-23.64%
9	13	240	210	10	-23.08%
10	14	230	200	12.5	-10.71%
11	13	255	215	12.5	-3.85% Y
12	13	245	225	12.25	-5.77%
13	12.75	243	225	12	-5.88%
14	13	265	225	11	-15.38%
15	13	258	232	9	-30.77%
				Life (Cycles):	**15**

Table C-35: NAS1291-4; 75% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	27.5	190	162	23.5	-14.55%
2	22	207	176	21.5	-2.27%
3	25.5	225	190	19.5	-23.53%
4	21.25	227	200	20.5	-3.53%
5	20	235	205	22.5	12.50%
6	19.5	238	207	21	7.69%

Appendix C (Continued)

Table C-35 (Continued)

7	17.5	240	218	18.2	4.00%
8	18.25	250	225	19.5	6.85% Y
9	18.25	250	225	17.7	-3.01%
10	16.75	260	225	16.25	-2.99%
11	14	240	215	14.5	3.57%
12	15.25	250	230	14.5	-4.92%
13	15	230	220	13	-13.33%
14	15	250	210	12	-20.00%
15	13	235	210	11.5	-11.54%
				Life (Cycles):	**15**

Table C-36: NAS1291-4; 75% Y - Trial Average

Trial Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	20.83	186.33	159	17.58	-14.85% Y
2	16.97	194.33	164.67	16.17	-5.01%
3	17.5	206.67	172	15.08	-11.00%
4	16	207.33	178.67	15.23	-5.19%
5	15.67	225	190	15.2	-5.56%
6	15.58	220	190. 67	14.97	-5.93%
7	15.33	230.33	201.33	14.07	-9.26%
8	15.33	233	208.33	13.33	-15.12%
9	14.92	235	207.33	12.73	-16.10%
10	14.75	234.67	203.33	12.92	-13.21%
11	13.33	236.33	204	12.33	-7.78%
12	13.75	239	215.67	12.05	-12.79%
13	13.75	233.33	213.33	11.67	-15.05%
14	13.8	248.33	211.67	11.25	-18.39%
15	12.83	236.33	210.33	10.17	-20.77%
				Life: (Cycles)	**15**

Appendix C (Continued)

C.2.4 85% Y Preload

Table C-37: NAS1291-4; 85% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	21	210	11	15	-28.57%
2	14	220	11.5	14.25	1.79%
3	14	210	9.5	12.5	-10.71%
4	12.5	210	7.5	12.5	0.00%
5	12.5	210	8	12	-4.00%
6	13	220	9	13	0.00%
7	13	220	12.5	13.5	3.85% Y
8	13	225	11	12	-7.69%
9	13	230	9.5	15.5	19.23%
10	13.5	235	10	13	-3.70%
11	13	225	8	13	0.00%
12	13	235	9.5	13	0.00%
13	13	235	9	13	0.00%
14	13.5	245	8.5	12	-11.11%
15	13.5	240	8.5	12.5	-7.41%
				Life (Cycles):	**15**

Table C-38: NAS1291-4; 85% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	18.5	221	180	16	-13.51%
2	12.5	230	210	12.5	0.00%
3	12.5	240	215	14	12.00%
4	14	260	230	13	-7.14%
5	13	260	230	12.5	-3.85% Y
6	14	260	240	12.5	-10.71%
7	13	275	245	15	15.38%
8	12.5	270	235	12	-4.00%
9	12.5	290	240	10.5	-16.00%
10	11.5	250	230	8.5	-26.09%
11	11.5	250	240	8.5	-26.09%

Table C-38 (Continued)

12	11.5	250	230	8.5	-26.09%
13	11	260	230	7.5	-31.82%
14	11.5	250*			
15					
		*Locknut 6-Point Hex Damage		**Life (Cycles):**	**14**

Table C-39: NAS1291-4; 85% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	14.5	205	180	11	-24.14%
2	11	190	152	11.25	2.27%
3	12.5	215	180	10	-20.00%
4	12	215	185	9.5	-20.83%
5	11.5	222	187	10.5	-8.70%
6	12	210	167	9.5	-20.83%
7	12	232	198	9	-25.00%
8	11.7	235	210	9.2	-21.37%
9	12.5	240	208	9.5	-24.00%
10	11.5	250	215	9.5	-17.39%
11	11.5	256	230	11.5	0.00%
12	11.5	265	230	10	-13.04%
13	12	270	230	9.5	-20.83%
14	12	270	237	10	-16.67%
15	12	260	240	9.5	-20.83%
				Life (Cycles):	**15**

Table C-40: NAS1291-4; 85% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	17	185	155	15.75	-7.35%
2	15	185	155	12.5	-16.67%
3	15	210	180	13	-13.33%
4	14.5	215	188.25	14	-3.45%
5	14.5	225	195	15.5	6.90%
6	14	230	210	15.5	10.71%
7	14	245	210	15	7.14%

Appendix C (Continued)

Table C-40 (Continued)

8	14	260	225	15.5	10.71%
9	14	260	220	17.5	25.00%
10	15	260	220	18.5	23.33%
11	14	280	230	18.5	32.14%
12	15	310*			
13					
14					
15					
			* Bolt Failed	**Life (Cycles):**	**11**

Table C-41: NAS1291-4; 85% Y - Trial Average

Trial Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	16.67	203.67	171.67	14.25	-15.00%
2	12.83	201.67	172.33	12.08	-4.80%
3	13.33	221.67	191.67	12.33	-7.11%
4	13.5	230	201.08	12.17	-10.47%
5	13	235.67	204	12.83	-1.88%
6	13.33	233.33	205.67	12.5	-6.94%
7	13	250.67	217.67	13	-0.82%
8	12.73	255	223.33	12..23	-4.88%
9	13	263.33	222.67	12.5	-5.00%
10	12.67	253.33	222.5	12.17	-6.71%
11	12.33	262	235	12.83	2.02%
12	12.67	257.5	230	9.25	-19.57%
13	11.5	265	230	8.5	-26.33%
14	11.75	270	237	10	-16.67%
15	12	260	240	9.5	-20.83%
				Life: (Cycles)	**13.75**

Appendix C (Continued)

C.2.5 Locknut Average

Table C-42: NAS1291-4; Locknut Average

Locknut Average					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	19.06	187	159	15.44	-18.72%
2	14.89	188.33	160.56	13.31	-10.29%
3	15	201.67	172.11	12.75	-13.90%
4	14.56	206.33	178.47	12.77	-12.88%
5	14.33	216.56	185.56	13.17	-9.13%
6	14.27	215.22	188.56	12.96	-10.21%
7	14.17	227.56	198.56	12.7	-10.53%
8	13.74	229.11	201.89	12.41	-10.33%
9	13.89	233.22	203.33	11.97	-14.35%
10	13.86	230.44	200.94	12.25	-12.58%
11	13.56	236.11	207.22	11.89	-11.99%
12	13.58	242.67	210.44	10.77	-18.50%
13	12.82	239.11	210.56	10.28	-20.32%
14	12.93	243	217.11	10.52	-19.03%
15	12.5	242.11	213.67	10.38	-17.02%
				Life: (Cycles)	**14.58**

C.3 NAS1805-4

C.3.1 Unseated

Table C-43: NAS1805-4; Unseated - Trial 1

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	22.5	21	22.5	-6.67%	0.00%
2	22.5	20	25	-11.11%	11.11%
3	26.5	22.5	30	-15.09%	13.21%
4	28	35	33	25.00%	17.86%
5	45	40	33	-11.11%	-26.67%
6	30	22	20	-26.67%	-33.33%

Appendix C (Continued)

Table C-43 (Continued)

7	20	20	20	0.00%	0.00%
8	17.5	12.5	10	-28.57%	-42.86%
9	7.5	4	5	-46.67%	-33.33%
10	3	3.5	3	16.67%	0.00%
11	3	2	2	-33.33%	-33.33%
12	2	2	1.75	0.00%	-12.50%
13					
14					
15					
				Life (Cycles):	**4**

Table C-44: NAS1805-4; Unseated - Trial 2

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	18.75	17.5	21.25	-6.67%	13.33%
2	25	22.5	27	-10.00%	8.00%
3	25	26	32.5	4.00%	30.00%
4	34	40	25	17.65%	-26.47%
5	17.5	16.25	17.5	-7.14%	0.00%
6	25	22.5	26.5	-10.00%	6.00%
7	17	12.5	15	-26.47%	-11.76%
8	5	3	4	-40.00%	-20.00%
9	4	3	2	-25.00%	-50.00%
10	2	1.5	1.5	-25.00%	-25.00%
11					
12					
13					
14					
15					
				Life (Cycles):	**3**

Appendix C (Continued)

Table C-45: NAS1805-4; Unseated - Trial 3

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	16.5	13.5	19	-18.18%	15.15%
2	16.25	14.5	18.75	-10.77%	15.38%
3	20	17.5	17.5	-12.50%	-12.50%
4	13	12	16.5	-7.69%	26.92%
5	16	12.5	17.5	-21.88%	9.38%
6	14.5	15	17.5	3.45%	20.69%
7	17.5	15	17.5	-14.29%	0.00%
8	12.5	20	15	60.00%	20.00%
9	12.5	9	12.5	-28.00%	0.00%
10	10	15	11.5	50.00%	15.00%
11	10	5.5	7.5	-45.00%	-25.00%
12	6	7	6.5	16.67%	8.33%
13	5	6	6	20.00%	20.00%
14	5.5	5	4	-9.09%	-27.27%
15	4	3	3.5	-25.00%	-12.50%
				Life (Cycles):	**14**

Table C-46: NAS1805-4; Unseated - Trial 4

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	17.5	16.5	22	-5.71%	25.71%
2	17.5	16	18.25	-8.57%	4.29%
3	17.5	13	18	-25.71%	2.86%
4	20	19.5	22.5	-2.50%	12.50%
5	20	16.5	20	-17.50%	0.00%
6	17.5	11	15	-37.14%	-14.29%
7	22.5	22.5	13.5	0.00%	-40.00%
8	12	12.5	14	4.17%	16.67%
9	12.5	7.5	10	-40.00%	-20.00%
10	6	7.5	7.5	25.00%	25.00%
11	12.5	10	10	-20.00%	-20.00%
12	5	2.5	3	-50.00%	-40.00%
13	5	3	4	-40.00%	-20.00%
14	4.5	2	3	-55.56%	-33.33%
15					
				Life (Cycles):	**11**

Appendix C (Continued)

Table C-47: NAS1805-4; Unseated - Trial Average

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	18.81	17.12	21.18	-9.31%	13.55%
2	20.31	18.25	22.25	-10.11%	9.70%
3	22.25	19.75	24.5	-12.33%	8.39%
4	23.75	26.63	24.25	8.11%	7.70%
5	24.62	21.31	22	-14.41%	-4.32%
6	21.75	17.62	19.75	-17.59%	-5.23%
7	19.25	17.5	16.5	-10.19%	-12.94%
8	11.75	12	10.75	-1.10%	-6.55%
9	9.12	5.87	7.37	-34.92%	-25.83%
10	5.25	6.87	5.87	16.67%	3.75% Y
11	8.5	5.83	6.5	-32.78%	-26.11%
12	4.33	3.83	3.75	-11.11%	-14.72%
13	5	4.5	5	-10.00%	0.00%
14	5	3.5	3.5	-32.32%	-30.30%
15	4	3	3.5	-25.00%	-12.50%
				Life (Cycles):	8

C.3.2 66% Y Preload

Table C-48: NAS1805-4; 66% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	17.5	105	15.5	15.5	-11.43%
2	15.5	112	15	18.5	19.35%
3	21.5	120	21	22	2.33%
4	18	130	20	15	-16.67%
5	14.5	118	22.5	17.5	20.69%
6	13.25	130	16	17	28.30%
7	15	130	15.5	17	13.33%
8	14	125	6.5	12.5	-10.71%
9	3	125	2	3	0.00%
10	2.5	130	1	2.5	0.00%
11	1.5	127	0	1.5	0.00%

Appendix C (Continued)

Table C-48 (Continued)

12					
13					
14					
15					
				Life: (Cycles)	9

Table C-49: NAS1805-4; 66% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	25	127	119	15.5	-38.00%
2	24.25	136	118	14.5	-40.21%
3	24	145	125	16	-33.33%
4	17.5	145	125	14	-20.00%
5	19	152	125	22	15.79%
6	40	161	140	32	-20.00%
7	28	173	150	59	110.71%
8	30	163	142	32	6.67%
9	25	170	150	26	4.00%
10	20	175	150	19	-5.00%
11	15	185	152	9	-40.00%
12	10	180	158	7	-30.00%
13	8	200	180	4	-50.00%
14	4	202	180	3	-25.00%
15	3	198	189	2	-33.33%
				Life: (Cycles)	14

Table C-50: NAS1805-4; 66% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	17.5	112	90	12	-31.43%
2	20.5	120	102	15	-26.83%
3	21	132	112	19	-9.52%
4	23.5	127	110	23	-2.13%
5	25	130	110	30	20.00%
6	28.5	145	120	35	22.81%

Appendix C (Continued)

Table C-50 (Continued)

7	25	163	145	30	20.00%
8	25	174	161	17.5	-30.00%
9	20	185	167	22.5	12.50%
10	20	195	180	14.5	-27.50%
11	17.5	270	240	15	-14.29%
12	15	340*			
13					
14					
15					
			*Bolt Failed	**Life: (Cycles)**	**12**

Table C-51: NAS1805-4; 66% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	22	122	105	10.5	-52.27%
2	15	135	115	15	0.00%
3	16	140	120	19.5	21.88%
4	16	160	139	17	6.25%
5	19	147	125	22.5	18.42%
6	22.5	150	125	31	37.78%
7	22.5	150	125	17.5	-22.22%
8	7.5	160	140	7.5	0.00%
9	7	161	140	7	0.00%
10	7	165	147	8	14.29%
11	6	171	155	5	-16.67%
12	4	175	157	2	-50.00%
13	2	183	166	1	-50.00%
14	1	185	165	1	0.00%
15					
				Life: (Cycles)	**12**

Appendix C (Continued)

Table C-52: NAS1805-4; 66% Y - Trial Average

Trial Average					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	21.5	120.33	104.67	12.67	-40.57%
2	19.97	130.33	111.67	14.83	-22.35%
3	20.33	139	119	18.17	-6.99%
4	19	144	124.67	18	-5.29%
5	21	143	120	24.83	18.07%
6	30.33	152	128.33	32.67	13.53%
7	25.17	162	140	35.5	36.16%
8	20.83	165.67	147.67	19	-7.78%
9	17.33	172	152.33	18.5	5.50%
10	15.67	178.33	159	13.83	-6.07%
11	12.83	208.67	182.33	9.67	-23.65%
12	9.67	177.5	157.5	4.5	-40.00%
13	5	191.5	173	2.5	-50.00%
14	2.5	193.5	172.5	2	-12.50%
15	3	198	189	2	-33.33%
				Life: (Cycles)	**12.67**

C.3.3 75% Y Preload

Table C-53: NAS1805-4; 75% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	21.5	138	15.7	12.5	-41.86%
2	21.5	141	21	21.5	0.00%
3	29	152	42	23	-20.69%
4	26	144	20	17	-34.62%
5	18	151	18.5	20	11.11%
6	13.7	169	9	10	-27.01%
7	9.5	163	7.5	7.7	-18.95%
8	4	180	3	2.5	-37.50%
9	0.25	186	1	1	300.00%
10					

Appendix C (Continued)

Table C-53 (Continued)

11					
12					
13					
14					
15					
				Life: (Cycles)	8

Table C-54: NAS1805-4; 75% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	19	125	105	13	-31.58%
2	17.5	130	110	14.5	-17.14%
3	17.5	130	112	16.5	-5.71%
4	17	145	125	20	17.65%
5	17	155	137	27.5	61.76%
6	16	173	155	23	43.75% Y
7	29	190	168	27.5	-5.17%
8	17.5	183	163	9	-48.57%
9	9.5	187	167	8.5	-10.53%
10	5	200	180	5	0.00%
11	5.5	205	185	9	63.64%
12	6.5	215	195	5.5	-15.38%
13	4	200	180	4	0.00%
14	3	210	190	2	-33.33%
15	1.5	215	190	2	33.33%
				Life: (Cycles)	14

Table C-55: NAS1805-4; 75% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	16.5	120	95	13	-21.21%
2	21.5	120	95	21	-2.33%
3	20.5	125	105	15	-26.83%
4	23	130	105	20	-13.04%
5	20	140	115	17.5	-12.50%

Appendix C (Continued)

Table C-55 (Continued)

6	16.5	155	125	17	3.03%
7	16	165	140	12.5	-21.88%
8	13	167	145	15.5	19.23%
9	13.5	182	160	7.5	-44.44%
10	8	195	177	5.5	-31.25%
11	6	195	180	4	-33.33%
12	3.5	200	177	1.5	-57.14%
13	1.5	195	175	2	33.33%
14	1	195	177	2	100.00%
15					
				Life: (Cycles)	**12**

Table C-56: NAS1805-4; 75% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	19.5	125	100	15.5	-20.51%
2	19.5	115	95	12	-38.46%
3	22	120	100	17.5	-20.45%
4	16	125	105	10	-37.50%
5	17	130	110	11	-35.29%
6	19.5	140	120	25	28.21%
7	15	150	130	11.75	-21.67%
8	9	160	140	10.5	16.67%
9	6	163	150	7	16.67%
10	3.5	189	175	7	100.00%
11	3.5	193	175	4	14.29%
12	3	205	190	3.75	25.00%
13	2.5	202	183	3	20.00%
14	1.75	198	180	2.5	42.86%
15					
				Life: (Cycles)	**12**

Appendix C (Continued)

Table C-57: NAS1805-4; 75% Y - Trial Average

Trial Average					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
1	18.33	123.33	100	13.83	-24.43%
2	19.5	121.67	100	15.83	-19.31%
3	20	125	105.67	16.33	-17.67%
4	18.67	133.33	111.67	16.67	-10.97%
5	18	141.67	120.67	18.67	4.66% Y
6	17.33	156	133.33	21.67	25.00%
7	20	168.33	146	17.25	-16.24%
8	13.17	170	149.33	11.67	-4.22%
9	9.67	177.33	159	7.67	-12.77%
10	5.5	194.67	177.33	5.83	22.92%
11	5	197.67	180	5.67	14.86%
12	4.33	206.67	187.33	3.58	-15.84%
13	2.67	199	179.33	3	17.78%
14	1.92	201	182.33	2.17	36.51%
15	1.5	215	190	2	33.33%
				Life: (Cycles)	**12.67**

C.3.4 85% Y Preload

Table C-58: NAS1805-4; 85% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	21	135	11	16.5	-21.43%
2	20	135	13.75	15	-25.00%
3	22	145	11	16.5	-25.00%
4	22.5	140	12	16	-28.89%
5	15.5	146	12.5	10	-35.48%
6	11.5	152	8	12.5	8.70%
7	6	150	2	6	0.00%

Appendix C (Continued)

Table C-58 (Continued)

8	3	153	3	2.5	-16.67%
9	2	160	2	1.5	-25.00%
10					
11					
12					
13					
14					
15					
				Life: (Cycles)	**7**

Table C-59: NAS1805-4; 85% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference between Assembly Prevailing and Removal Prevailing**
1	14.5	135	105	9.5	-34.48%
2	17.5	125	102	14	-20.00%
3	18	135	109	12.5	-30.56%
4	16.5	145	120	21	27.27%
5	22.5	148	123	21	-6.67%
6	28	173	138	26.5	-5.36%
7	22.5	170	131	14.5	-35.56%
8	15.5	158	127	15	-3.23%
9	15.5	160	130	5	-67.74%
10	5.5	170	140	6	9.09%
11	5.5	178	148	5	-9.09%
12	5	178	155	5.5	10.00%
13	5	185	160	4	-20.00%
14	2	190	163	1.5	-25.00%
15	1	200	170	1	0.00%
				Life: (Cycles)	**14**

Appendix C (Continued)

Table C-60: NAS1805-4; 85% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
1	22.5	135	110	11	-51.11%
2	23.5	155	130	15.5	-34.04%
3	25.5	175	150	19.5	-23.53%
4	28.5	190	165	25	-12.28%
5	20	180	155	20	0.00%
6	18	195	175	22.5	25.00%
7	15	155	135	17.5	16.67%
8	12.5	183	155	11.5	-8.00%
9	13.25	188	160	10	-24.53%
10	8.5	195	170	3	-64.71%
11	2	205	176	2.5	25.00%
12	1.5	190	165	1	-33.33%
13					
14					
15					
				Life: (Cycles)	10

Table C-61: NAS1805-4; 85% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	22.5	125	100	14.5	-35.56%
2	17.5	125	100	13.5	-22.86%
3	12	145	100	4.5	-62.50%
4	7.5	140	117	8	6.67%
5	9.5	143	120	9	-5.26%
6	8	157	135	11.25	40.63%
7	12.5	155	130	13	4.00%
8	20	175	145	16	-20.00%
9	10	160	134	11	10.00%
10	12.5	185	160	20	60.00%

Appendix C (Continued)

Table C-61 (Continued)

11	14	190	110	12.5	-10.71%
12	11	197	170	16.5	50.00%
13	10.5	201	175	10.5	0.00%
14	10	200	180	11	10.00%
15	5	220	183	9	80.00%
				Life: (Cycles)	**15**

Table C-62: NAS1805-4; 85% Y - Trial Average

Trial Averages					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	19.83	131.67	105	11.67	-40.38%
2	19.5	135	110.67	14.33	-25.63%
3	18.5	151.67	119.67	12.17	-38.86%
4	17.5	158.33	134	18	7.22%
5	17.33	157	132.67	16.67	-3.98%
6	18	175	149.33	20.08	20.09%
7	16.67	160	132	15	-4.96%
8	16	172	142.33	14.17	-10.41%
9	12.92	169.33	141.33	8.67	-27.42%
10	8.83	183.33	156.67	9.67	1.46%
11	7.17	191	144.67	6.67	1.73%
12	5.83	188.33	163.33	7.67	8.89%
13	7.75	193	167.5	7.25	-10.00%
14	6	195	171.5	6.25	-7.50%
15	3	210	176.5	5	40.00%
				Life: (Cycles)	**13**

Appendix C (Continued)

C.3.5 Locknut Average

Table C-63: NAS1805-4; Locknut Average

Locknut Averages					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	19.89	125.11	103.22	12.72	-35.13%
2	19.64	129	107.64	15	-22.43%
3	19.61	138.56	114.78	15.56	-21.17%
4	18.39	145.22	123.64	17.56	-3.01%
5	18.78	147.22	124.64	20.06	6.25%
6	21.89	161	137	24.81	19.54%
7	20.61	163.64	139.33	22.58	4.99%
8	16.67	169.22	146.64	14.94	-7.47%
9	13.31	172.89	150.89	11.61	-11.56%
10	10	185.64	164.33	9.78	6.10%
11	8.33	199.11	169	7.33	-2.35%
12	6.61	190.83	169.39	5.25	-15.65%
13	5.14	194.5	173.27	4.25	-14.07%
14	3.47	196.5	175.64	3.47	5.50%
15	2.5	207.67	185.17	3	13.33%
				Life: (Cycles)	**12.78**

C.4 MS17825-4

C.4.1 Unseated

Table C-64: MS17825-4; Unseated - Trial 1

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	9.5	4.5	8	-52.63%	-15.79%
2	7	4	6	-42.86%	-14.29%
3	6	4.75	5	-20.83%	-16.67%
4	5	4.5	5	-10.00%	0.00%
5	5	4.25	4.75	-15.00%	-5.00%
6	5	4	4.75	-20.00%	-5.00%
7	4.75	4	4.75	-15.79%	0.00%

Appendix C (Continued)

Table C-64 (Continued)

8	4.5	4	4.5	-11.11%	0.00%
9	4.5	4	4.25	-11.11%	-5.56%
10	4.5	4	4.25	-11.11%	-5.56%
11	4.5	4.25	4.5	-5.56%	0.00%
12	4.5	4	4.25	-11.11%	-5.56%
13	4.5	4	4.5	-11.11%	0.00%
14	4.5	4	4.5	-11.11%	0.00%
15	4.75	3.75	4.75	-21.05%	0.00%
				Life (Cycles):	**15**

Table C-65: MS17825-4; Unseated - Trial 2

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	8	7	7.5	-12.50%	-6.25%
2	6	5	5.5	-16.67%	-8.33%
3	5.5	4.5	5.5	-18.18%	0.00%
4	5.5	4.25	4.75	-22.73%	-13.64%
5	5.25	4.75	5	-9.52%	-4.76%
6	5	4.75	4.75	-5.00%	-5.00%
7	5	4.5	4.75	-10.00%	-5.00%
8	5	4.5	5	-10.00%	0.00%
9	5	4.5	5	-10.00%	0.00%
10	5	4	4.75	-20.00%	-5.00%
11	5	4.25	4.75	-15.00%	-5.00%
12	5	4.25	4.75	-15.00%	-5.00%
13	5	4	4.5	-20.00%	-10.00%
14	5	4	4.5	-20.00%	-10.00%
15	5	4.25	4.5	-15.00%	-10.00%
				Life (Cycles):	**15**

Table C-66: MS17825-4; Unseated - Trial 3

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	7.5	5.75	6	-23.33%	-20.00%
2	5.5	4.75	4.75	-13.64%	-13.64%
3	4.5	4	4.25	-11.11%	-5.56%

Appendix C (Continued)

Table C-66 (Continued)

4	4.25	3.5	4	-17.65%	-5.88%
5	4.25	3.5	4	-17.65%	-5.88%
6	4.25	3.5	4	-17.65%	-5.88%
7	4.25	3.5	4	-17.65%	-5.88%
8	4.25	3.5	4	-17.65%	-5.88%
9	4	3.25	4	-18.75% Y	0.00%
10	4	3.5	4	-12.50%	0.00%
11	4	3.5	4	-12.50%	0.00%
12	4.5	3.5	4	-22.22%	-11.11%
13	4.25	3.5	4	-17.65%	-5.88%
14	4.25	3.5	4	-17.65%	-5.88%
15	4	3.5	4	-12.50%	0.00%
				Life (Cycles):	**15**

Table C-67: MS17825-4; Unseated - Trial 4

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	9	7	7.5	-22.22%	-16.67%
2	6.5	5.5	6	-15.38%	-7.69%
3	6	5	5.5	-16.67%	-8.33%
4	5.5	5	5	-9.09%	-9.09%
5	5.25	5	5	-4.76%	-4.76%
6	5.25	5	5.25	-4.76%	0.00%
7	5.25	5	5	-4.76%	-4.76%
8	5.25	5	5.5	-4.76%	4.76%
9	5	4.5	5	-10.00%	0.00%
10	5.5	5	5.25	-9.09%	-4.55%
11	5.5	4.75	5.25	-13.64%	-4.55%
12	5.25	4.75	5	-9.52%	-4.76%
13	5.5	4.5	5	-18.18%	-9.09%
14	5.25	4.5	5	-14.29%	-4.76%
15	5.25	4.5	5	-14.29%	-4.76%
				Life (Cycles):	**15**

Appendix C (Continued)

Table C-68: MS17825-4; Unseated - Trial Average

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	8.5	6.06	7.25	-27.67%	-14.68%
2	6.25	4.81	5.56	-22.14%	-10.99%
3	5.5	4.56	5.06	-16.70%	-7.64%
4	5.06	4.31	4.69	-14.87%	-7.15%
5	4.94	4.38	4.69	-11.73%	-5.10%
6	4.88	4.31	4.69	-11.85% Y	-3.97%
7	4.81	4.25	4.63	-12.05%	-3.91%
8	4.75	4.25	4.75	-10.88%	-0.28%
9	4.63	4.06	4.56	-12.47%	-1.39%
10	4.75	4.13	4.56	-13.18%	-3.78%
11	4.75	4.19	4.63	-11.67%	-2.39%
12	4.81	4.13	4.5	-14.46%	-6.61%
13	4.81	4	4.5	-16.73%	-6.24%
14	4.75	4	4.5	-15.76%	-5.16%
15	4.75	4	4.56	-15.71%	-3.69%
				Life (Cycles):	15

C.4.2 66% Y Preload

Table C-69: MS17825-4; 66% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	7	141	6.25	6.5	-7.14%
2	5	154	5.5	5.75	15.00%
3	5	163	5	5	0.00%
4	5	184	5	5	0.00%
5	5	211	4.75	5	0.00%
6	5	232	4.5	4.75	-5.00%
7	4.75	240	4.25	4.5	-5.26%
8	4.75	252	4.25	4.5	-5.26%
9	4.5	279	4.25	4.5	0.00%
10	4.25	270	4	4.5	5.88%

Appendix C (Continued)

Table C-69 (Continued)

11	4	251	4	4.25	6.25%
12	4.5	250	4.5	4.5	0.00%
13	5	240	4	4.5	-10.00%
14	4.75	226	4.5	4.5	-5.26%
15	4.75	181	4.25	4.5	-5.26%
				Life (Cycles):	**15**

Table C-70: MS17825-4; 66% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	7.5	144	127	5	-33.33%
2	5.5	163	137	4.5	-18.18%
3	5.25	166	144	4.5	-14.29%
4	5	197	177	4.25	-15.00%
5	4.5	214	197	4.25	-5.56%
6	4.5	229	198	4	-11.11%
7	4.25	250	225	3.75	-11.76%
8	4.25	279	260	3.75	-11.76%
9	4	281	259	3.5	-12.50%
10	4	250	232	3.5	-12.50%
11	4	200	230	3.25	-18.75% Y
12	3.75	200	280	3.5	-6.67%
13	3.75	191	278	3.5	-6.67%
14	4	210	281	3.25	-18.75% Y
15	3.75	220	320	3.25	-13.33%
				Life (Cycles):	**11**

Table C-71: MS17825-4; 66% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	6.75	150	135	4.5	-33.33%
2	4.75	185	170	3.75	-21.05%
3	4.25	217	198	3.75	-11.76%
4	4	200	175	3.75	-6.25%
5	4	235	215	3.75	-6.25%
6	4	250	230	4	0.00%

Appendix C (Continued)

Table C-71 (Continued)

7	3.75	220	190	3.75	0.00%
8	3.5	240	200	3.5	0.00%
9	3.5	240	210	3.5	0.00%
10	3.5	250	220	3.5	0.00%
11	3.75	280	250	3.5	-6.67%
12	3.75	265	230	3.5	-6.67%
13	3.5	280	250	3.25	-7.14%
14	3.5	280	250	3.5	0.00%
15	3.75	300	275	3.5	-6.67%
				Life (Cycles):	**13**

Table C-72: MS17825-4; 66% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	8	155	135	5.25	-34.38%
2	5.25	170	140	5	-4.76%
3	5	195	180	4.25	-15.00%
4	4.5	207	195	4.25	-5.56%
5	4.5	235	215	3.75	-16.67%
6	4.25	240	220	3.75	-11.76%
7	4.25	260	225	3.5	-17.65%
8	4.25	240	220	3.75	-11.76%
9	4	260	220	3.5	-12.50%
10	4	250	210	3.5	-12.50%
11	4	240	210	3.5	-12.50%
12	4	230	200	3.25	-18.75% Y
13	3.75	280	210	3.25	-13.33%
14	3.75	230	210	3.25	-13.33%
15					
				Life (Cycles):	**12**

Appendix C (Continued)

Table C-73: MS17825-4; 66% Y - Trial Average

Trial Average					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	7.42	149.67	132.33	4.92	-33.68%
2	5.17	172.67	149	4.42	-14.67%
3	4.83	192.67	174	4.17	-13.68%
4	4.5	201.33	182.33	4.08	-8.94%
5	4.33	228	209	3.92	-9.49%
6	4.25	239.67	216	3.92	-7.63%
7	4.08	243.33	213.33	3.67	-9.80%
8	4	253	226.67	3.67	-7.84%
9	3.83	260.33	229.67	3.5	-8.33%
10	3.83	250	220.67	3.5	-8.33%
11	3.92	240	230	3.42	-12.64%
12	3.83	231.67	236.67	3.42	-10.69%
13	3.67	250.33	246	3.33	-9.05%
14	3.75	240	247	3.33	-10.69%
15	3.75	260	297.5	3.38	-10.00%
				Life (Cycles):	**12**

C.4.3 75% Y Preload

Table C-74: MS17825-4; 75% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	10	180	8	8	-20.00%
2	7	203	6	6.5	-7.14%
3	6	214	5.5	5.5	-8.33%
4	5.5	240	5	5	-9.09%
5	5.5	260	4.75	5	-9.09%
6	5.25	300	4.5	4.5	-14.29%
7	5.25	290	4.5	5	-4.76%
8	5	292	4	4.5	-10.00%
9	5	292	4	4.5	-10.00%
10	5	295	3.75	4.25	-15.00%

Appendix C (Continued)

Table C-74 (Continued)

11	4.75	290	3.75	4	-15.79%
12	4.5	295	3.5	4	-11.11%
13	4.5	290	3.75	4	-11.11%
14	4.25	290	3.5	4	-5.88%
15	4.25	292	3.75	4	-5.88%
				Life (Cycles):	**15**

Table C-75: MS17825-4; 75% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	8	157	140	5.25	-34.38%
2	6	185	160	4.5	-25.00%
3	5.5	206	178	4.75	-13.64%
4	5	243	210	4.5	-10.00%
5	5	244	212	4.25	-15.00%
6	4.75	235	200	4.25	-10.53%
7	4.5	310	250	4.25	-5.56%
8	4.5	260	205	4	-11.11%
9	4.75	230	200	4	-15.79%
10	5	260	230	4	-20.00%
11	4.5	290	230	4	-11.11%
12	4.5	290	230	3.75	-16.67%
13	4.25	265	220	3.75	-11.76%
14	4	290	230	3.5	-12.50%
15	4	250	210	3.5	-12.50%
				Life (Cycles):	**15**

Table C-76: MS17825-4; 75% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	8	175	145	4.25	-46.88%
2	4.75	180	158	3.75	-21.05%
3	4.25	180	150	3.5	-17.65%
4	3.75	192	170	3.5	-6.67%
5	3.75	237	210	3.25	-13.33%
6	4	240	205	3.25	-18.75% Y

Appendix C (Continued)

Table C-76 (Continued)

7	4	235	195	3	-25.00%
8					
9					
10					
11					
12					
13					
14					
15					
				Life (Cycles):	**5**

Table C-77: MS17825-4; 75% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	9	185	165	5	-44.44%
2	6	205	192	4.5	-25.00%
3	5	235	205	4	-20.00%
4	4.5	230	202	3.75	-16.67%
5	4	250	235	3.5	-12.50%
6	3.75	262	250	3.5	-6.67%
7	3.75	260	250	3.25	-13.33%
8	3.75	273	260	3.25	-13.33%
9	4	280	260	3.25	-18.75% Y
10					
11					
12					
13					
14					
15					
				Life (Cycles):	**7**

Appendix C (Continued)

Table C-78: MS17825-4; 75% Y - Trial Average

Trial Average					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	8.33	172.33	150	4.83	-41.90%
2	5.583	190	170	4.25	-23.68%
3	4.92	207	177.67	4.08	-17.09%
4	4.42	221.67	194	3.92	-11.11%
5	4.25	243.67	219	3.67	-13.61%
6	4.17	245.67	218.33	3.67	-11.98%
7	4.08	268.33	231.67	3.5	-14.63%
8	4.13	266.5	156.33	3.63	-12.22%
9	4.38	255	154.67	3.63	-17.27%
10	5	260	116.88	4	-20.00%
11	4.5	290	116.88	4	-11.11%
12	4.5	290	116.75	3.75	-16.67%
13	4.25	265	111.88	3.75	-11.76%
14	4	290	116.75	3.5	-12.50%
15	4	250	106.88	3.5	-12.50%
				Life (Cycles):	9

C.4.4 85% Y Preload

Table C-79: MS17825-4; 85% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	11	215	6	6.5	-40.91%
2	6	235	5	5.5	-8.33%
3	5.5	270	4.5	5	-9.09%
4	5	290	4	4.75	-5.00%
5	5	310	3.75	4.75	-5.00%
6	4.75	312	3.5	4.5	-5.26%
7	4.75	320	3.25	4	-15.79%
8	4.75	340	3.5	4.5	-5.26%
9	4.5	330	3.5	4.75	5.56%
10	5	325	3	4.5	-10.00%

Appendix C (Continued)

Table C-79 (Continued)

11	5	303	3	4.5	-10.00%
12	4.75	300	3	4.5	-5.26%
13					
14					
15					
				Life (Cycles):	**7**

Table C-80: MS17825-4; 85% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	10	184	162	5.25	-47.50%
2	6.5	210	188	4.25	-34.62%
3	6	235	205	4	-33.33%
4	6	270	238	3.25	-45.83%
5	5.75	260	235	3.25	-43.48%
6	5.75	270	250	3.25	-43.48%
7					
8					
9					
10					
11					
12					
13					
14					
15					
				Life (Cycles):	**4**

Table C-81: MS17825-4; 85% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	9	200	175	5.5	-38.89%
2	6	235	212	4	-33.33%
3	5	270	260	4	-20.00%
4	5	265	210	4	-20.00%
5	5	285	270	3.75	-25.00%
6	5	280	260	3.5	-30.00%

Appendix C (Continued)

Table C-81 (Continued)

7	5	310	280	4	-20.00%
8	5	305	270	4	-20.00%
9	5	310	270	4.5	-10.00%
10	5	300	240	4.25	-15.00%
11	5	270	207	4.5	-10.00%
12	5.25	270	235	4.5	-14.29%
13	5.5	310	230	5	-9.09%
14	5	350	270	4.5	-10.00%
15	5.5	330	280	4.5	-18.18%
				Life (Cycles):	**15**

Table C-82: MS17825-4; 85% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	10	210	190	5.5	-45.00%
2	6	260	250	5	-16.67%
3	5.5	290	260	4.75	-13.64%
4	5	300	275	5	0.00%
5	5	300	290	4.75	-5.00%
6	5.5	305	270	5	-9.09%
7	5.5	305	255	5	-9.09%
8	5	275	245	5	0.00%
9	5	300	260	5	0.00%
10	5.5	280	260	5	-9.09%
11	5	300	250	5.5	10.00%
12	4.5	200	150	5	11.11%
13	5	170	145	5	0.00%
14	4.5	180	150	4.5	0.00%
15	4.5	200	150	4.5	0.00%
				Life (Cycles):	**15**

Appendix C (Continued)

Table C-83: MS17825-4; 85% Y - Trial Average

Trial Average					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	9.67	198	175.67	5.42	-43.80%
2	6.17	235	216.67	4.42	-28.21%
3	5.5	265	241.67	4.25	-22.32%
4	5.33	278.33	241	4.08	-21.94%
5	5.25	281.67	265	3.92	-24.49%
6	5.42	285	260	3.92	-27.52%
7	5.25	307.5	179.42	4.5	-14.55%
8	5	290	172.83	4.5	-10.00%
9	5	305	177.83	4.75	-5.00%
10	5.25	290	167.67	4.63	-12.05%
11	5	285	153.33	5	0.00%
12	4.88	235	129.33	4.75	-1.59%
13	5.25	240	187.5	5	-4.55%
14	4.75	265	210	4.5	-5.00%
15	5	265	215	4.5	-9.09%
				Life (Cycles):	**11.33**

C.4.5 Locknut Average

Table C-84: MS17825-4; Locknut Average

Locknut Average					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	8.47	173.33	152.67	5.06	-39.79%
2	5.64	199.22	178.56	4.36	-22.18%
3	5.08	221.56	197.78	4.17	-17.70%
4	4.75	233.78	205.78	4.03	-14.00%
5	4.61	251.11	231	3.83	-15.86%
6	4.61	256.78	231.64	3.83	-15.71%
7	4.47	273.06	208.139	3.89	-12.99%
8	4.38	269.83	185.27	3.93	-10.02%
9	4.40	273.64	187.39	3.96	-10.20%
10	4.69	266.67	168.40	4.04	-13.46%
11	4.47	271.67	166.74	4.14	-7.92%

Appendix C (Continued)

Table C-84 (Continued)

12	4.40	252.22	160.92	3.97	-9.65%
13	4.39	251.78	181.79	4.02	-8.45%
14	4.17	265	191.25	3.78	-9.40%
15	4.25	258.33	206.45	3.79	-10.53%
				Life (Cycles):	**10.78**

C.4.6 Lubrication Test

Table C-85: MS17825-4 3-IN-ONE; 85% Y - Trial 5

Trial 5 - TIO					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	4.5	122.5	80	3	-33.33%
2	3.5	160	67.5	2.5	-28.57%
3	3	100	60	2	-33.33%
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
				Life (Cycles):	**0**

Appendix C (Continued)

C.5 MS21044D4

C.5.1 Unseated

Table C-86: MS21044D4; Unseated - Trial 1

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	21	16.25	18	-22.62%	-14.29%
2	16	9.5	15	-40.63%	-6.25%
3	15	12.5	13.5	-16.67%	-10.00%
4	13	10	13.5	-23.08%	3.85% Y
5	14.5	9	13.5	-37.93%	-6.90%
6	14	10	13.5	-28.57%	-3.57%
7	14.5	10.5	12.5	-27.59%	-13.79%
8	14.5	10.25	14.5	-29.31%	0.00%
9	14	7.5	14	-46.43%	0.00%
10	13.5	10.5	13	-22.22%	-3.70%
11	13	11.5	12.5	-11.54%	-3.85% Y
12	13.5	9.25	13.5	-31.48%	0.00%
13	9	8	8	-11.11%	-11.11%
14	7.5	5	5.5	-33.33%	-26.67%
15	6	4	5.5	-33.33%	-8.33%
				Life (Cycles):	**15**

Table C-87: MS21044D4; Unseated - Trial 2

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	22.5	14	19.25	-37.78%	-14.44%
2	17.75	13	17.5	-26.76%	-1.41%
3	18.5	13	17.5	-29.73%	-5.41%
4	16.25	11	16	-32.31%	-1.54%
5	17.5	11.5	15	-34.29%	-14.29%
6	17	15	16.5	-11.76%	-2.94%
7	17	12.25	16.5	-27.94%	-2.94%
8	16.5	12	16.5	-27.27%	0.00%
9	17.5	11.5	16	-34.29%	-8.57%

Appendix C (Continued)

Table C-87 (Continued)

10	17	11.75	16	-30.88%	-5.88%
11	15.5	11.25	16.5	-27.42%	6.45%
12	15	14	15	-6.67%	0.00%
13	16	10.75	15	-32.81%	-6.25%
14	15	14	16	-6.67%	6.67%
15	16	13	15.5	-18.75% Y	-3.13%
				Life (Cycles):	**15**

Table C-88: MS21044D4; Unseated - Trial 3

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	22.5	16	21.5	-28.89%	-4.44%
2	20	14.5	20	-27.50%	0.00%
3	17.5	15	18	-14.29%	2.86%
4	20	13.5	17.5	-32.50%	-12.50%
5	17.5	14	18.5	-20.00%	5.71%
6	16.5	13.5	16.5	-18.18%	0.00%
7	15.5	12.5	16.25	-19.35%	4.84%
8	16.5	11	16	-33.33%	-3.03%
9	16	12.5	17.5	-21.88%	9.38%
10	17.5	12.5	15	-28.57%	-14.29%
11	15.5	14.5	15.5	-6.45%	0.00%
12	17	13	15	-23.53%	-11.76%
13	15.5	13	14	-16.13%	-9.68%
14	13.5	14.5	14.5	7.41%	7.41%
15	15	14.5	15	-3.33%	0.00%
				Life (Cycles):	**15**

Table C-89: MS21044D4; Unseated - Trial 4

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	23	17	21	-26.09%	-8.70%
2	19	15.5	17.5	-18.42%	-7.89%
3	18	15.5	18	-13.89%	0.00%
4	18.5	14.5	18	-21.62%	-2.70%

Appendix C (Continued)

Table C-89 (Continued)

5	18.5	13	16.5	-29.73%	-10.81%
6	18	14.5	17.5	-19.44%	-2.78%
7	17.5	13.5	16.5	-22.86%	-5.71%
8	16.5	12	16.5	-27.27%	0.00%
9	16.5	13	16.5	-21.21%	0.00%
10	16	16.75	16.5	4.69%	3.13%
11	17.5	12	16	-31.43%	-8.57%
12	16.5	13.5	15.5	-18.18%	-6.06%
13	15	12	16	-20.00%	6.67%
14	16.5	15.5	15	-6.06%	-9.09%
15	16.5	11.5	15	-30.30%	-9.09%
				Life (Cycles):	**15**

Table C-90: MS21044D4; Unseated - Trial Average

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	22.25	15.81	19.94	-28.84%	-10.47%
2	18.19	13.13	17.5	-28.33%	-3.89%
3	17.25	14	16.75	-18.64%	-3.14%
4	16.94	12.25	16.25	-27.38%	-3.22%
5	17	11.88	15.88	-30.49%	-6.57%
6	16.38	13.25	16	-19.49%	-2.32%
7	16.13	12.19	15.43	-24.43%	-4.40%
8	16	11.31	15.88	-29.30%	-0.76%
9	16	11.13	16	-30.95%	0.20%
10	16	12.88	15.13	-19.25%	-5.19%
11	15.38	12.31	15.13	-19.21%	-1.49%
12	15.5	12.43	14.75	-19.96%	-4.46%
13	13.88	10.94	13.25	-20.01%	-5.09%
14	13.13	12.25	12.75	-9.66% Y	-5.42%
15	13.38	10.75	12.75	-21.43%	-5.14%
				Life (Cycles):	15

Appendix C (Continued)

C.5.2 66% Y Preload

Table C-91: MS21044D4; 66% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	25	175	18.75	21.5	-14.00%
2	21	195	16.5	18.5	-11.90%
3	17.5	200	15	18	2.86%
4	17.5	200	15	16.5	-5.71%
5	17.5	200	15	17.5	0.00%
6	17.5	197.5	12.5	15.5	-11.43%
7	15.5	205	11.5	15	-3.23%
8	15	215	10	16	6.67%
9	15	220	12.5	15	0.00%
10	15	235	12.5	15	0.00%
11	16	242.5	13	17.5	9.38%
12	17.5	280	12.5	17	-2.86%
13	17.5	280	12	16	-8.57%
14	15.5	280	11.5	14.5	-6.45%
15	15	310	11.5	16.5	10.00%
				Life: (Cycles)	**15**

Table C-92: MS21044D4; 66% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	22.5	180	150	12.5	-44.44%
2	20	197.5	175	11.5	-42.50%
3	20	210	180	10.5	-47.50%
4	20	220	182.5	9.5	-52.50%
5	19	240	205	8.5	-55.26%
6	18	260	225	9	-50.00%
7	17.5	300	260	8	-54.29%
8	17.5	325	280	8	-54.29%
9	16	350	310	7.5	-53.13%
10	15.5	355	290	7	-54.84%
11	15	310	270	7	-53.33%

Appendix C (Continued)

Table C-92 (Continued)

12	15	310	255	6.5	-56.67%
13	15	310	280	7	-53.33%
14	15.5	300	280	6	-61.29%
15	15	300	270	6.5	-56.67%
				Life: (Cycles)	**15**

Table C-93: MS21044D4; 66% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	27.5	190	170	13.5	-50.91%
2	23	215	170	10.5	-54.35%
3	20	205	180	11	-45.00%
4	18	215	185	8	-55.56%
5	18	220	200	9	-50.00%
6	17	245	207.5	8	-52.94%
7	15.5	290	240	7.5	-51.61%
8	16.5	310	240	8	-51.52%
9	15.5	310	270	7	-54.84%
10	15	350	310	7.5	-50.00%
11	17.5	400	350	7	-60.00%
12	15.5	380	340	7	-54.84%
13	15	310	280	7	-53.33%
14	14.5	420	370	6.5	-55.17%
15	15	400	370	6.75	-55.00%
				Life: (Cycles)	**15**

Table C-94: MS21044D4; 66% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	20	170	145	12	-40.00%
2	21	180	167.5	10.5	-50.00%
3	21	205	175	11.5	-45.24%
4	20	205	175	11	-45.00%
5	20	210	180	9	-55.00%
6	20	215	180	9.5	-52.50%

Table C-94 (Continued)

7	19.5	225	195	8.5	-56.41%
8	19.5	250	210	9	-53.85% Y
9	19	280	230	8.5	-55.26%
10	17.5	320	310	9	-48.57%
11	17.5	350	290	9.5	-45.71%
12	17.5	400	370	9.5	-45.71%
13	17.5	375	350	8	-54.29%
14	17.5	335	280	9	-48.57%
15	17	320	270	8.75	-48.53%
				Life: (Cycles)	**15**

Table C-95: MS21044D4; 66% Y - Trial Average

Trial Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	23.33	180	155	12.67	-45.12%
2	21.33	197.5	170.83	10.83	-48.95%
3	20.33	206.67	178.33	11	-45.91%
4	19.33	213.33	180.83	9.5	-51.02%
5	19	223.33	195	8.83	-53.42%
6	18.33	240	204.17	8.83	-51.81%
7	17.5	271.67	231.67	8	-54.10%
8	17.83	295	243.33	8.33	-53.22%
9	16.83	313.33	270	7.67	-54.41%
10	16	341.67	303.33	7.83	-51.14%
11	16.67	353.33	303.33	7.83	-53.02%
12	16	363.33	321.67	7.67	-52.41%
13	15.83	331.67	214	7.33	-53.81%
14	15.83	351.67	310	7.17	-54.93%
15	15.67	340	303.33	7.33	-52.60%
				Life: (Cycles)	**15**

Appendix C (Continued)

C.5.3 75% Y Preload

Table C-96: MS21044D4; 75% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	24.5	225	20	20.5	-16.33%
2	20.5	220	18	19.5	-4.88%
3	21	222.5	17.5	17	-19.05%
4	20	220	16.5	18	-10.00%
5	20	235	16	17.5	-12.50%
6	18	225	15	17	-5.56%
7	18	232.5	15.5	16	-11.11%
8	18.5	225	15	16.5	-10.81%
9	18	240	15	16	-11.11%
10	19	242.5	16	15.5	-18.42%
11	17.5	235	15	15.5	-11.43%
12	17.5	250	14.5	15.5	-11.43%
13	16	260	13.5	14.5	-9.38%
14	17.5	310	13.5	15.5	-11.43%
15	15.5	290	12.5	13.5	-12.90%
				Life: (Cycles)	**15**

Table C-97: MS21044D4; 75% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	27.5	215	185	11.5	-58.18%
2	20.5	235	200	10.5	-48.78%
3	19.5	235	200	10.5	-46.15%
4	18.5	245	210	9.5	-48.65%
5	20	255	225	10	-50.00%
6	18	270	240	9	-50.00%
7	18	320	260	9.5	-47.22%
8	17.5	360	340	9	-48.57%
9	18.5	370	310	9	-51.35%
10	17.5	420	340	9.25	-47.14%
11	17	420	420	9	-47.06%

Appendix C (Continued)

Table C-97 (Continued)

12	20	430	400	8.5	-57.50%
13	17	370	310	10.75	-36.76%
14	16.5	450	400	9	-45.45%
15	17.5	350	300	8	-54.29%
				Life: (Cycles)	**15**

Table C-98: MS21044D4; 75% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	22.5	235	195	14.5	-35.56%
2	21.5	230	195	12	-44.19%
3	21.5	237.5	210	10	-53.49%
4	19.5	250	220	8.5	-56.41%
5	18.5	270	235	10.5	-43.24%
6	17.5	315	280	7.5	-57.14%
7	17	340	280	7.75	-54.41%
8	17	420	335	8.5	-50.00%
9	17.5	425	400	8	-54.29%
10	17	360	300	8.5	-50.00%
11	15.5	350	300	9.5	-38.71%
12	17	345	305	7.5	-55.88%
13	15	340	310	8	-46.67%
14	17.5	355	305	8	-54.29%
15	15.5	340	300	9	-41.94%
				Life: (Cycles)	**15**

Table C-99: MS21044D4; 75% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	20	212.5	175	9	-55.00%
2	17.5	230	195	8	-54.29%
3	18	255	207.5	7.25	-59.72%
4	18	260	220	7	-61.11%
5	17.5	285	240	7.5	-57.14%
6	17	335	270	10	-41.18%

Table C-99 (Continued)

7	16	385	340	7.5	-53.13%
8	18	420	340	6.25	-65.28%
9	17.5	420	380	6	-65.71%
10	15	360	280	7	-53.33%
11	17.5	430	380	7	-60.00%
12	15	420	390	7.5	-50.00%
13	14.5	350	305	8.5	-41.38%
14	15	345	305	6	-60.00%
15	14	355	320	6	-57.14%
				Life: (Cycles)	**15**

Table C-100: MS21044D4; 75% Y - Trial Average

Trial Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	23.33	220.83	185	11.67	-49.58%
2	19.83	231.67	196.67	10.17	-49.08%
3	19.67	242.5	205.83	9.25	-53.12%
4	18.67	251.67	216.67	8.33	-55.39%
5	18.67	270	233.33	9.33	-50.13%
6	17.5	306.67	263.33	8.83	-49.44%
7	17	348.33	293.33	8.25	-51.59%
8	17.5	400	338.33	7.92	-54.62%
9	17.83	405	363.33	7.67	-57.12%
10	16.5	380	306.67	8.25	-50.16%
11	16.67	400	366.67	8.5	-48.59%
12	17.33	398.33	365	7.83	-54.46%
13	15.5	353.33	308.33	9.08	-41.60%
14	16.33	383.33	336.67	7.67	-53.25%
15	15.67	348.33	306.67	7.67	-51.12%
				Life: (Cycles)	**15**

Appendix C (Continued)

C.5.4 85% Y Preload

Table C-101: MS21044D4; 85% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	23	290	19.5	20.25	-11.96%
2	20	280	18	17.5	-12.50%
3	19	280	17.5	18	-5.26%
4	19.5	320	16	17	-12.82%
5	18	360	16	17	-5.56%
6	19	390	15	16.5	-13.16%
7	19	380	15	18	-5.26%
8	17.5	365	14.5	15	-14.29%
9	18	385	13	13.5	-25.00%
10	16	380	13	13.5	-15.63%
11	17	380	12.5	13	-23.53%
12	16	370	14	16.5	3.13%
13	17	370	12.5	13.5	-20.59%
14	16	380	12.5	13.5	-15.63%
15	15.5	360	12	13	-16.13%
				Life: (Cycles)	**15**

Table C-102: MS21044D4; 85% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	22.5	235	200	11	-51.11%
2	18	250	200	9.5	-47.22%
3	18	260	220	8	-55.56%
4	16	270	230	7.5	-53.13%
5	16	290	250	8.5	-46.88%
6	17	320	280	8	-52.94%
7	17	340	300	8	-52.94%
8	16	350	300	8.5	-46.88%
9	16	480	440	9.5	-40.63%
10	16	370	330	10	-37.50%

Appendix C (Continued)

Table C-102 (Continued)

11	17	480	460	11.5	-32.35%
12	18	380*			
13					
14					
15					
			*Bolt Failed	**Life: (Cycles)**	**11**

Table C-103: MS21044D4; 85% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	22	250	230	11	-50.00%
2	19	280	250	8.5	-55.26%
3	17.5	310	260	8	-54.29%
4	18	360	290	6.25	-65.28%
5	16	380	320	7	-56.25%
6	16	360	320	7	-56.25%
7	17.5	480	440	8.5	-51.43%
8	16	370	320	6.5	-59.38%
9	15	400	350	7.5	-50.00%
10	15.5	390	350	8.5	-45.16%
11	14.5	390	360	5	-65.52%
12	14.5	370	340	6	-58.62%
13	12.5	370	350	8.5	-32.00%
14	13.5	400	350	10	-25.93%
15	16.5	375	340	11	-33.33%
				Life: (Cycles)	**15**

Table C-104: MS21044D4; 85% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	25	250	210	12.5	-50.00%
2	22.5	250	220	10	-55.56%
3	18	250	230	11	-38.89%
4	17.5	270	220	9	-48.57%
5	17.5	260	230	8.5	-51.43%

Appendix C (Continued)

Table C-104 (Continued)

6	17.5	280	250	8	-54.29%
7	16	280	330	7	-56.25%
8	15	350	300	7	-53.33%
9	14.5	380	330	6.5	-55.17%
10	16	380	330	7	-56.25%
11	16	380	340	6.5	-59.38%
12	15	380	350	7	-53.33%
13	17.5	390	340	7.5	-57.14%
14	15	380	340	8.5	-43.33%
15	15	360	340	9.5	-36.67%
				Life: (Cycles)	**15**

Table C-105: MS21044D4; 85% Y - Trial Average

Trial Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	23.17	245	213.33	11.5	-50.37%
2	19.83	260	223.33	9.33	-52.68%
3	17.83	273.33	236.67	9	-49.58%
4	17.17	300	246.67	7.583	-55.66% Y
5	16.5	310	266.67	8	-51.52%
6	16.83	320	283.33	7.67	-54.49%
7	16.83	366.67	356.67	7.83	-53.54%
8	15.67	356.67	306.67	7.33	-53.19%
9	15.17	420	373.33	7.83	-48.60%
10	15.83	380	336.67	8.5	-46.30%
11	15.83	416.67	386.67	7.67	-52.42%
12	15.83	375	345	6.5	-55.98%
13	15	380	345	8	-44.57%
14	14.25	390	345	9.25	-34.63%
15	15.75	367.5	340	10.25	-35.00%
				Life: (Cycles)	**13.67**

Appendix C (Continued)

C.5.5 Locknut Average

Table C-106: MS21044D4; Locknut Average

Locknut Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	23.27	215.27	184.64	11.94	-48.36%
2	20.33	229.72	196.94	10.11	-50.24%
3	19.27	240.83	206.94	9.75	-49.54%
4	18.39	255	214.72	8.472	-54.02%
5	18.06	267.78	231.67	8.72	-51.69%
6	17.56	288.89	250.27	8.64	-51.92%
7	17.111	328.89	293.89	8.028	-53.08%
8	17	350.56	296.11	7.86	-53.68%
9	16.61	379.64	335.56	7.72	-53.38%
10	16.111	367.22	315.56	8.19	-49.20%
11	16.39	390	352.22	8	-51.34%
12	16.39	378.89	343.89	7.33	-54.28%
13	15.44	355	318.89	8.14	-46.61%
14	15.47	375	330.56	8.03	-47.63%
15	15.69	351.94	316.67	8.42	-46.51%
				Life: (Cycles)	**14.56**

C.6 MS21044D4 with Lubrication

C.6.1 Unseated – Lubricated

Table C-107: MS21044D4 Braycote; Unseated - Trial 1

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	9	7	7.5	-22.22%	-16.67%
2	6.5	5.25	5.75	-19.23%	-11.54%
3	6.25	5.25	6.25	-16.00%	0.00%
4	6.25	5.25	6.5	-16.00%	4.00%
5	6.25	5.5	6.5	-12.00%	4.00%
6	6.5	6	6.75	-7.69%	3.85% Y

Appendix C (Continued)

Table C-107 (Continued)

7	7	6.5	7	-7.14%	0.00%
8	7	7	7.5	0.00%	7.14%
9	6.75	6.25	7	-7.41%	3.70%
10	7.25	6.75	7.25	-6.90%	0.00%
11	7	6.25	7	-10.71%	0.00%
12	7.5	6.25	7.75	-16.67%	3.33%
13	7.25	6.25	7	-13.79%	-3.45%
14	7	6	7	-14.29%	0.00%
15	7.5	6.5	7.25	-13.33%	-3.33%
				Life (Cycles):	**15**

Table C-108: MS21044D4 Braycote; Unseated - Trial 2

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	6	6	6.5	0.00%	8.33%
2	5	5	5.5	0.00%	10.00%
3	5.75	5.5	5.5	-4.35%	-4.35%
4	5.5	5.25	5.5	-4.55%	0.00%
5	5.5	5.5	6.5	0.00%	18.18%
6	5.25	5.25	5.5	0.00%	4.76%
7	6	5.5	6	-8.33%	0.00%
8	5.75	6	5.5	4.35%	-4.35%
9	5.5	5.5	5.5	0.00%	0.00%
10	5.5	5	5.5	-9.09%	0.00%
11	6.75	6	6.75	-11.11%	0.00%
12	6.5	5.75	6.5	-11.54%	0.00%
13	7	5.5	6	-21.43%	-14.29%
14	6	5.5	6.25	-8.33%	4.17%
15	5.75	5.5	6	-4.35%	4.35%
				Life (Cycles):	**15**

Appendix C (Continued)

Table C-109: MS21044D4 Braycote; Unseated - Trial 3

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	7.5	6.75	7.25	-10.00%	-3.33%
2	5.5	5	6	-9.09%	9.09%
3	5.5	5.5	5.75	0.00%	4.55%
4	5	4.75	5.5	-5.00%	10.00%
5	5.5	5.5	5.5	0.00%	0.00%
6	6	5.5	6	-8.33%	0.00%
7	6.5	6.5	7.25	0.00%	11.54%
8	7.25	6.25	6.75	-13.79%	-6.90%
9	7.5	6	7	-20.00%	-6.67%
10	7	6.25	6.5	-10.71%	-7.14%
11	7	6	7	-14.29%	0.00%
12	7	5.75	7	-17.86%	0.00%
13	6.5	5.75	6.25	-11.54%	-3.85% Y
14	6.75	5.75	7	-14.81%	3.70%
15	6.5	5.5	7	-15.38%	7.69%
				Life (Cycles):	**15**

Table C-110: MS21044D4 Braycote; Unseated - Trial 4

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	5.5	5.5	6	0.00%	9.09%
2	5	5	5.5	0.00%	10.00%
3	5	5.25	5.5	5.00%	10.00%
4	6	5	6.5	-16.67%	8.33%
5	5.5	5	6.5	-9.09%	18.18%
6	6	4.75	5.75	-20.83%	-4.17%
7	5.5	5.5	5.75	0.00%	4.55%
8	5.5	5.25	6.25	-4.55%	13.64%
9	6.5	5	6.5	-23.08%	0.00%
10	5.5	5.25	6.5	-4.55%	18.18%
11	5.75	5.5	5.75	-4.35%	0.00%
12	6.25	5.5	6.25	-12.00%	0.00%
13	6.25	5.25	6.75	-16.00%	8.00%
14	6.5	5.5	7	-15.38%	7.69%
15	6	5.5	6.5	-8.33%	8.33%
				Life (Cycles):	**15**

Appendix C (Continued)

Table C-111: MS21044D4 Braycote; Unseated - Trial Average

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	7	6.31	6.81	-8.06%	-0.64%
2	5.5	5.06	5.69	-7.08%	4.39%
3	5.63	5.38	5.75	-3.84%	2.55%
4	5.69	5.06	6	-10.55%	5.58%
5	5.69	5.38	6.25	-5.27%	10.09%
6	5.94	5.38	6	-9.21%	1.11%
7	6.25	6	6.5	-3.87%	4.02%
8	6.38	6.13	6.5	-3.50%	2.38%
9	6.56	5.69	6.5	-12.62%	-0.74%
10	6.31	5.81	6.43	-7.81%	2.76%
11	6.63	5.94	6.63	-10.11%	0.00%
12	6.81	5.81	6.88	-14.52%	0.83%
13	6.75	5.69	6.5	-15.69%	-3.40%
14	6.56	5.69	6.81	-13.20%	3.89%
15	6.44	5.75	6.69	-10.35%	4.26%
				Life (Cycles):	15

C.6.2 66% Y Preload – Lubricated

Table C-112: MS21044D4 Braycote; 66% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Removal Prevailing (in-lbs)**	**Assem. Prevailing Ver. (in-lbs)***	**Percent Difference Assem. Ver.**
1	12	101	5	5	-58.33%
2	5.5	111	5.5	5.5	0.00%
3	5	130	6	7	40.00%
4	7	156	7	7.2	2.86%
5	6.5	160	7	7.5	15.38%
6	7	167	6.5	6.5	-7.14%
7	6.25	167	6	6.5	4.00%
8	6	170	6.25	6.5	8.33%
9	6.5	167	6.5	6	-7.69%
10	6.25	166	6	6.25	0.00%

Appendix C (Continued)

Table C-112 (Continued)

11	6	161	5.75	6	0.00%
12	5.75	168	6	6	4.35%
13	5.5	170	6	6.25	13.64%
14	6	175	6.25	6.5	8.33%
15	6	170	5.75	5.75	-4.17%
				Life: (Cycles)	**15**

Table C-113: MS21044D4 Braycote; 66% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	13.75	110	89	7.5	-45.45%
2	7	136	111	5.5	-21.43%
3	6.25	155	134	5.5	-12.00%
4	6.25	168	148	5.75	-8.00%
5	5.75	169	149	5.2	-9.57%
6	5.75	171	145	5	-13.04%
7	5.5	171	150	5	-9.09%
8	5.5	173	144	4.9	-10.91%
9	5.5	175	154	4.75	-13.64%
10	5.25	177	154	4.5	-14.29%
11	5	178	158	4.25	-15.00%
12	4.75	181	156	4	-15.79%
13	4.75	187	165	4	-15.79%
14	4.75	185	167	3.5	-26.32%
15	4.75	194	166	3.75	-21.05%
				Life: (Cycles)	**15**

Table C-114: MS21044D4 Braycote; 66% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	13	119	90	6	-53.85% Y
2	6.5	152	125	6.25	-3.85% Y
3	7.5	160	133	6	-20.00%
4	6	162	130	5.5	-8.33%
5	5.5	180	155	4.75	-13.64%
6	5.25	195	160	4.75	-9.52%

Appendix C (Continued)

Table C-114 (Continued)

7	5.25	190	160	4.5	-14.29%
8	5.25	185	165	4.5	-14.29%
9	4.25	192	170	4	-5.88%
10	3.75	190	170	3	-20.00%
11	4	210	180	3.25	-18.75% Y
12	4	212	190	3.25	-18.75% Y
13					
14					
15					
				Life: (Cycles)	**10**

Table C-115: MS21044D4 Braycote; 66% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	13.5	145	110	6	-55.56%
2	6	150	125	6	0.00%
3	6	180	150	5	-16.67%
4	5.5	170	145	4.75	-13.64%
5	4.75	170	145	4.75	0.00%
6	5.5	170	145	4.75	-13.64%
7	5.5	172	150	5	-9.09%
8	5.25	175	155	4.5	-14.29%
9	5	180	157	4.5	-10.00%
10	5.25	175	155	4.5	-14.29%
11	5.25	176	151	4.5	-14.29%
12	5.25	180	162	4.25	-19.05%
13	5.25	180	155	4	-23.81%
14	5.25	180	155	4	-23.81%
15	5	180	160	4	-20.00%
				Life: (Cycles)	**15**

Appendix C (Continued)

Table C-116: MS21044D4 Braycote; 66% Y - Trial Average

Trial Average					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	13.42	124.67	96.33	6.5	-51.62%
2	6.5	146	120.33	5.92	-8.42%
3	6.58	165	139	5.5	-16.22%
4	5.92	166.67	141	5.33	-9.99%
5	5.33	173	149.67	4.9	-7.73%
6	5.5	178.67	150	4.83	-12.07%
7	5.42	177.67	153.33	4.83	-10.82%
8	5.33	177.67	154.67	4.63	-13.16%
9	4.92	182.33	160.33	4.42	-9.84%
10	4.75	180.67	159.67	4	-16.19%
11	4.75	188	163	4	-16.01%
12	4.67	191	169.33	3.83	-17.86%
13	5	183.5	108.67	4	-19.80%
14	5	182.5	161	3.75	-25.06%
15	4.88	187	163	3.88	-20.53%
				Life: (Cycles)	**13.33**

C.6.3 75% Y Preload – Lubricated

Table C-117: MS21044D4 Braycote; 75% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	12.1	136	6	6.25	-48.35%
2	7.5	170	5.5	6.5	-13.33%
3	6.75	190	5.25	5.75	-14.81%
4	6.5	201	5.75	5.5	-15.38%
5	6	205	5.5	5.75	-4.17%
6	6.25	190	5.75	5.75	-8.00%
7	6	188	5.25	5.5	-8.33%
8	5.5	190	5.25	5.25	-4.55%
9	5.75	190	5	5	-13.04%
10	6	189	5.25	5.5	-8.33%

Appendix C (Continued)

Table C-117 (Continued)

11	6	191	5.25	5.25	-12.50%
12	5.75	189	5.25	5	-13.04%
13	5.5	197	5	5	-9.09%
14	5.5	205	4.75	5	-9.09%
15	5.5	192	4.5	4.75	-13.64%
				Life: (Cycles)	**15**

Table C-118: MS21044D4 Braycote; 75% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	12	130	102	6	-50.00%
2	5.5	135	113	5.5	0.00%
3	5.25	169	143	5.5	4.76%
4	5.5	180	155	4.5	-18.18%
5	5	190	154	4.25	-15.00%
6	4.75	186	154	4.25	-10.53%
7	4.75	187	161	4	-15.79%
8	4.5	195	170	4	-11.11%
9	4.5	205	180	3.75	-16.67%
10	4.75	204	176	3.75	-21.05%
11	4.5	199	171	3.5	-22.22%
12	4.25	194	168	3.5	-17.65%
13	4.25	193	175	3	-29.41%
14	4.25	196	180	3.25	-23.53%
15	4.25	194	170	3.25	-23.53%
				Life: (Cycles)	**13**

Table C-119: MS21044D4 Braycote; 75% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	13	140	108	7	-46.15%
2	7	157	132	6	-14.29%
3	7	180	155	5.75	-17.86%
4	7	190	165	5	-28.57%
5	6.5	184	160	5	-23.08%

Appendix C (Continued)

Table C-119 (Continued)

6	6.5	180	160	5	-23.08%
7	5	190	165	4.25	-15.00%
8	4.75	190	163	4	-15.79%
9	4.75	185	163	4	-15.79%
10	4.75	190	160	4	-15.79%
11	4.75	190	165	3.75	-21.05%
12	4.5	195	170	3.5	-22.22%
13	4	190	165	3.25	-18.75% Y
14	4	185	167	3	-25.00%
15	3.75	190	170	3	-20.00%
				Life: (Cycles)	**13**

Table C-120: MS21044D4 Braycote; 75% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	11.5	115	90	6	-47.83%
2	5.5	135	110	5.5	0.00%
3	5	150	120	4.5	-10.00%
4	4	155	130	3.75	-6.25%
5	4	170	150	3.75	-6.25%
6	3.5	180	150	4	14.29%
7	3.75	185	160	3.75	0.00%
8	4	176	155	4	0.00%
9	4	180	165	3.5	-12.50%
10	4	180	163	4	0.00%
11	4.5	183	164	3.5	-22.22%
12	4.25	190	160	3.5	-17.65%
13	4	190	158	3	-25.00%
14	3.75	195	165	3	-20.00%
15	3.5	188	160	3	-14.29%
				Life: (Cycles)	**13**

Appendix C (Continued)

Table C-121: MS21044D4 Braycote; 75% Y - Trial Average

Trial Average					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	12.17	128.33	100	6.33	-47.99%
2	6	142.33	118.33	5.67	-4.76%
3	5.75	166.33	139.33	5.25	-7.70%
4	5.5	175	150	4.42	-17.67%
5	5.17	181.33	154.67	4.33	-14.78%
6	4.92	182	154.67	4.42	-6.44%
7	4.5	187.33	162	4	-10.26%
8	4.42	187	162.67	4	-8.97%
9	4.42	190	169.33	3.75	-14.99%
10	4.5	191.33	166.33	3.92	-12.28%
11	4.583	190.67	166.67	3.58	-21.83%
12	4.33	193	166	3.5	-19.17%
13	4.08	191	166	3.08	-24.39%
14	4	192	170.67	3.08	-22.84%
15	3.83	190.67	166.67	3.08	-19.27%
				Life: (Cycles)	**13**

C.6.4 85% Y Preload – Lubricated

Table C-122: MS21044D4 Braycote; 85% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	11	150	6.75	6.5	-40.91%
2	5.75	185	5.5	5.25	-8.70%
3	5	220	5.75	5.5	10.00%
4	4.75	227	5	5.25	10.53%
5	4.75	245	4.75	5	5.26%
6	4.5	248	4.75	5	11.11%
7	4.5	255	4.25	4.5	0.00%
8	4.5	260	4.5	4.5	0.00%
9	4.25	250	4	4	-5.88%
10	5	270	4.25	4.5	-10.00%

Appendix C (Continued)

Table C-122 (Continued)

11	5	288	4.25	4.5	-10.00%
12	5	300	4.25	4.5	-10.00%
13	5	300	4.5	5	0.00%
14	4.75	280	4	4	-15.79%
15	4.75	282	4	4.25	-10.53%
				Life: (Cycles)	**15**

Table C-123: MS21044D4 Braycote; 85% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	11	153	120	7.75	-29.55%
2	7	195	105	6.5	-7.14%
3	7.25	250	203	6	-17.24%
4	7	292	260	6	-14.29%
5	6.75	350	289	5.5	-18.52%
6	6.5	350	285	5.75	-11.54%
7	5.5	360	320	4.75	-13.64%
8	5.5	330	295	4.25	-22.73%
9	5.5	335	320	4	-27.27%
10	5	360	320	4	-20.00%
11	5	380	335	3.5	-30.00%
12	4.75	390	340	3.5	-26.32%
13	4.5	400	350	3.5	-22.22%
14	4.5	400	340	3.25	-27.78%
15	4.5	390	335	3	-33.33%
				Life: (Cycles)	**14**

Table C-124: MS21044D4 Braycote; 85% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	11.5	157	127	7	-39.13%
2	6.5	225	180	5.5	-15.38%
3	5.5	218	177	5	-9.09%
4	5.5	210	173	4	-27.27%
5	5	241	190	4	-20.00%
6	4.75	280	260	3.75	-21.05%

Appendix C (Continued)

Table C-124 (Continued)

7	4.75	320	280	3.5	-26.32%
8	4.75	320	290	3.25	-31.58%
9	4.25	310	299	3	-29.41%
10	4.25	330	300	2.75	-35.29%
11					
12					
13					
14					
15					
				Life: (Cycles)	**8**

Table C-125: MS21044D4 Braycote; 85% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	13.5	177	140	6	-55.56%
2	6	200	145	5.5	-8.33%
3	5.5	245	183	4.5	-18.18%
4	4.75	270	230	4	-15.79%
5	4	270	215	3.75	-6.25%
6	4	320	260	3.75	-6.25%
7	4.25	360	320	3.75	-11.76%
8	4.25	375	330	3.75	-11.76%
9	4.25	340	270	3.5	-17.65%
10	4.25	370	330	3.75	-11.76%
11	4.25	360	320	3.5	-17.65%
12	4.5	390	330	3.25	-27.78%
13	4.5	350	330	3	-33.33%
14	4.75	365	330	3	-36.84%
15					
				Life: (Cycles)	**12**

Appendix C (Continued)

Table C-126: MS21044D4 3-IN-ONE; 85% Y - Trial 5

Trial 5 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	13	175	137.5	7	-46.15%
2	9.5	170	137.5	6	-36.84%
3	9.5	180	150	5.5	-42.11%
4	8	170	140	5.5	-31.25%
5	8	170	145	6	-25.00%
6	7	160	135	5	-28.57%
7	7	145	117.5	5	-28.57%
8	7	155	120	4	-42.86%
9	8	147.5	120	4.75	-40.63%
10	7	175	145	4.75	-32.14%
11	6.75	160	135	4.75	-29.63%
12	7	165	140	5.5	-21.43%
13	6	165	140	5	-16.67%
14	6	162.5	137.5	5	-16.67%
15	6.5	152.5	130	5	-23.08%
				Life: (Cycles)	15

Table C-127: MS21044D4 Braycote; 85% Y - Trial Average

Trial Average					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	12	162.33	129	6.92	-41.41%
2	6.5	206.67	143.33	5.83	-10.29%
3	6.08	237.67	187.67	5.17	-14.84%
4	5.75	257.33	221	4.67	-19.12%
5	5.25	287	231.33	4.42	-14.92%
6	5.08	316.67	268.33	4.42	-12.95%
7	4.83	346.67	306.67	4	-17.24%
8	4.83	341.67	305	3.75	-22.02%
9	4.67	328.33	296.33	3.5	-24.78%
10	4.5	353.33	316.67	3.5	-22.35%
11	4.63	370	327.5	3.5	-23.82%
12	4.63	390	335	3.38	-27.05%
13	4.5	375	340	3.25	-27.78%
14	4.63	382.5	335	3.13	-32.31%

Appendix C (Continued)

Table C-127 (Continued)

15	4.5	390	335	3	-33.33%
				Life: (Cycles)	**11.33**

C.6.5 Locknut Average – Lubricated

Table C-128: MS21044D4 Braycote; Locknut Average

Locknut Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	12.53	138.64	108.64	6.58	-47.01%
2	6.33	165	127.33	5.81	-7.82%
3	6.14	189.67	155.33	5.31	-12.92%
4	5.72	199.62	170.67	4.81	-15.59%
5	5.25	213.78	178.56	4.55	-12.48%
6	5.17	225.78	191	4.56	-10.48%
7	4.92	237.21	207.33	4.28	-12.77%
8	4.861	235.64	207.64	4.13	-14.72%
9	4.67	233.56	208.67	3.89	-16.53%
10	4.583	241.78	214.22	3.81	-16.94%
11	4.65	249.56	219.06	3.69	-20.56%
12	4.54	258	223.64	3.56	-21.36%
13	4.53	249.83	204.89	3.64	-23.99%
14	4.54	252.33	222.22	3.32	-26.74%
15	4.40	255.89	221.56	3.32	-24.38%
				Life: (Cycles)	**12.56**

Appendix C (Continued)

C.7 NAS1021N4

C.7.1 Unseated

Table C-129: NAS1021N4; Unseated - Trial 1

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	22.5	17.5	21	-22.22%	-6.67%
2	19	13.5	18	-28.95%	-5.26%
3	17	12.5	17	-26.47%	0.00%
4	16	12	14.5	-25.00%	-9.38%
5	16.5	11	16	-33.33%	-3.03%
6	16.5	11.75	16.5	-28.79%	0.00%
7	17	12	16	-29.41%	-5.88%
8	16	11.25	15	-29.69%	-6.25%
9	15.5	11.5	15	-25.81%	-3.23%
10	15.5	11.5	15	-25.81%	-3.23%
11	15.5	10.5	14	-32.26%	-9.68%
12	14.5	10.75	14	-25.86%	-3.45%
13	15	10.5	14	-30.00%	-6.67%
14	14.5	10	14	-31.03%	-3.45%
15	14.5	10.75	13.5	-25.86%	-6.90%
				Life (Cycles):	**15**

Table C-130: NAS1021N4; Unseated - Trial 2

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	21.5	17	20	-20.93%	-6.98%
2	18.5	13.5	17	-27.03%	-8.11%
3	16	11	18	-31.25%	12.50%
4	16.5	11	16.5	-33.33%	0.00%
5	15	10.75	15	-28.33%	0.00%
6	15.25	10.5	15	-31.15%	-1.64%
7	15.5	10.5	15	-32.26%	-3.23%
8	15.5	10.5	14.5	-32.26%	-6.45%
9	15	10	14	-33.33%	-6.67%

Appendix C (Continued)

Table C-130 (Continued)

10	15	9.5	14.5	-36.67%	-3.33%
11	15	8.5	14.5	-43.33%	-3.33%
12	14	9	14	-35.71%	0.00%
13	12.5	8	13.5	-36.00%	8.00%
14	13	8	13.5	-38.46%	3.85% Y
15	13	8	13.5	-38.46%	3.85% Y
				Life (Cycles):	**15**

Table C-131: NAS1021N4; Unseated - Trial 3

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	22.5	16.5	20	-26.67%	-11.11%
2	19	14.5	17.5	-23.68%	-7.89%
3	17.5	16.5	18	-5.71%	2.86%
4	18	13.25	15.5	-26.39%	-13.89%
5	17	13	15.5	-23.53%	-8.82%
6	16.5	12.75	16	-22.73%	-3.03%
7	17.5	12.5	16	-28.57%	-8.57%
8	16	12.5	16	-21.88%	0.00%
9	16.5	11	15	-33.33%	-9.09%
10	16	11.5	15.5	-28.13%	-3.13%
11	16	11.5	16	-28.13%	0.00%
12	15.5	10.5	15.5	-32.26%	0.00%
13	15.5	11.5	15	-25.81%	-3.23%
14	15.5	11	14.5	-29.03%	-6.45%
15	15	11.5	15.5	-23.33%	3.33%
				Life (Cycles):	**15**

Table C-132: NAS1021N4; Unseated - Trial 4

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	20	15.75	17.5	-21.25%	-12.50%
2	17	12.5	15	-26.47%	-11.76%
3	15.5	12	15.5	-22.58%	0.00%
4	15.5	11.5	15	-25.81%	-3.23%
5	15	11	14.5	-26.67%	-3.33%

Table C-132 (Continued)

6	15.5	10.5	14.5	-32.26%	-6.45%
7	15	10	14	-33.33%	-6.67%
8	14	10.25	13.5	-26.79%	-3.57%
9	15	10.5	13.5	-30.00%	-10.00%
10	13	9.5	13.5	-26.92%	3.85% Y
11	14	9.5	14	-32.14%	0.00%
12	13.5	9.5	13	-29.63%	-3.70%
13	13.5	9	13	-33.33%	-3.70%
14	12.5	7.5	13	-40.00%	4.00%
15	14	9	13.5	-35.71%	-3.57%
				Life (Cycles):	**15**

Table C-133: NAS1021N4; Unseated - Trial Average

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	21.63	16.69	19.63	-22.77%	-9.31%
2	18.38	13.5	16.88	-26.53%	-8.26%
3	16.5	13	17.13	-21.50%	3.84%
4	16.5	11.94	15.38	-27.63%	-6.62%
5	15.88	11.44	15.25	-27.97%	-3.80%
6	15.94	11.38	15.5	-28.73%	-2.78%
7	16.25	11.25	15.25	-30.89%	-6.09%
8	15.38	11.13	14.75	-27.65%	-4.07%
9	15.5	10.75	14.38	-30.62%	-7.25%
10	14.88	10.5	14.63	-29.38%	-1.46%
11	15.13	10	14.63	-33.96%	-3.25%
12	14.38	9.94	14.13	-30.87%	-1.79%
13	14.13	9.75	13.88	-31.28%	-1.40%
14	13.88	9.13	13.75	-34.63%	-0.51%
15	14.13	9.81	14	-30.84%	-0.82%
				Life (Cycles):	15

Appendix C (Continued)

C.7.2 66% Y Preload

Table C-134: NAS1021N4; 66% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	17.5	145	12.5	19.5	11.43%
2	19	147.5	12.5	18.5	-2.63%
3	17.5	160	12	19	8.57%
4	18	162.25	14	17.5	-2.78%
5	20	175	14	20	0.00%
6	20	175	16.5	19.5	-2.50%
7	20	170	16.25	21	5.00%
8	20.5	175	17	20	-2.44%
9	19	185	16	18	-5.26%
10	20	185	16	17	-15.00%
11	19	200	16	16	-15.79%
12	19	215	15	17	-10.53%
13	20	230	12	17.5	-12.50%
14	17.5	265	13	17	-2.86%
15	17	250	13	18	5.88%
				Life: (Cycles)	**15**

Table C-135: NAS1021N4; 66% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	22.5	175	162.5	15.5	-31.11%
2	20	207.25	205	12.5	-37.50%
3	18.5	245	245	10.5	-43.24%
4	17.5	250	240	11	-37.14%
5	16	276	260	10.25	-35.94%
6	16	270	260	9.75	-39.06%
7	15.5	275	265	10	-35.48%
8	16	280	280	9	-43.75% Y
9	15.5	280	270	10	-35.48%
10	16	275	300	9.5	-40.63%

Appendix C (Continued)

Table C-135 (Continued)

11	16	270	285	9	-43.75% Y
12	16	280	260	9	-43.75% Y
13	15.5	270	250	8.25	-46.77%
14	15	260	220	9.75	-35.00%
15	15	275	240	10	-33.33%
				Life: (Cycles)	**15**

Table C-136: NAS1021N4; 66% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	22.5	165	150	11.25	-50.00%
2	19.5	195	175	9	-53.85% Y
3	17.5	225	235	9.25	-47.14%
4	17.5	260	250	9	-48.57%
5	17	290	260	8.75	-48.53%
6	15	280	250	9.5	-36.67%
7	14.5	285	255	8	-44.83%
8	16	290	260	8	-50.00%
9	15	270	250	8.5	-43.33%
10	15.5	300	250	7.5	-51.61%
11	15	250	250	8.5	-43.33%
12	15	280	230	7.5	-50.00%
13	15	280	250	7.5	-50.00%
14	14.5	280	230	7.5	-48.28%
15	15	280	250	7	-53.33%
				Life: (Cycles)	**15**

Table C-137: NAS1021N4; 66% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	19	172.5	170	14	-26.32%
2	17.5	225	200	10.5	-40.00%
3	17.5	270	250	9	-48.57%
4	16	260	250	10.5	-34.38%
5	16	275	255	9.5	-40.63%

Appendix C (Continued)

Table C-137 (Continued)

6	15.5	280	250	9	-41.94%
7	14.5	280	260	8.75	-39.66% Y
8	15	260	250	9	-40.00%
9	15	265	260	8.5	-43.33%
10	14.5	255	220	8.25	-43.10%
11	15	270	230	8.5	-43.33%
12	14	260	230	8.25	-41.07%
13	14.5	250	220	8.5	-41.38%
14	14.5	250	225	8.75	-39.66% Y
15	14.5	240	240	9	-37.93%
				Life: (Cycles)	**15**

Table C-138: NAS1021N4; 66% Y - Trial Average

Trial Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	21.33	170.83	160.83	13.583	-35.81%
2	19	209.08	193.33	10.67	-43.78%
3	17.83	246.67	243.33	9.58	-46.32%
4	17	256.67	246.67	10.17	-40.03%
5	16.33	280.33	258.33	9.5	-41.70%
6	15.5	276.67	253.33	9.42	-39.22%
7	14.83	280	260	8.92	-39.99%
8	15.67	276.67	263.33	8.67	-44.58%
9	15.17	271.67	260	9	-40.72%
10	15.33	276.67	256.67	8.42	-45.11%
11	15.33	263.33	255	8.67	-43.47%
12	15	273.33	240	8.25	-44.94%
13	15	266.67	240	8.08	-46.05%
14	14.67	263.33	225	8.67	-40.98%
15	14.83	265	243.33	8.67	-41.53%
				Life: (Cycles)	**15**

Appendix C (Continued)

C.7.3 75% Y Preload

Table C-139: NAS1021N4; 75% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	21	205	18	21	0.00%
2	20	215	13	16.5	-17.50%
3	17.5	240	11.5	14	-20.00%
4	15	260	10	15	0.00%
5	16	280	9	14	-12.50%
6	15.5	290	13	13	-16.13%
7	15.5	300	12	14	-9.68%
8	14	290	11.5	13	-7.14%
9	15	320	11	12.5	-16.67%
10	14	310	12	12.5	-10.71%
11	14.5	330	11.5	13.5	-6.90%
12	14	320	11.5	12	-14.29%
13	13	300	3	9	-30.77%
14	12.5	310	11	12.5	0.00%
15	12.5	300	11	12	-4.00%
				Life: (Cycles)	**15**

Table C-140: NAS1021N4; 75% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	17.5	180	165	9	-48.57%
2	18.5	190	170	10	-45.95%
3	18	250	190	10.75	-40.28%
4	18	260	200	9.5	-47.22%
5	17	300	280	9.5	-44.12%
6	16.5	310	290	9.5	-42.42%
7	17	330	310	9	-47.06%
8	17.5	330	300	9	-48.57%
9	16.5	320	310	11	-33.33%
10	16.5	320	275	10.5	-36.36%

Appendix C (Continued)

Table C-140 (Continued)

11	16	300	270	10.5	-34.38%
12	15	300	240	10	-33.33%
13	14.5	260	230	8.5	-41.38%
14	16	320	260	8.5	-46.88%
15	15	290	240	10	-33.33%
				Life: (Cycles)	**15**

Table C-141: NAS1021N4; 75% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	22.5	200	190	12	-46.67%
2	18.5	250	235	9.5	-48.65%
3	18	270	250	9	-50.00%
4	17.5	280	280	10.5	-40.00%
5	17.5	300	270	8	-54.29%
6	15.5	300	270	7.5	-51.61%
7	15	280	270	8	-46.67%
8	15.5	310	290	7	-54.84%
9	15.5	300	275	6.5	-58.06%
10	15	290	250	6.5	-56.67%
11	15	300	250	5.5	-63.33%
12	15	300	260	6.5	-56.67%
13	15.5	310	270	7.25	-53.23%
14	14.5	260	250	7	-51.72%
15	13.5	310	280	6.5	-51.85% Y
				Life: (Cycles)	**15**

Table C-142: NAS1021N4; 75% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	22	225	200	11.5	-47.73%
2	16.5	280	265	9	-45.45%
3	14.5	290	270	8.5	-41.38%
4	14	310	290	7.5	-46.43%
5	14.5	300	290	8.5	-41.38%

Appendix C (Continued)

Table C-142 (Continued)

6	15	330	285	8.5	-43.33%
7	14.5	310	270	8	-44.83%
8	14.5	320	300	8	-44.83%
9	15	280	250	8.5	-43.33%
10	13	320	270	7.5	-42.31%
11	14.5	250	250	7.5	-48.28%
12	14.5	290	250	10.5	-27.59%
13	8.75	270	240	3.5	-60.00%
14	10	280	250	5.5	-45.00%
15	12.5	320	220	6	-52.00%
				Life: (Cycles)	**15**

Table C-143: NAS1021N4; 75% Y - Trial Average

Trial Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	20.67	201.67	185	10.83	-47.66% Y
2	17.83	240	223.33	9.5	-46.68%
3	16.83	270	236.67	9.42	-43.89%
4	16.5	283.33	256.67	9.17	-44.55%
5	16.33	300	280	8.67	-46.59%
6	15.67	313.33	281.67	8.5	-45.79%
7	15.5	306.67	283.33	8.33	-46.18%
8	15.83	320	296.67	8	-49.41%
9	15.67	300	278.33	8.67	-44.91%
10	14.83	310	265	8.17	-45.11%
11	15.17	283.33	256.67	7.83	-48.66% Y
12	14.83	296.67	250	9	-39.20%
13	12.92	280	246.67	6.42	-51.54%
14	13.5	286.67	253.33	7	-47.87%
15	13.67	306.67	246.67	7.5	-45.73%
				Life: (Cycles)	**15**

Appendix C (Continued)

C.7.4 85% Y Preload

Table C-144: NAS1021N4; 85% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	20	240	18	21	5.00%
2	19.5	265	14	18.5	-5.13%
3	17.5	305	12.25	16.5	-5.71%
4	20	340	14.5	16.5	-17.50%
5	16.5	280	12.5	17	3.03%
6	16	330	15	15	-6.25%
7	15	370	13.5	14	-6.67%
8	15	280	12.5	13	-13.33%
9	15	340	12.5	13.5	-10.00%
10	15	370	12.5	12.5	-16.67%
11	15	370	11	13	-13.33%
12	14.5	370	11.5	13.5	-6.90%
13	14	360	11	11	-21.43%
14	12.5	340	10.5	13	4.00%
15	12.5	350	10	12.5	0.00%
				Life: (Cycles)	15

Table C-145: NAS1021N4; 85% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	20	230	220	12	-40.00%
2	16	300	285	10	-37.50%
3	17	340	320	10	-41.18%
4	17.5	320	300	7.5	-57.14%
5	15	330	320	7.5	-50.00%
6	14.5	350	320	7.5	-48.28%
7	14	340	305	8	-42.86%
8	14	320	300	6.75	-51.79%
9	13	340	300	6.75	-48.08%
10	14	300	280	6	-57.14%
11	13	315	280	7.5	-42.31%

Appendix C (Continued)

Table C-145 (Continued)

12	14	350	270	7	-50.00%
13	13.5	370	300	6.75	-50.00%
14	13	330	290	5	-61.54%
15	13	330	300	6	-53.85%
				Life: (Cycles)	**15**

Table C-146: NAS1021N4; 85% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	19	270	260	12.5	-34.21%
2	20	320	310	11	-45.00%
3	17.5	330	320	10	-42.86%
4	15.5	350	320	10	-35.48%
5	16	360	340	9.5	-40.63%
6	15.5	360	340	10	-35.48%
7	15.5	350	330	10	-35.48%
8	15	340	320	9	-40.00%
9	16	320	290	11.5	-28.13%
10	15	310	270	8.5	-43.33%
11	15	340	290	10.5	-30.00%
12	17.5	330	270	7	-60.00%
13	15	360	290	8.5	-43.33%
14	17	360	270	10	-41.18%
15	16	350	285	12	-25.00%
				Life: (Cycles)	**15**

Table C-147: NAS1021N4; 85% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	18	240	215	11.5	-36.11%
2	17.5	300	280	8.5	-51.43%
3	16.5	330	320	9.5	-42.42%
4	15	360	330	9.5	-36.67%
5	15	380	355	8	-46.67%
6	12.5	360	340	8	-36.00%
7	13	350	315	7.5	-42.31%

Appendix C (Continued)

Table C-147 (Continued)

8	14	330	300	7	-50.00%
9	15	315	290	7.5	-50.00%
10	12	305	270	7.5	-37.50%
11	13.5	300	260	7	-48.15%
12	12.5	340	260	5.75	-54.00%
13	13	310	290	5.25	-59.62%
14	15	360	280	7	-53.33%
15	16	360	285	30	87.50%
				Life: (Cycles)	**15**

Table C-148: NAS1021N4; 85% Y - Trial Average

Trial Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	19	246.67	231.67	12	-36.77%
2	17.83	306.67	291.67	9.83	-44.64%
3	17	333.33	320	9.83	-42.15%
4	16	343.33	316.67	9	-43.10%
5	15.33	356.67	338.33	8.33	-45.76%
6	14.17	356.67	333.33	8.5	-39.92%
7	14.17	346.67	316.67	8.5	-40.22%
8	14.33	330	306.67	7.58	-47.26%
9	14.67	325	293.33	8.58	-42.07%
10	13.67	305	273.33	7.33	-45.99%
11	13.83	318.33	276.67	8.33	-40.15%
12	14.67	340	266.67	6.58	-54.67%
13	13.83	346.67	293.33	6.83	-50.98%
14	15	350	280	7.33	-52.02%
15	15	346.67	290	16	2.88%
				Life: (Cycles)	**15**

Appendix C (Continued)

C.7.5 Locknut Average

Table C-149: NAS1021N4; Locknut Average

Locknut Average					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	20.33	206.39	192.5	12.14	-40.08%
2	18.22	251.92	236.11	10	-45.04%
3	17.22	283.33	266.67	9.61	-44.12%
4	16.5	294.64	273.33	9.64	-42.56%
5	16	312.33	292.22	8.83	-44.69%
6	15.11	315.56	289.64	8.81	-41.64%
7	14.83	311.11	286.67	8.583	-42.13%
8	15.27	308.89	288.89	8.08	-47.09%
9	15.17	298.89	277.22	8.75	-42.56%
10	14.61	297.22	265	7.97	-45.41%
11	14.78	288.33	262.78	8.27	-44.10%
12	14.83	303.33	252.22	7.94	-46.27%
13	13.92	297.78	260	7.1111	-49.52%
14	14.39	300	252.78	7.67	-46.95%
15	14.5	306.11	260	10.72	-28.13%
				Life: (Cycles)	**15**

C.8 NAS1021N4 with Lubrication

C.8.1 Unseated – Lubricated

Table C-150: NAS1021N4 Braycote; Unseated - Trial 1

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	6.5	4.5	5.25	-30.77%	-19.23%
2	4.25	3.75	4	-11.76%	-5.88%
3	4	3.25	3.75	-18.75% Y	-6.25%
4	3.75	3.25	3.75	-13.33%	0.00%
5	3.5	3	3.5	-14.29%	0.00%

Appendix C (Continued)

Table C-150 (Continued)

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				Life (Cycles):	**3**

Table C-151: NAS1021N4 Braycote; Unseated - Trial 2

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	6	4.75	5.25	-20.83%	-12.50%
2	4.5	4	4.5	-11.11%	0.00%
3	4	3.25	3.5	-18.75% Y	-12.50%
4	3.75	3.25	3.5	-13.33%	-6.67%
5	3.75	3	3.5	-20.00%	-6.67%
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				Life (Cycles):	**3**

Appendix C (Continued)

Table C-152: NAS1021N4 Braycote; Unseated - Trial 3

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	5.75	4.5	5	-21.74%	-13.04%
2	4	3.5	4	-12.50%	0.00%
3	3.75	3	3.5	-20.00%	-6.67%
4	3.75	3	3.25	-20.00%	-13.33%
5	3.5	3	3.25	-14.29%	-7.14%
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15					
				Life (Cycles):	3

Table C-153: NAS1021N4 Braycote; Unseated - Trial 4

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	6	5	5.5	-16.67%	-8.33%
2	4.25	3.5	4	-17.65%	-5.88%
3	4	3.25	3.75	-18.75%	-6.25%
4	3.5	3	3.5	-14.29%	0.00%
5	3.5	3	3.5	-14.29%	0.00%
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				Life (Cycles):	3

Appendix C (Continued)

Table C-154: NAS1021N4 Braycote; Unseated - Trial Average

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	6.06	4.69	5.25	-22.50%	-13.27%
2	4.25	3.69	4.13	-13.25%	-2.94%
3	3.94	3.19	3.63	-19.06%	-7.91%
4	3.69	3.13	3.5	-15.23%	-5.00%
5	3.56	3	3.44	-15.71%	-3.45%
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15					
				Life (Cycles):	3

C.8.2 66% Y Preload – Lubricated

Table C-155:NAS1021N4 Braycote; 66% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	7	105	5	4.5	-35.71%
2	4.25	79	3.7	4	-5.88%
3	4	71	3.5	3.75	-6.25%
4	3.75	63	3.25	3.5	-6.67%
5	3.5	58.5	3.25	3.5	0.00%
6	3.5	57.5	3	3.25	-7.14%
7	3.75	53	3	3.25	-13.33%
8	3.5	53	3	3	-14.29%
9	3.5	50	3	3.25	-7.14%
10	3.5	51	3	3.25	-7.14%

Appendix C (Continued)

Table C-155 (Continued)

11	3.5	52	3	3.25	-7.14%
12	3.5	48	3	3.25	-7.14%
13	3.5	52	3	3.25	-7.14%
14	3.5	54	3	3	-14.29%
15	3.5	53	3	3.25	-7.14%
				Life: (Cycles)	**6**

Table C-156:NAS1021N4 Braycote; 66% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	7.5	116	94	4.25	-43.33%
2	4.25	84	62	3.5	-17.65%
3	4	78	61	3	-25.00%
4	3.5	80	61	3	-14.29%
5	3.5	84	60	3	-14.29%
6	3.5	97	80	3.75	7.14%
7	3.5	94	68	3.25	-7.14%
8	3.5	96	74	3.25	-7.14%
9	3.25	98	75	2.75	-15.38%
10	3.4	89	66	2.5	-26.47%
11	3.25	91	65	2.5	-23.08%
12					
13					
14					
15					
				Life: (Cycles)	**3**

Table C-157: NAS1021N4 Braycote; 66% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	8	102	83	3.75	-53.13%
2	3.5	85	65	3	-14.29%
3	3.25	78	60	2.75	-15.38%
4	3	80	60	2.5	-16.67%
5					

Appendix C (Continued)

Table C-157 (Continued)

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				Life: (Cycles)	**2**

Table C-158: NAS1021N4 Braycote; 66% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	10	112	85	4.25	-57.50%
2	3.75	101	80	3	-20.00%
3	3.25	100	85	3	-7.69%
4	3	95	70	2.75	-8.33%
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				Life: (Cycles)	**2**

Appendix C (Continued)

Table C-159: NAS1021N4 Braycote; 66% Y - Trial Average

Trial Average					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	8.5	110	87.33	4.08	-51.32%
2	3.83	90	69	3.17	-17.31%
3	3.5	85.33	68.67	2.92	-16.03%
4	3.17	85	63.67	2.75	-13.10%
5	3.5	84	60	3	-14.29%
6	3.5	97	80	3.75	7.14%
7	3.5	94	68	3.25	-7.14%
8	3.5	96	74	3.25	-7.14%
9	3.25	98	75	2.75	-15.38%
10	3.4	89	66	2.5	-26.47%
11	3.25	91	65	2.5	-23.08%
12					
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15					
				Life: (Cycles)	**2.33**

C.8.3 75% Y Preload – Lubricated

Table C-160: NAS1021N4 Braycote; 75% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	10	131	5.5	5.25	-47.50%
2	4	132	4	4	0.00%
3	3.75	150	3.5	3.75	0.00%
4	3.75	186	3.5	3.75	0.00%
5	3.75	215	3.5	3.5	-6.67%
6	3.75	238	3.75	3.5	-6.67%
7	3.75	294	3.5	3.25	-13.33%
8	4	289	4	4	0.00%
9	5.25	360*			

Appendix C (Continued)

Table C-160 (Continued)

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			*Bolt Failed	**Life: (Cycles)**	**7**

Table C-161: NAS1021N4 Braycote; 75% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	9	125	100	4	-55.56%
2	3.75	144	110	3	-20.00%
3	3.25	180	168	3	-7.69%
4	3.25	207	186	2.75	-15.38%
5	3	210	192	2.75	-8.33%
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				Life: (Cycles)	**2**

Table C-162: NAS1021N4 Braycote; 75% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	8	102	80	5	-37.50%
2	4.25	90	68	3.5	-17.65%
3	3.5	84	60	3.25	-7.14%
4	3.25	77	57	3	-7.69%

Appendix C (Continued)

Table C-162 (Continued)

5	3	73	62	2.75	-8.33%
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				Life: (Cycles)	**3**

Table C-163: NAS1021N4 Braycote; 75% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	8	117	92	4.5	-43.75% Y
2	3.5	97	75	3.25	-7.14%
3	3.5	100	80	3.5	0.00%
4	3.25	90	75	3	-7.69%
5	3	78	69	2.75	-8.33%
6	3	85	70	2.75	-8.33%
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				Life: (Cycles)	**2**

Appendix C (Continued)

Table C-164: NAS1021N4 Braycote; 75% Y - Trial Average

Trial Average					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	8.33	114.67	90.67	4.5	-45.60%
2	3.83	110.33	84.33	3.25	-14.93%
3	3.42	121.33	102.67	3.25	-4.95%
4	3.25	124.67	106	2.92	-10.26%
5	3	120.33	107.67	2.75	-8.33%
6	3	85	70	2.75	-8.33%
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15					
				Life: (Cycles)	**2.33**

C.8.4 85% Y Preload – Lubricated

Table C-165: NAS1021N4 Braycote; 85% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	7.5	117	4.5	4.25	-43.33%
2	4	110	3.25	3.5	-12.50%
3	3.25	100	3	3	-7.69%
4	3	96	2.75	2.75	-8.33%
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Appendix C (Continued)

Table C-165 (Continued)

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				Life: (Cycles)	**2**

Table C-166: NAS1021N4 Braycote; 85% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	6	136	106	4	-33.33%
2	3.5	115	94	3	-14.29%
3	3	104	74	2.75	-8.33%
4	3	110	85	2.75	-8.33%
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				Life: (Cycles)	**2**

Appendix C (Continued)

Table C-167: NAS1021N4 Braycote; 85% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	9	115	81	4	-55.56%
2	4	100	70	3.5	-12.50%
3	3.25	90	60	3	-7.69%
4	3	90	60	2.75	-8.33%
5	3	91	61	2.5	-16.67%
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15					
				Life: (Cycles)	3

Table C-168: NAS1021N4 Braycote; 85% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	9	125	87	4	-55.56%
2	4	92	65	3	-25.00%
3	3.25	90	62	2.75	-15.38%
4	3	91	65	2.5	-16.67%
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Table C-168 (Continued)

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				Life: (Cycles)	2

Table C-169: NAS1021N4 3-IN-ONE; 85% Y - Trial 5

Trial 5 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	12	140	100	6	-50.00%
2	9	115	77.5	6.25	-30.56%
3	7.5	127.5	85	5.75	-23.33%
4	7	125	85	5.25	-25.00%
5	6.25	115	80	5	-20.00%
6	5.75	110	75	5	-13.04%
7	6	105	70	5	-16.67%
8	5.5	110	35	5	-9.09%
9	5.5	110	72.5	4.5	-18.18%
10	5	107.5	75	4.5	-10.00%
11	5	105	75	4.5	-10.00%
12	5.5	112.5	75	4.5	-18.18%
13	5	110	75	4.5	-10.00%
14	5	115	85	4.5	-10.00%
15	5	112.5	80	4.25	-15.00%
				Life: (Cycles)	15

Table C-170: NAS1021N4 Braycote; 85% Y - Trial Average

Trial Average					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	8	125.33	91.33	4	-48.15%
2	3.83	102.33	76.33	3.17	-17.26%
3	3.17	94.67	65.33	2.83	-10.47%
4	3	97	70	2.67	-11.11%
5	3	91	61	2.5	-16.67%
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Appendix C (Continued)

Table C-170 (Continued)

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				Life: (Cycles)	**2.33**

C.8.5 Locknut Average – Lubricated

Table C-171: NAS1021N4 Braycote; Locknut Average

Locknut Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	8.27	116.67	89.78	4.19	-48.36%
2	3.83	100.89	76.56	3.19	-16.50%
3	3.36	100.64	78.89	3	-10.48%
4	3.14	102.22	79.89	2.78	-11.49%
5	3.17	98.64	76.22	2.75	-13.10%
6	3.25	91	75	3.25	-0.60%
7	3.5	94	68	3.25	-7.14%
8	3.5	96	74	3.25	-7.14%
9	3.25	98	75	2.75	-15.38%
10	3.4	89	66	2.5	-26.47%
11	3.25	91	65	2.5	-23.08%
12					
13					
14					
15					
				Life: (Cycles)	**2.33**

Appendix C (Continued)

C.9 Grade 8

C.9.1 Unseated

Table C-172: Grade 8; Unseated - Trial 1

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	9.5	6.25	9	-34.21%	-5.26%
2	7.5	5	7.5	-33.33%	0.00%
3	7.25	6.25	7.25	-13.79%	0.00%
4	6.5	5.75	6.5	-11.54%	0.00%
5	6.5	5.75	6.5	-11.54%	0.00%
6	6	5.5	6.25	-8.33%	4.17%
7	6	5.25	6.25	-12.50%	4.17%
8	6	5.5	6.25	-8.33%	4.17%
9	6	5.5	6	-8.33%	0.00%
10	5.75	5.25	6	-8.70%	4.35%
11	5.75	5	5.75	-13.04%	0.00%
12	5.5	5	5.75	-9.09%	4.55%
13	5.5	5	5.75	-9.09%	4.55%
14	5.5	4.75	5.75	-13.64%	4.55%
15	5.25	4.75	5.5	-9.52%	4.76%
				Life (Cycles):	**15**

Table C-173: Grade 8; Unseated - Trial 2

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	10.5	9	10.5	-14.29%	0.00%
2	9.25	7.5	9	-18.92%	-2.70%
3	8	7	8.5	-12.50%	6.25%
4	7.5	6.75	8	-10.00%	6.67%
5	7.5	6.5	7.75	-13.33%	3.33%
6	7	6.5	7.25	-7.14%	3.57%
7	7	6.5	7.5	-7.14%	7.14%
8	7	6.5	7.5	-7.14%	7.14%
9	7	6.25	7.25	-10.71%	3.57%
10	6.75	6	7	-11.11%	3.70%
11	6	6	7	0.00%	16.67%

Appendix C (Continued)

Table C-173 (Continued)

12	7	6	7.25	-14.29%	3.57%
13	6.25	6	7	-4.00%	12.00%
14	6	6	7	0.00%	16.67%
15	6.5	6	6.75	-7.69%	3.85% Y
				Life (Cycles):	**15**

Table C-174: Grade 8; Unseated - Trial 3

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	9.5	7.75	9	-18.42%	-5.26%
2	8.25	7.5	8.5	-9.09%	3.03%
3	8	7	8	-12.50%	0.00%
4	7.75	7	7.75	-9.68%	0.00%
5	7.5	6.5	7.5	-13.33%	0.00%
6	7.25	6.5	7.5	-10.34%	3.45%
7	7.25	6.25	7.25	-13.79%	0.00%
8	7.5	6.5	7.25	-13.33%	-3.33%
9	6.75	6	6.75	-11.11%	0.00%
10	6.75	6.5	7	-3.70%	3.70%
11	6.25	6.25	6.75	0.00%	8.00%
12	6.75	6.5	6.75	-3.70%	0.00%
13	6.5	6	6.5	-7.69%	0.00%
14	6	6	6.25	0.00%	4.17%
15	6	5.75	6.5	-4.17%	8.33%
				Life (Cycles):	**15**

Table C-175: Grade 8; Unseated - Trial 4

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	9	7.25	8.25	-19.44%	-8.33%
2	7.5	6.5	7.5	-13.33%	0.00%
3	7	6.25	7	-10.71%	0.00%
4	6.75	6.25	6.75	-7.41%	0.00%
5	6.5	6	7	-7.69%	7.69%
6	6.5	6	7	-7.69%	7.69%
7	6	5.75	6.5	-4.17%	8.33%

Appendix C (Continued)

Table C-175 (Continued)

8	6	6	6.5	0.00%	8.33%
9	6.25	5.75	6.75	-8.00%	8.00%
10	6.25	5.5	6.5	-12.00%	4.00%
11	6	5.5	6.25	-8.33%	4.17%
12	6	5.75	6.25	-4.17%	4.17%
13	6	5.5	6.25	-8.33%	4.17%
14	6	5.75	6.5	-4.17%	8.33%
15	5.75	5.5	6	-4.35%	4.35%
				Life (Cycles):	**15**

Table C-176: Grade 8; Unseated - Trial Average

Cycle	Assembly Prevailing (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Removal	Percent Difference Assem. Ver.
1	9.63	7.56	9.19	-21.59%	-4.71%
2	8.13	6.63	8.13	-18.67%	0.08%
3	7.56	6.63	7.69	-12.38%	1.56%
4	7.13	6.44	7.25	-9.66% Y	1.67%
5	7	6.19	7.19	-11.47%	2.76%
6	6.69	6.13	7	-8.38%	4.72%
7	6.56	5.94	6.88	-9.40%	4.91%
8	6.63	6.13	6.88	-7.20%	4.08%
9	6.5	5.88	6.69	-9.54%	2.89%
10	6.38	5.81	6.63	-8.88%	3.94%
11	6	5.69	6.44	-5.34%	7.21%
12	6.31	5.81	6.5	-7.81%	3.07%
13	6.06	5.63	6.38	-7.28%	5.18%
14	5.88	5.63	6.38	-4.45%	8.43%
15	5.88	5.5	6.19	-6.43%	5.32%
				Life (Cycles):	15

Appendix C (Continued)

C.9.2 66% Y Preload

Table C-177: Grade 8; 66% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	10.5	68	11	10	-4.76%
2	7	290	6.5	6.5	-7.14%
3	6.5	190	6	6.25	-3.85% Y
4	5.75	260	6.5	6.25	8.70%
5	5.75	250	6	6	4.35%
6	5.5	265	6	6.25	13.64%
7	5.75	220	5.75	6	4.35%
8	5.25	235	6	6	14.29%
9	5	170	5.5	5.75	15.00%
10	5	190	5.75	5.75	15.00%
11	5	180	5.5	5.5	10.00%
12	5	193	5.5	5.75	15.00%
13	5	166	5.5	5.5	10.00%
14	5	165	5.5	5.5	10.00%
15	5	162	5.5	5.5	10.00%
				Life: (Cycles)	**15**

Table C-178: Grade 8; 66% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	8.5	170	140	5.5	-35.29%
2	5	155	123	5	0.00%
3	5.25	165	130	4.5	-14.29%
4	5	175	140	4.25	-15.00%
5	5	150	115	4.25	-15.00%
6	4.75	140	105	4.25	-10.53%
7	4.75	126	100	4.25	-10.53%
8	4.5	145	115	4	-11.11%
9	4.5	165	130	4	-11.11%
10	4.5	165	128	4	-11.11%
11	4.5	150	112	4	-11.11%

Table C-178 (Continued)

12	4.5	155	125	4	-11.11%
13	4.25	142	115	4	-5.88%
14	4.5	155	115	4	-11.11%
15	4	180	142	4.25	6.25%
				Life: (Cycles)	**15**

Table C-179: Grade 8; 66% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	14	160	125	4.75	-66.07%
2	7.5	155	125	6.5	-13.33%
3	7	155	125	6.5	-7.14%
4	7	148	120	6	-14.29%
5	7	198	118	6	-14.29%
6	6.5	185	160	6	-7.69%
7	6.5	172	143	6	-7.69%
8	6.5	175	152	6	-7.69%
9	6.25	183	155	5.75	-8.00%
10	6.25	180	155	5.75	-8.00%
11	6	180	155	5.5	-8.33%
12	5.75	155	130	5.5	-4.35%
13	5.75	165	145	5.5	-4.35%
14	5.5	175	150	5.5	0.00%
15	5.5	170	150	5.25	-4.55%
				Life: (Cycles)	**15**

Table C-180: Grade 8; 66% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	10.5	155	125	6.75	-35.71%
2	6.5	135	105	6	-7.69%
3	6	145	115	5.5	-8.33%
4	6	170	135	5.25	-12.50%
5	5.5	173	145	5	-9.09%
6	5.5	140	115	5	-9.09%
7	5.5	155	130	4.75	-13.64%

Appendix C (Continued)

Table C-180 (Continued)

8	5.25	175	145	4.5	-14.29%
9	5	160	130	4.5	-10.00%
10	5	170	140	4.5	-10.00%
11	4.75	145	115	4.5	-5.26%
12	4.75	145	123	4.5	-5.26%
13	4.5	155	125	4.25	-5.56%
14	4.5	145	120	4.5	0.00%
15	4.5	145	115	4.5	0.00%
				Life: (Cycles)	**15**

Table C-181: Grade 8; 66% Y - Trial Average

Trial Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	11	161.67	130	5.67	-45.69%
2	6.33	148.33	117.67	5.83	-7.01%
3	6.08	155	123.33	5.5	-9.92%
4	6	164.33	131.67	5.17	-13.93%
5	5.83	173.67	126	5.08	-12.79%
6	5.58	155	126.67	5.08	-9.10%
7	5.58	151	124.33	5	-10.62%
8	5.42	165	137.33	4.83	-11.03%
9	5.25	169.33	138.33	4.75	-9.70%
10	5.25	171.67	141	4.75	-9.70%
11	5.08	158.33	127.33	4.67	-8.24%
12	5	151.67	126	4.67	-6.91%
13	4.83	154	128.33	4.58	-5.26%
14	4.83	158.33	128.33	4.67	-3.70%
15	4.67	165	135.67	4.67	0.57%
				Life (Cycles):	**15**

Appendix C (Continued)

C.9.3 75% Y Preload

Table C-182: Grade 8; 75% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Removal Prevailing (in-lbs)	Assem. Prevailing Ver. (in-lbs)*	Percent Difference Assem. Ver.
1	11	198	12	8.5	-22.73%
2	9	221	10	8.5	-5.56%
3	8	212	7.7	8	0.00%
4	8	212	7.5	8	0.00%
5	7	196	7.5	8	14.29%
6	7.25	177	6.5	8.5	17.24%
7	8	190	7	7.75	-3.13%
8	7	200	7	7.5	7.14%
9	6.75	180	7	7.25	7.41%
10	6.5	167	7	7.25	11.54%
11	6.25	170	6.5	7	12.00%
12	6.25	160	6.5	7	12.00%
13	6	168	6.75	7	16.67%
14	6.25	158	6.75	7	12.00%
15	6	155	6.5	7	16.67%
				Life: (Cycles)	**15**

Table C-183: Grade 8; 75% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	12.5	230	210	7	-44.00%
2	8	345	310	8.5	6.25%
3	7.5	340	310	8.75	16.67%
4	7.5	225	200	9	20.00%
5	7	240	220	8	14.29%
6	6.75	190	190	7.75	14.81%
7	7.5	180	170	7.5	0.00%
8	7	220	200	7.5	7.14%
9	7	220	180	7	0.00%
10	6.75	240	205	7	3.70%

Appendix C (Continued)

Table C-183 (Continued)

11	6.75	220	177	7	3.70%
12	6.75	230	190	6.5	-3.70%
13	6.25	215	163	6.5	4.00%
14	6.5	237	185	6.5	0.00%
15	6.5	225	175	6.5	0.00%
				Life: (Cycles)	**15**

Table C-184: Grade 8; 75% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	10.5	165	140	8	-23.81%
2	8	160	130	6.75	-15.63%
3	7	130	110	6.25	-10.71%
4	6.75	135	120	6.25	-7.41%
5	6.5	165	140	5.75	-11.54%
6	6.25	145	127	5.75	-8.00%
7	5.75	147	125	5.75	0.00%
8	5.75	150	130	5.5	-4.35%
9	5.75	143	117	5.5	-4.35%
10	5.5	127	107	5.25	-4.55%
11	5.5	125	107	5.25	-4.55%
12	5.5	155	125	5.25	-4.55%
13	5.25	133	110	5	-4.76%
14	5.25	122	100	5	-4.76%
15	5.25	135	110	5	-4.76%
				Life: (Cycles)	**15**

Table C-185: Grade 8; 75% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	10	173	140	7.5	-25.00%
2	8	140	123	7	-12.50%
3	7.75	148	180	6.75	-12.90%
4	7.75	145	117	7	-9.68%
5	7	155	130	7	0.00%

Appendix C (Continued)

Table C-185 (Continued)

6	7	145	120	6.5	-7.14%
7	6.5	142	110	6.5	0.00%
8	6.5	147	120	6.25	-3.85% Y
9	6.5	135	110	6.25	-3.85% Y
10	6.5	135	107	6	-7.69%
11	6.25	140	117	6	-4.00%
12	6.5	145	122	6	-7.69%
13	6.25	135	115	6	-4.00%
14	6	133	110	6	0.00%
15	6	140	113	5.5	-8.33%
				Life: (Cycles)	**15**

Table C-186: Grade 8; 75% Y - Trial Average

Trial Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	11	189.33	163.33	7.5	-30.94%
2	8	215	187.67	7.42	-7.29%
3	7.42	206	200	7.25	-2.32%
4	7.33	168.33	145.67	7.42	0.97%
5	6.83	186.67	163.33	6.92	0.92%
6	6.67	160	145.67	6.67	-0.11%
7	6.583	156.33	135	6.58	0.00%
8	6.42	172.33	150	6.42	-0.35%
9	6.42	166	135.67	6.25	-2.73%
10	6.25	167.33	139.67	6.08	-2.84%
11	6.17	161.67	133.67	6.08	-1.61%
12	6.25	176.67	145.67	5.92	-5.31%
13	5.92	161	129.33	5.83	-1.59%
14	5.92	164	131.67	5.83	-1.59%
15	5.92	166.67	132.67	5.67	-4.37%
				Life (Cycles):	**15**

Appendix C (Continued)

C.9.4 85% Y Preload

Table C-187: Grade 8; 85% Y - Trial 1

Trial 1 - Half Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Removal Prevailing (in-lbs)**	**Assem. Prevailing Ver. (in-lbs)***	**Percent Difference Assem. Ver.**
1	12.5	320	7.5	7.5	-40.00%
2	7.5	260	7	9	20.00%
3	8.25	275	8	7	-15.15%
4	7	200	7.5	6.75	-3.57%
5	6.5	215	7.5	6.75	3.85% Y
6	6.5	175	7.25	6	-7.69%
7	6.5	190	7	6.75	3.85% Y
8	6.5	230	7	6.75	3.85% Y
9	6.75	190	6.5	6.5	-3.70%
10	6.5	180	6	7.25	11.54%
11	7	200	6.5	6.25	-10.71%
12	6.5	190	7	7	7.69%
13	6	183	7	7.5	25.00%
14	6.5	175	7	7	7.69%
15	6.5	175	6.5	7	7.69%
				Life: (Cycles)	**15**

Table C-188: Grade 8; 85% Y - Trial 2

Trial 2 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	12.5	185	145	7.5	-40.00%
2	9.5	195	152	8.25	-13.16%
3	8.5	180	145	8	-5.88%
4	8.25	190	160	7.5	-9.09%
5	7.75	197	160	7.25	-6.45%
6	7.5	185	145	7.25	-3.33%
7	7.5	168	135	7.25	-3.33%
8	7	179	142	7.25	3.57%
9	7	174	135	7	0.00%
10	7	177	140	6.75	-3.57%
11	6.75	180	142	6.5	-3.70%

Appendix C (Continued)

Table C-188 (Continued)

12	6.5	180	140	6.5	0.00%
13	6.5	175	150	6.75	3.85%
14	6.5	170	143	6.75	3.85%
15	6.5	173	144	6.75	3.85%
				Life: (Cycles)	**15**

Table C-189: Grade 8; 85% Y - Trial 3

Trial 3 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	12.5	255	210	9.5	-24.00%
2	8.5	300	230	8.5	0.00%
3	8	250	210	7.5	-6.25%
4	7.25	230	210	7.5	3.45%
5	7.25	230	190	7.5	3.45%
6	7	220	190	7.25	3.57%
7	7	195	160	7.25	3.57%
8	7	198	160	7	0.00%
9	6.75	192	157	7.25	7.41%
10	6.75	200	165	7	3.70%
11	6.75	170	145	7	3.70%
12	6.25	190	155	7.5	20.00%
13	6.5	180	150	7.5	15.38%
14	7	185	147	7.25	3.57%
15	6.5	180	150	7	7.69%
				Life: (Cycles)	**15**

Table C-190: Grade 8; 85% Y - Trial 4

Trial 4 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	10	163	120	7.5	-25.00%
2	7	185	140	6.75	-3.57%
3	6.25	160	125	6.5	4.00%
4	6	150	120	6.5	8.33%
5	5.5	150	115	6.25	13.64%
6	5.5	179	140	6	9.09%
7	5	155	115	6	20.00%

Appendix C (Continued)

Table C-190 (Continued)

8	5	160	123	6	20.00%
9	5	190	150	6	20.00%
10	5	175	140	5.75	15.00%
11	5	190	155	5.5	10.00%
12	5	250	195	5.25	5.00%
13	4.75	170	145	5.5	15.79%
14	4.75	182	144	5.25	10.53%
15	4.75	190	150	5.5	15.79%
				Life: (Cycles)	**15**

Table C-191: Grade 8; 85% Y - Trial Average

Trial Average					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	11.67	201	158.33	8.17	-29.67%
2	8.33	226.67	174	7.83	-5.58%
3	7.58	196.67	160	7.33	-2.71%
4	7.17	190	163.33	7.17	0.90%
5	6.83	192.33	155	7	3.54%
6	6.67	194.67	158.33	6.83	3.11%
7	6.5	172.67	136.67	6.83	6.75% Y
8	6.33	179	141.67	6.75	7.86%
9	6.25	185.33	147.33	6.75	9.14%
10	6.25	184	148.33	6.5	5.04%
11	6.17	180	147.33	6.33	3.33%
12	5.92	206.67	163.33	6.42	8.33%
13	5.92	175	148.33	6.58	11.67%
14	6.08	179	144.67	6.42	5.98%
15	5.92	181	148	6.42	9.11%
				Life (Cycles):	**15**

Appendix C (Continued)

C.9.5 Locknut Average

Table C-192: Grade 8; Locknut Average

Locknut Average					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	11.22	184	150.56	7.11	-35.43%
2	7.56	196.67	159.78	7.03	-6.63%
3	7.03	185.89	161.11	6.69	-4.98%
4	6.83	174.22	146.89	6.58	-4.02%
5	6.5	184.22	148.11	6.33	-2.78%
6	6.31	169.89	143.56	6.19	-2.03%
7	6.2222	160	132	6.14	-1.29%
8	6.06	172.11	143	6	-1.17%
9	5.97	173.56	140.64	5.92	-1.10%
10	5.92	174.33	143	5.78	-2.50%
11	5.81	166.67	136.11	5.69	-2.17%
12	5.72	178.33	145	5.67	-1.30%
13	5.56	163.33	135.33	5.67	1.61%
14	5.61	167.11	134.89	5.64	0.23%
15	5.5	170.89	138.78	5.58	1.77%
				Life (Cycles):	**15**

C.9.6 Lubrication Test

Table C-193: Grade 8 No Lubrication; 85% Y - Trial 5

Trial 5 - Full Cycle					
Cycle	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference Removal
1	15	380	290	8	-46.67%
2	15	450*			-100.00%
3					
4					
5					
6					
7					
8					

Appendix C (Continued)

Table C-193 (Continued)

9					
10					
11					
12					
13					
14					
15					
			*Bolt Failed	**Life: (Cycles)**	**1**

Table C-194: Grade 8 Braycote; 85% Y - Trial 6

Trial 6 - Full Cycle					
Cycle	**Assembly Prevailing (in-lbs)**	**Tightening (in-lbs)**	**Breakloose (in-lbs)**	**Removal Prevailing (in-lbs)**	**Percent Difference Removal**
1	5	225	175	4.5	-10.00%
2	3	205	165	3.25	8.33%
3	3	200	150	3.25	8.33%
4	2.75	207.5	180	3.5	27.27%
5	2.75	235	195	3.25	18.18%
6	2.75	280	240	3.25	18.18%
7	2.75	260	225	3	9.09%
8	2.75	320	280	3	9.09%
9	2.75	340	320	3.25	18.18%
10	2.75	350	330	3.25	18.18%
11	2.75	260	220	3	9.09%
12	3	310	295	3.25	8.33%
13	3	340	295	3	0.00%
14	3	280	230	3.25	8.33%
15	3	290	250	3	0.00%
				Life: (Cycles)	**15**

Appendix D: Individual Locknut Plots

D.1 MS21043-4

D.1.1 Unseated

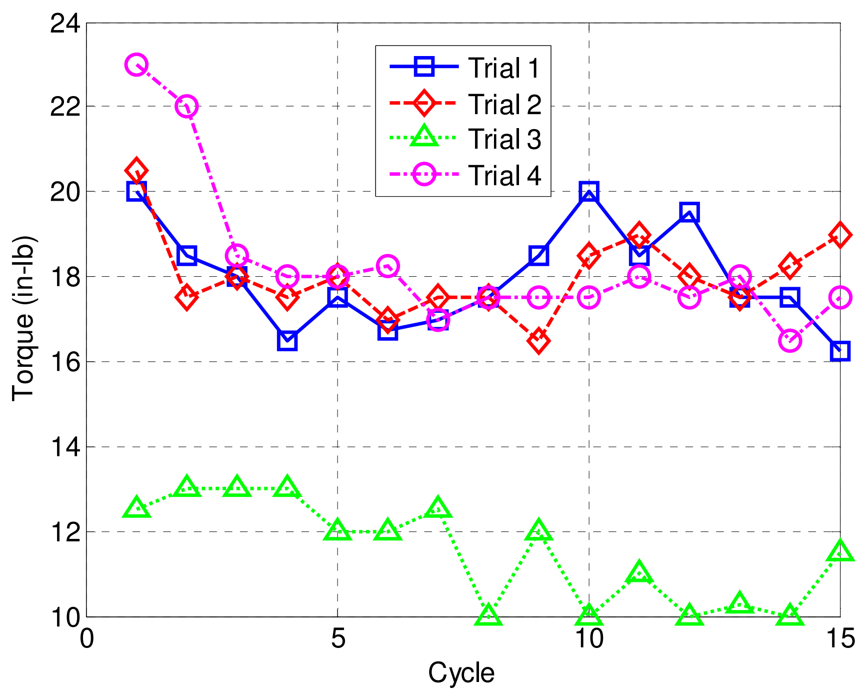

Figure D-1: MS21043-4 Assembly Prevailing Torque; Unseated

Appendix D (Continued)

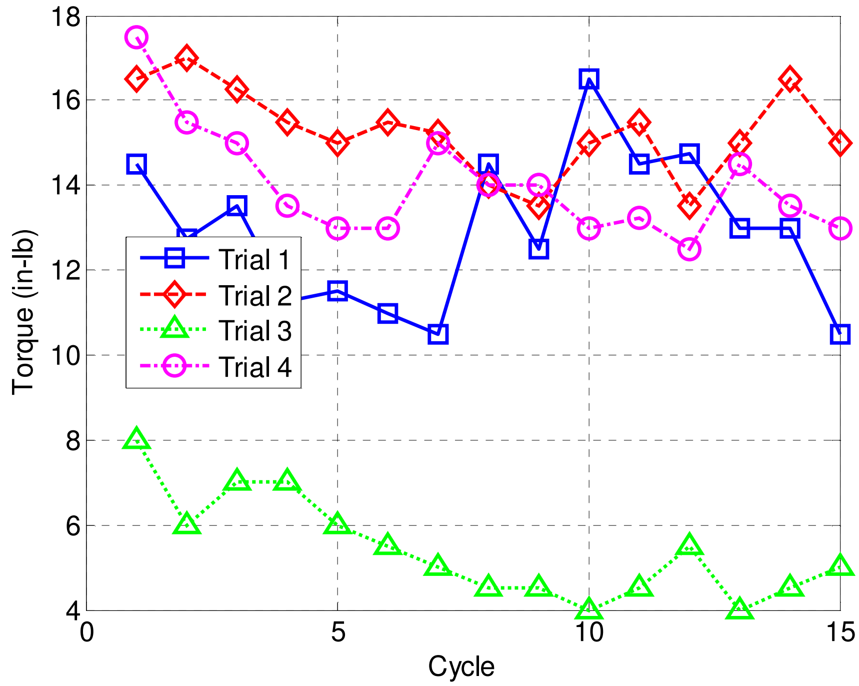

Figure D-2: MS21043-4 Removal Prevailing Torque; Unseated

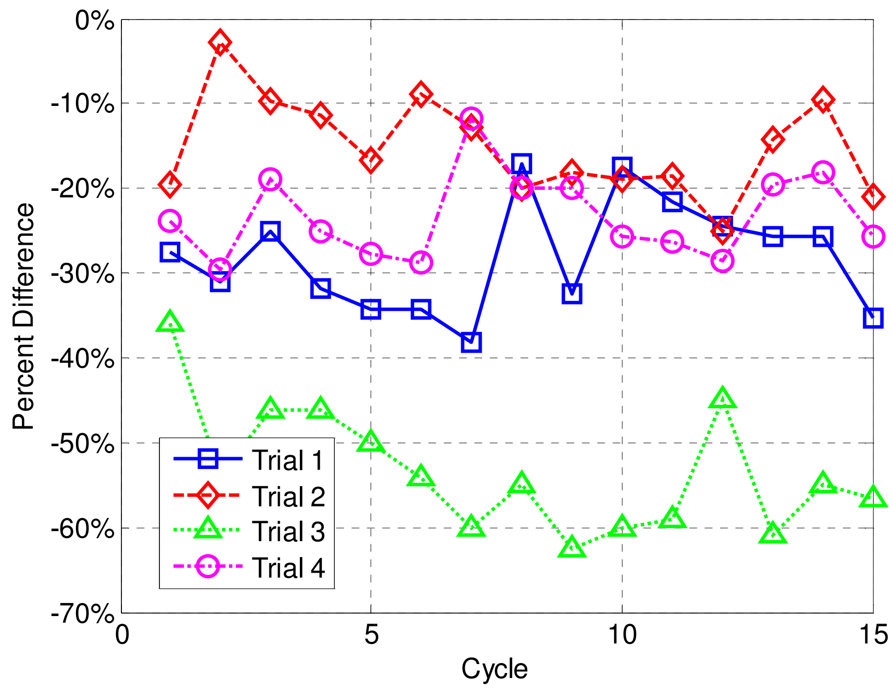

Figure D-3: MS21043-4 Percent Difference; Unseated

Appendix D (Continued)

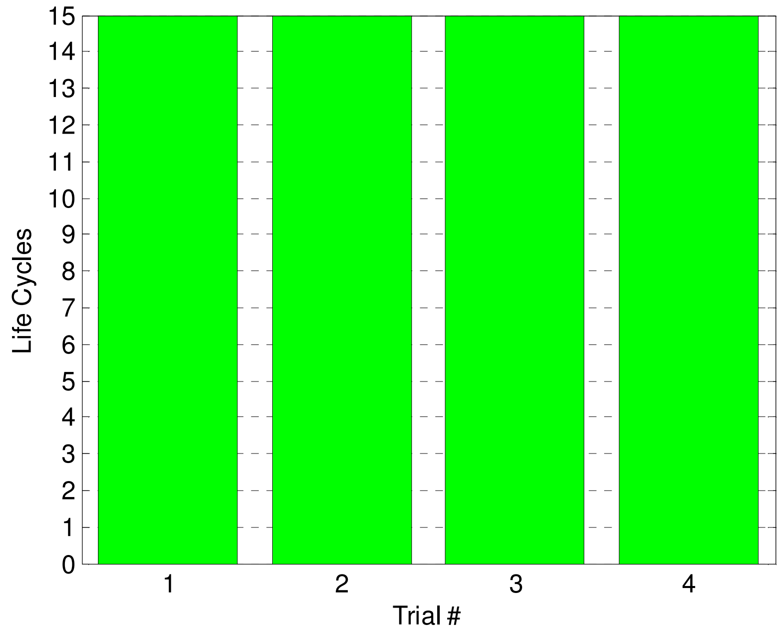

Figure D-4: MS21043-4 Life; Unseated

D.1.2 66% Y Preload

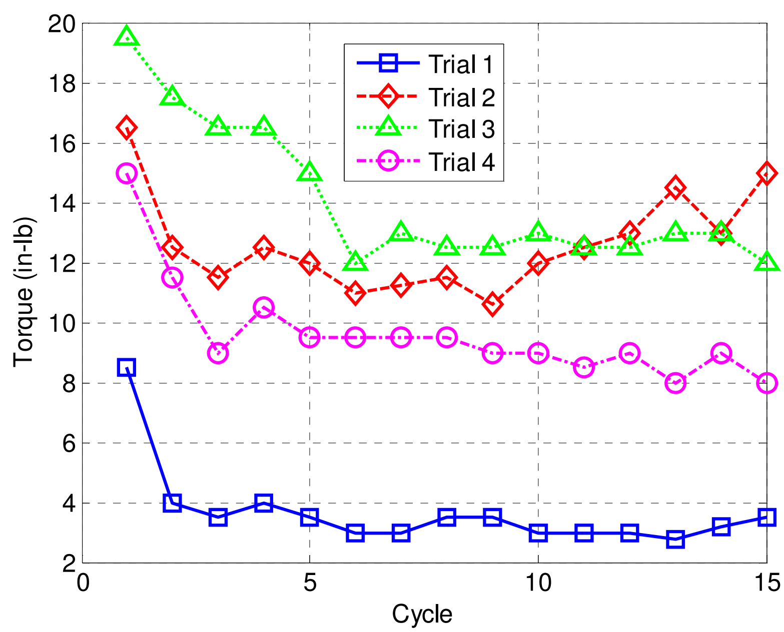

Figure D-5: MS21043-4 Assembly Prevailing Torque; 66% Y Preload

Appendix D (Continued)

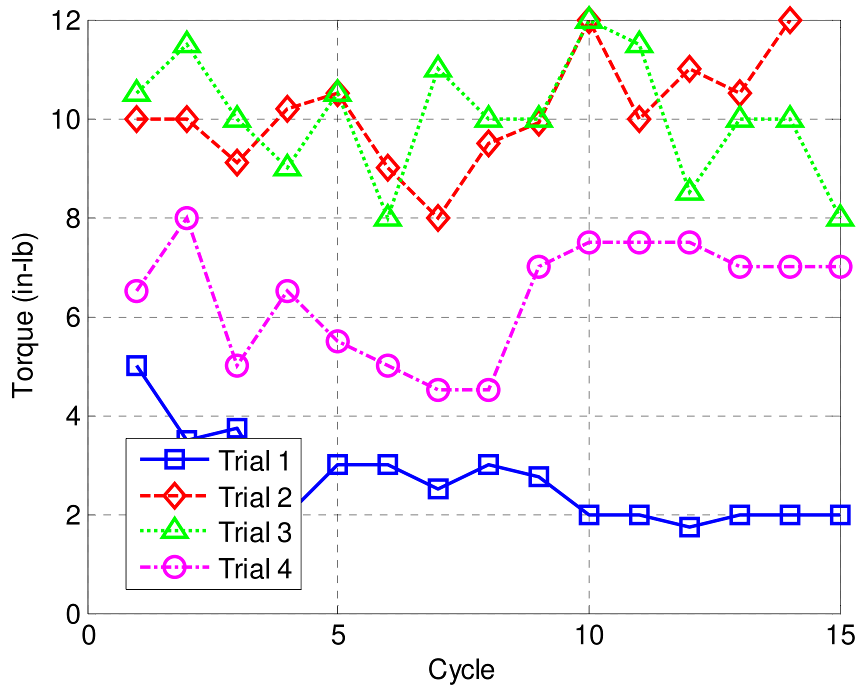

Figure D-6: MS21043-4 Removal Prevailing Torque; 66% Y Preload

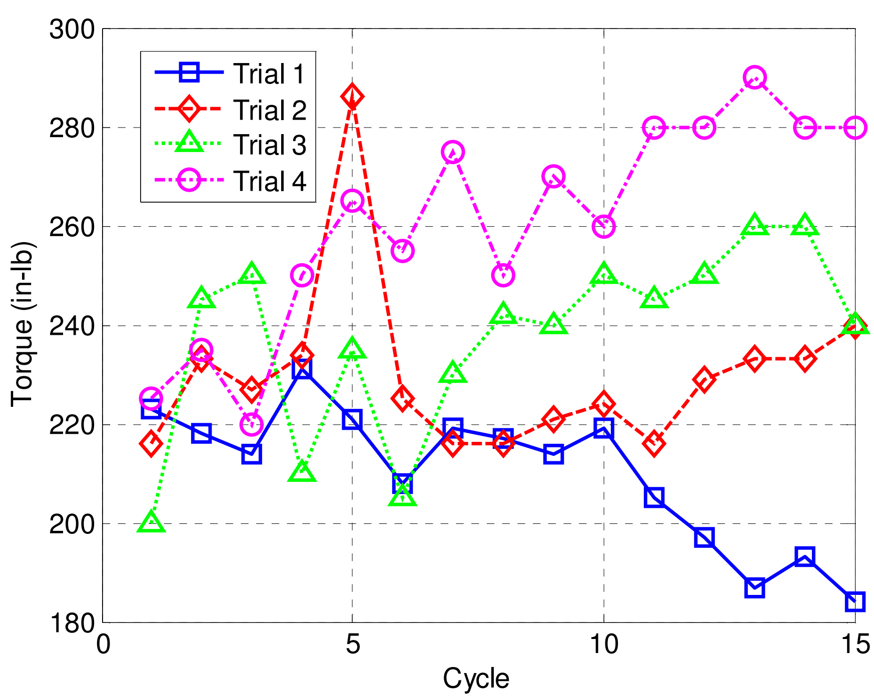

Figure D-7: MS21043-4 Tightening Torque; 66% Y Preload

Appendix D (Continued)

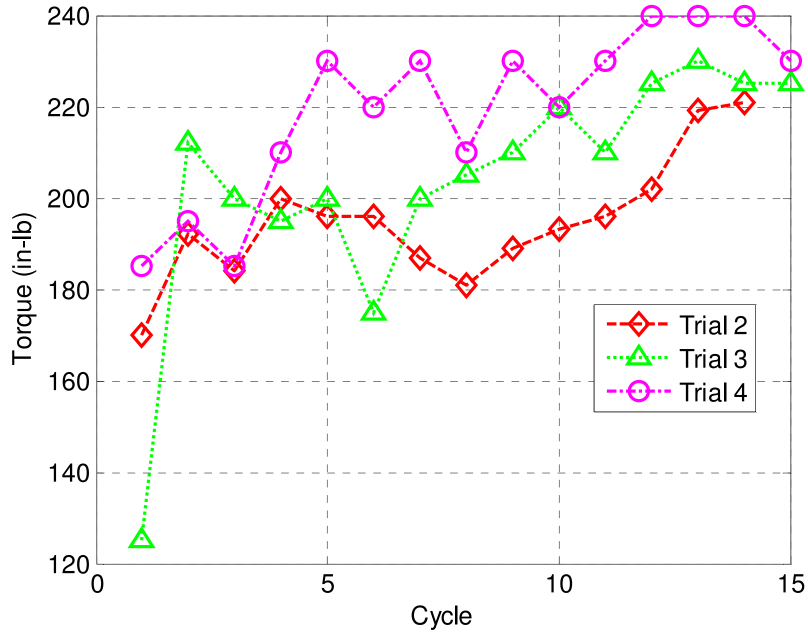

Figure D-8: MS21043-4 Breakloose Torque; 66% Y Preload

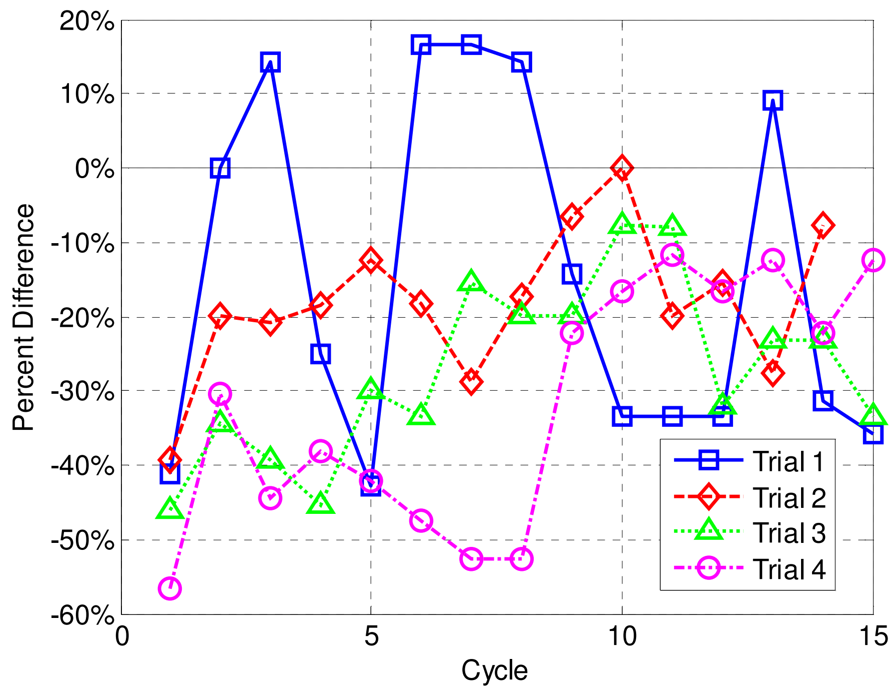

Figure D-9: MS21043-4 Percent Difference; 66% Y Preload

Appendix D (Continued)

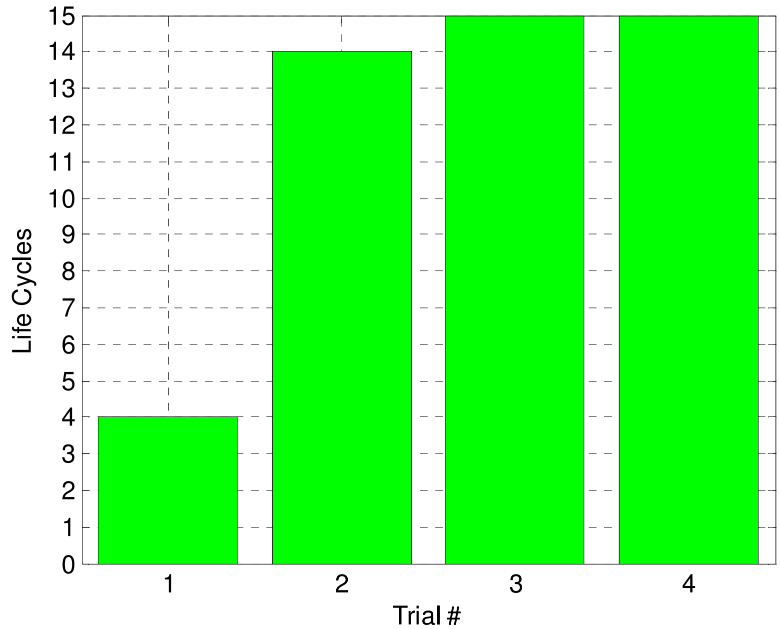

Figure D-10: MS21043-4 Life; 66% Y Preload

D.1.3 75% Y Preload

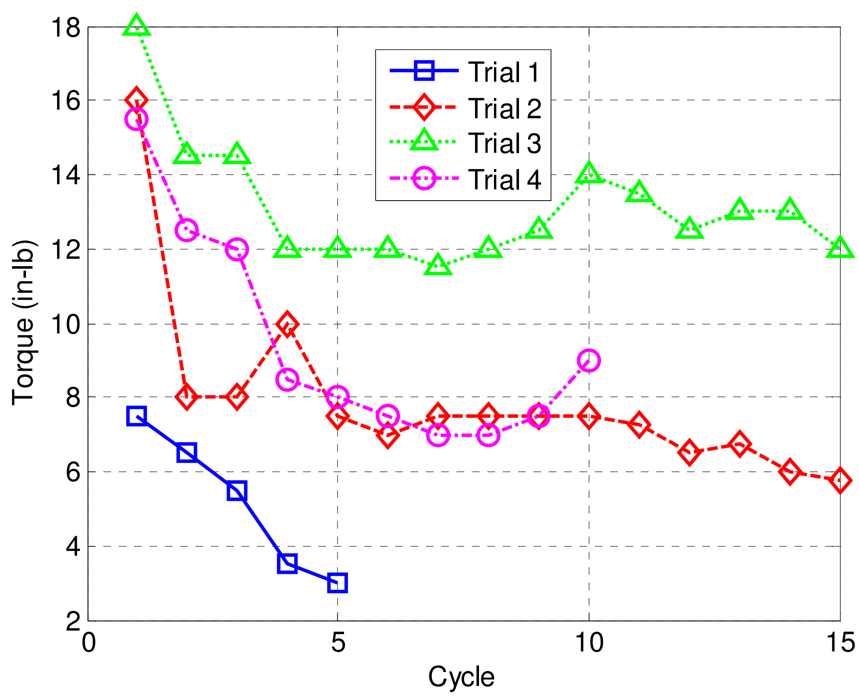

Figure D-11: MS21043-4 Assembly Prevailing Torque; 75% Y Preload

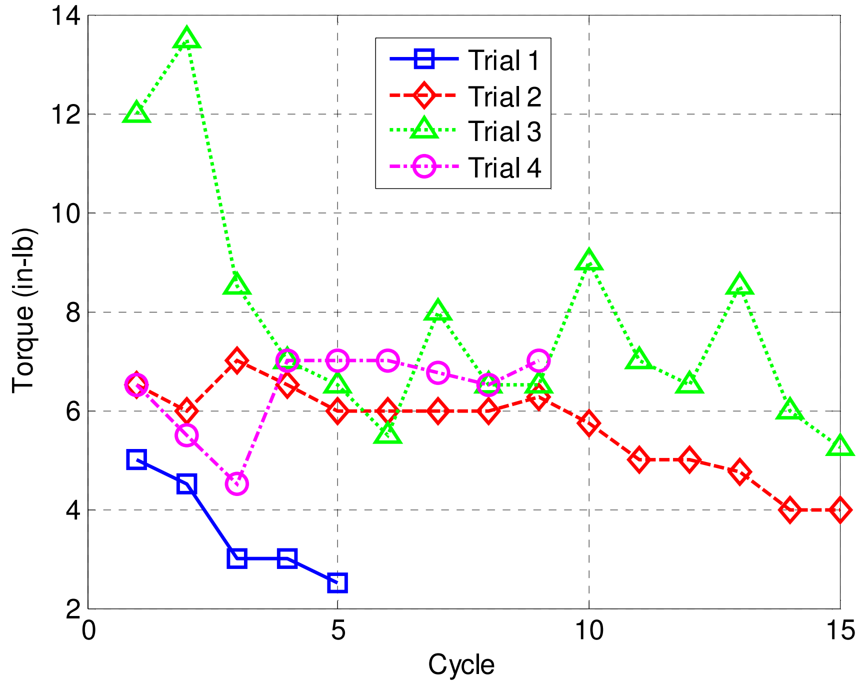

Figure D-12: MS21043-4 Removal Prevailing Torque; 75% Y Preload

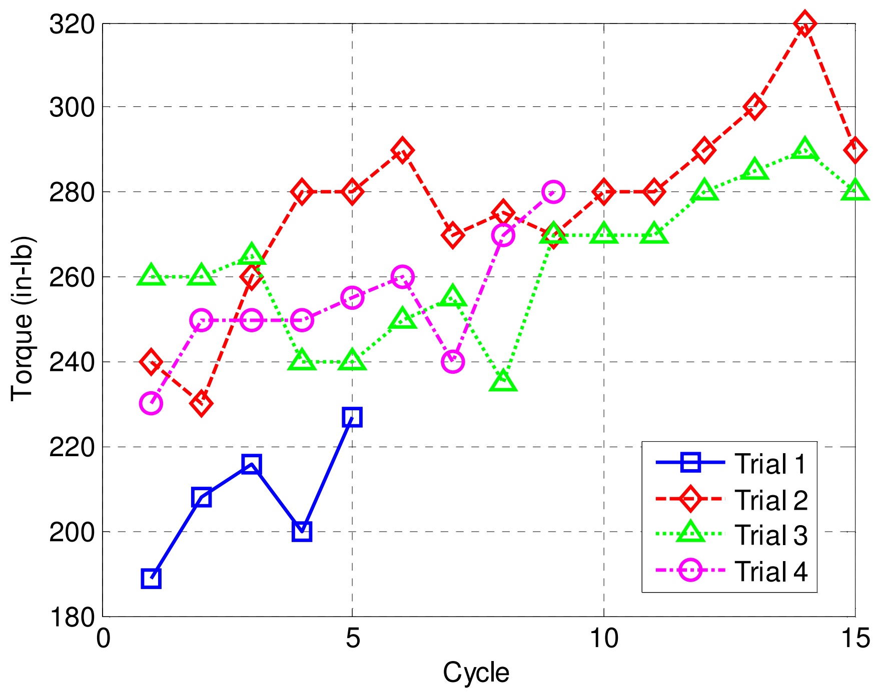

Figure D-13: MS21043-4 Tightening Torque; 75% Y Preload

Appendix D (Continued)

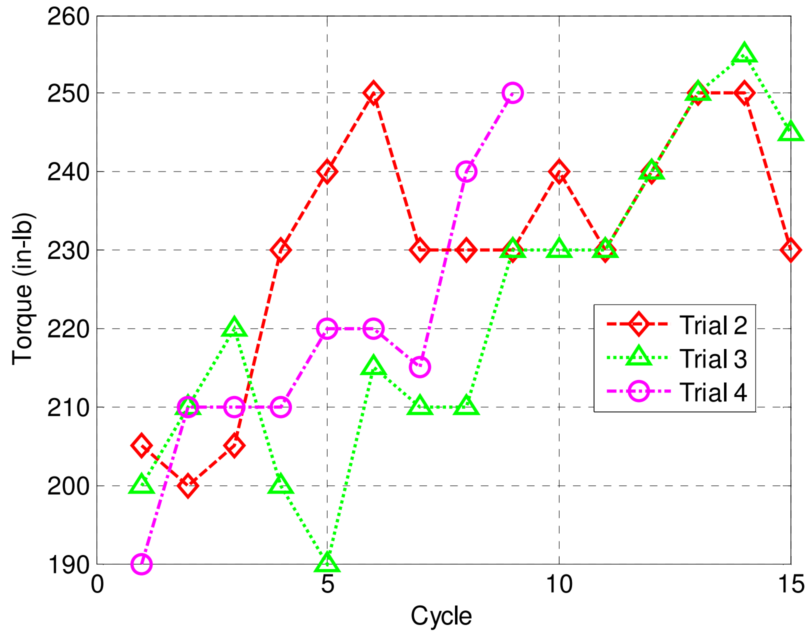

Figure D-14: MS21043-4 Breakloose Torque; 75% Y Preload

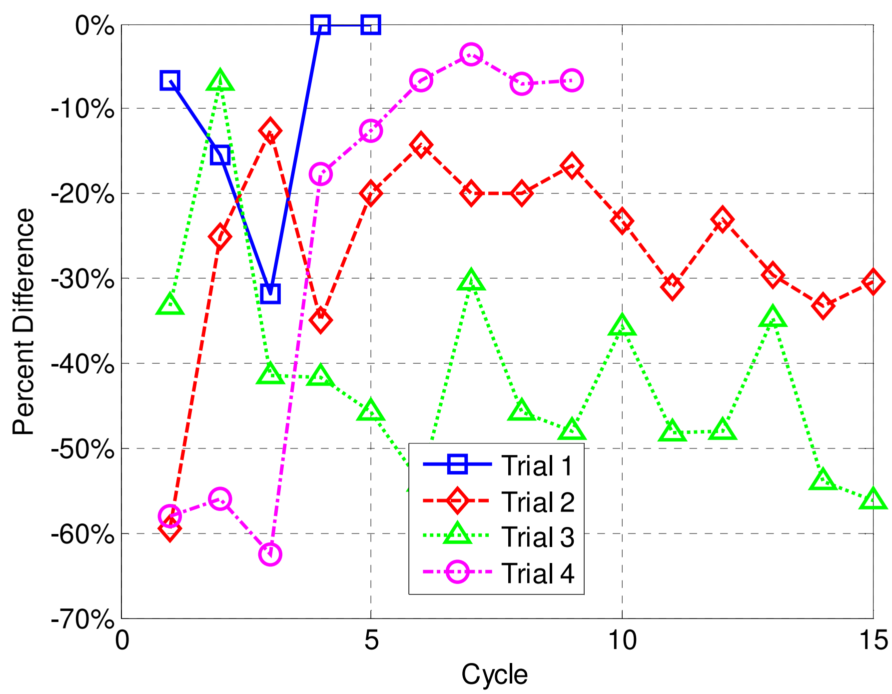

Figure D-15: MS21043-4 Percent Difference; 75% Y Preload

Appendix D (Continued)

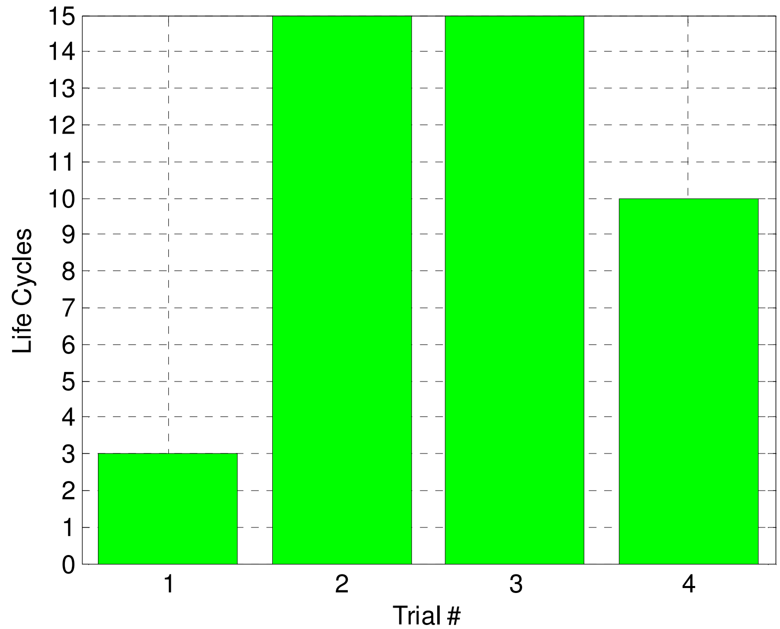

Figure D-16: MS21043-4 Life; 75% Y Preload

D.1.4 85% Y Preload

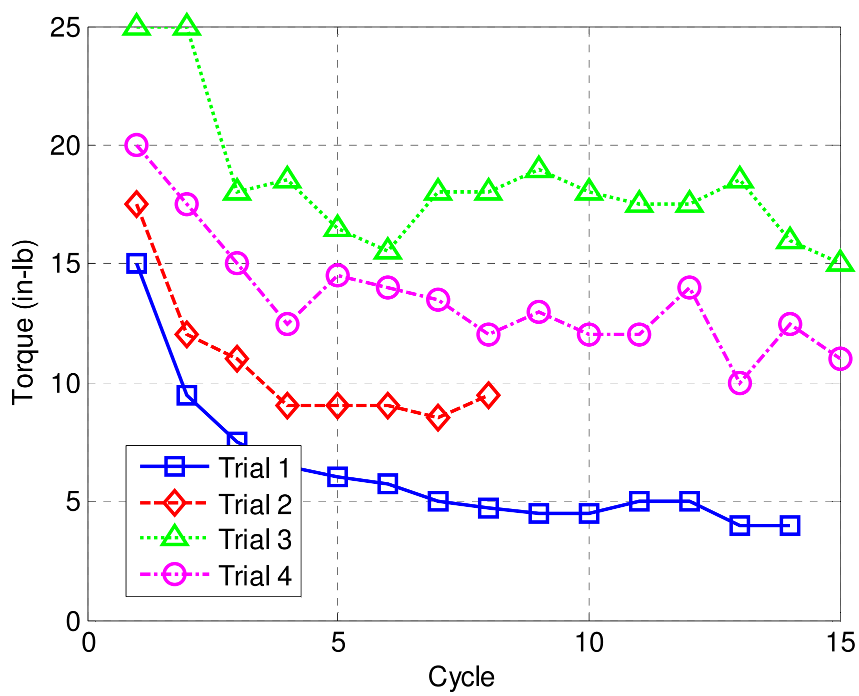

Figure D-17: MS21043-4 Assembly Prevailing Torque; 85% Y Preload

Appendix D (Continued)

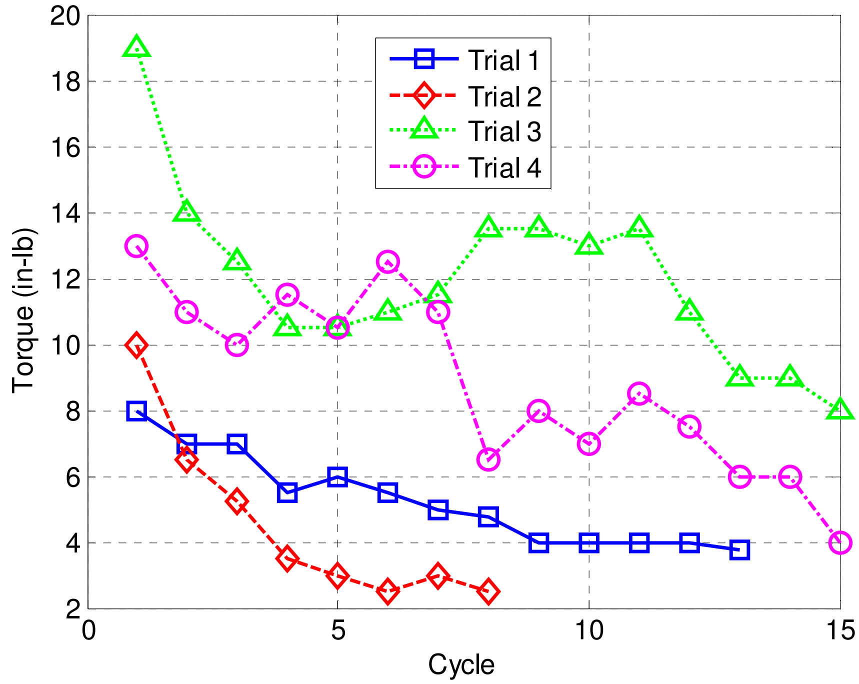

Figure D-18: MS21043-4 Removal Prevailing Torque; 85% Y Preload

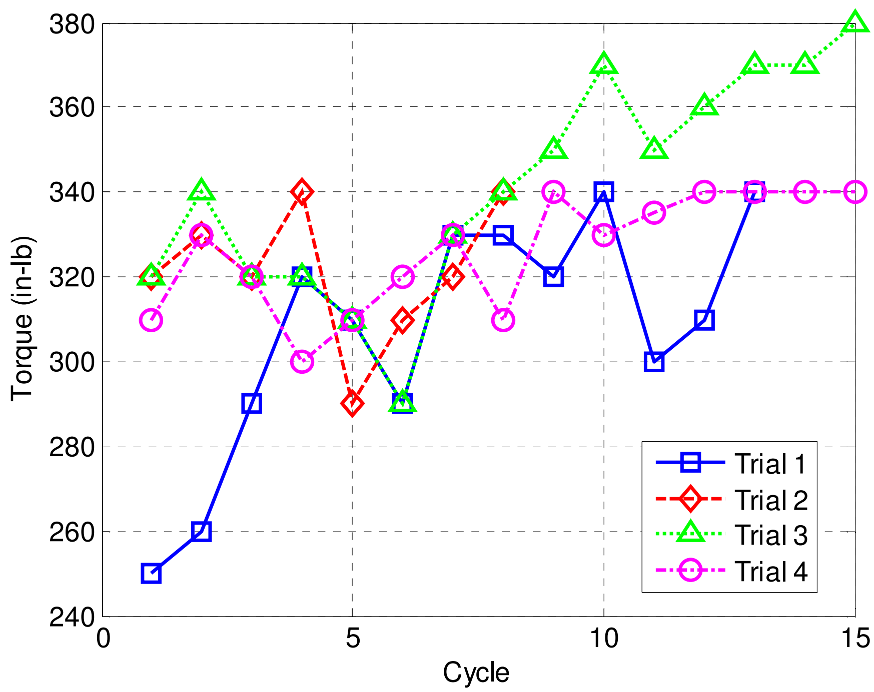

Figure D-19: MS21043-4 Tightening Torque; 85% Y Preload

Appendix D (Continued)

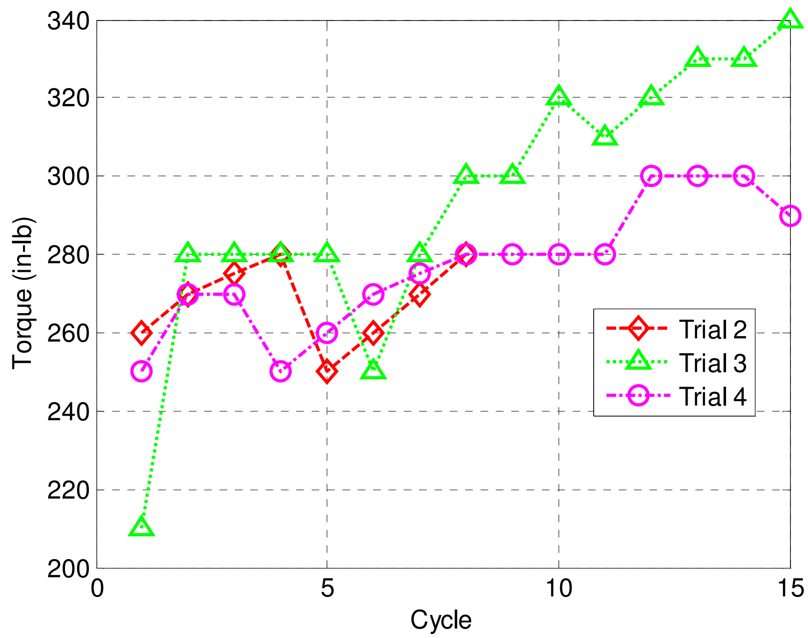

Figure D-20: MS21043-4 Breakloose Torque; 85% Y Preload

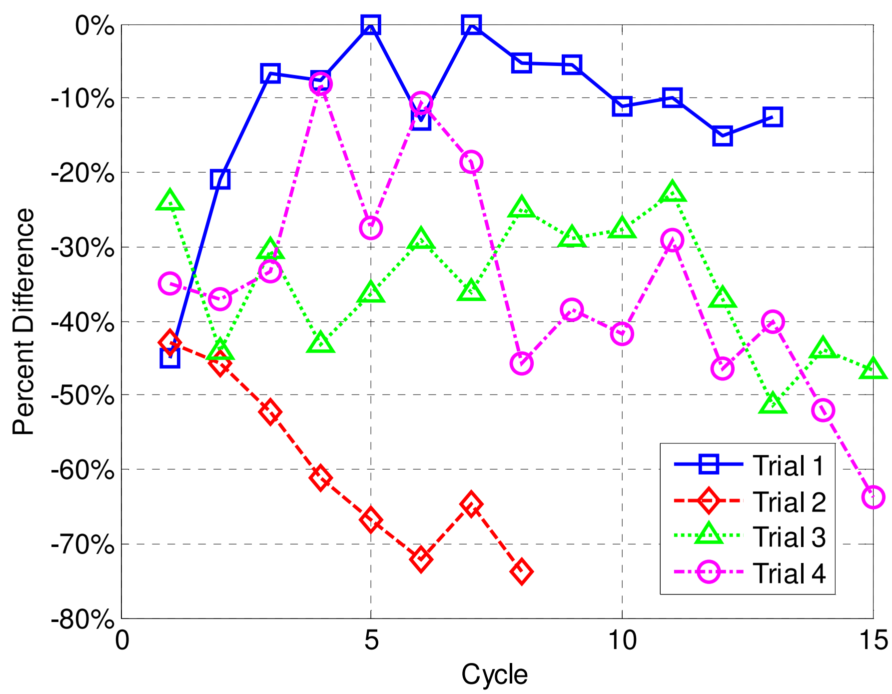

Figure D-21: MS21043-4 Percent Difference; 85% Y Preload

Appendix D (Continued)

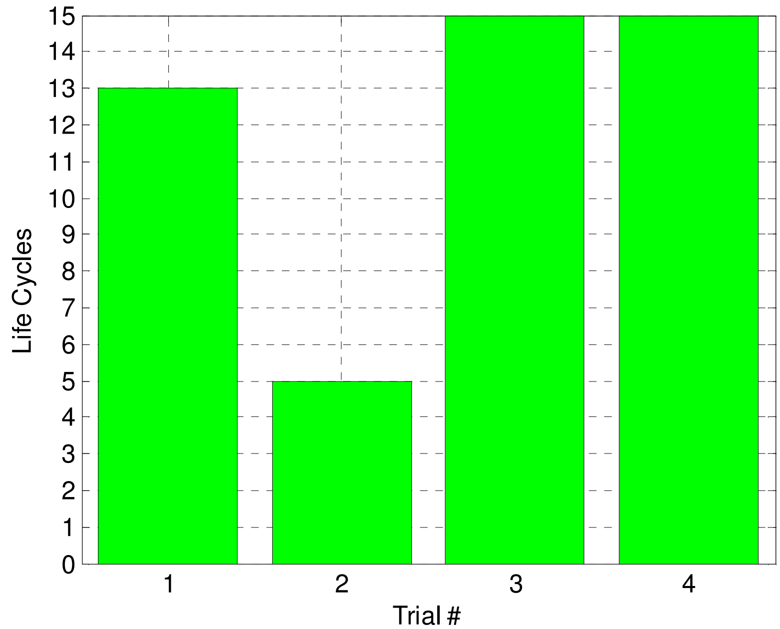

Figure D-22: MS21043-4 Life; 85% Y Preload

D.1.5 Preload Averages

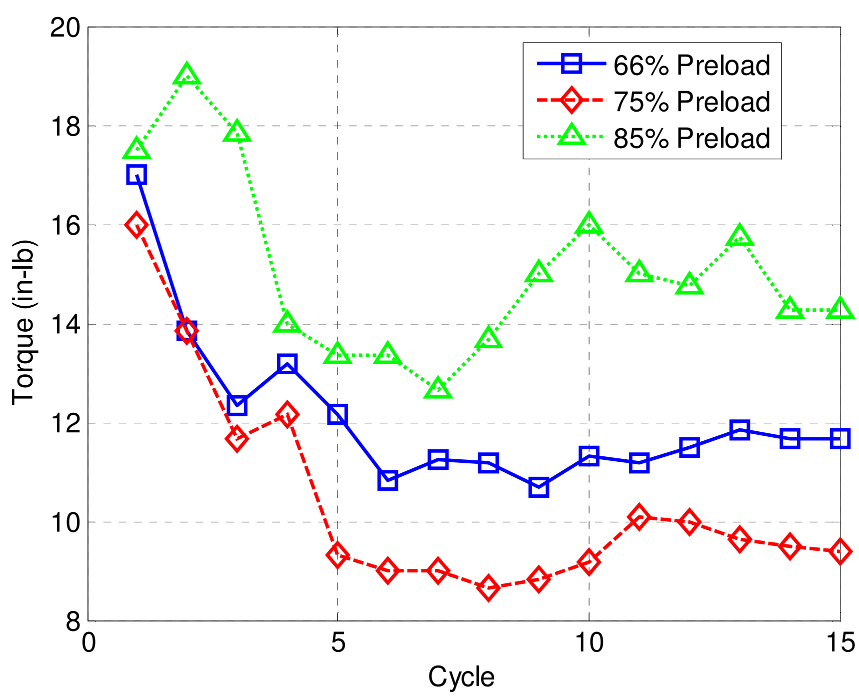

Figure D-23: MS21043-4 Assembly Prevailing Torque; Trial Average

Appendix D (Continued)

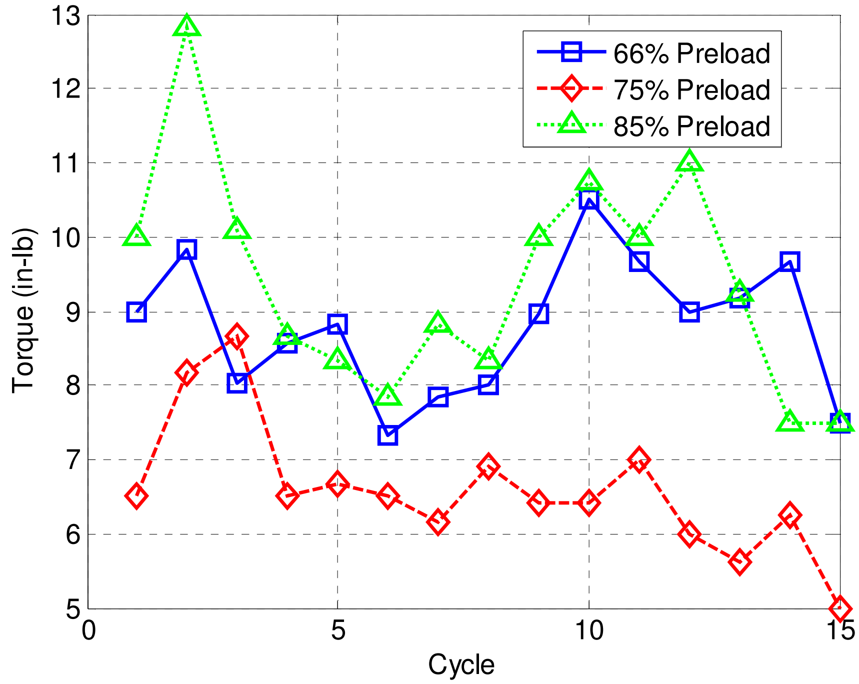

Figure D-24: MS21043-4 Removal Prevailing Torque; Trial Average

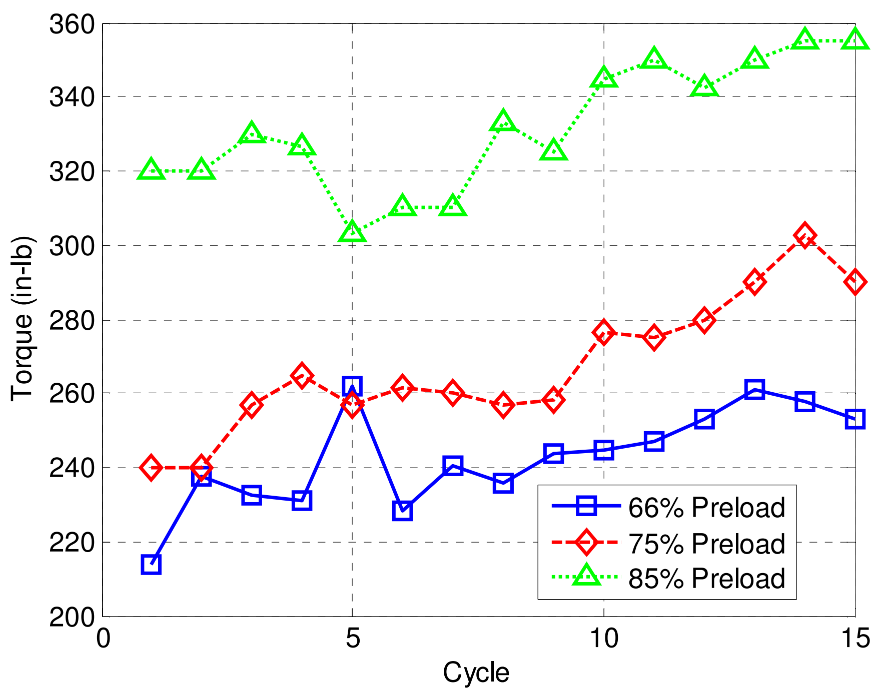

Figure D-25: MS21043-4 Tightening Torque; Trial Average

Appendix D (Continued)

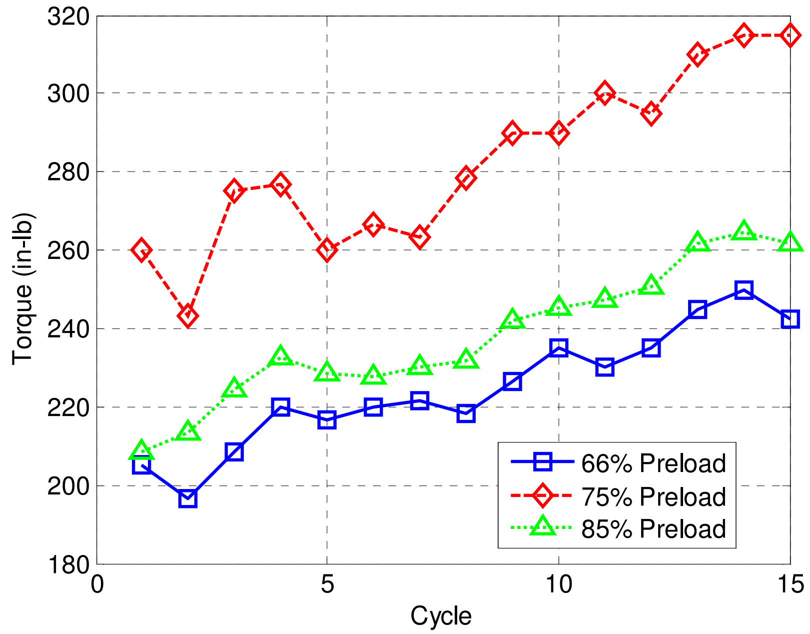

Figure D-26: MS21043-4 Breakloose Torque; Trial Average

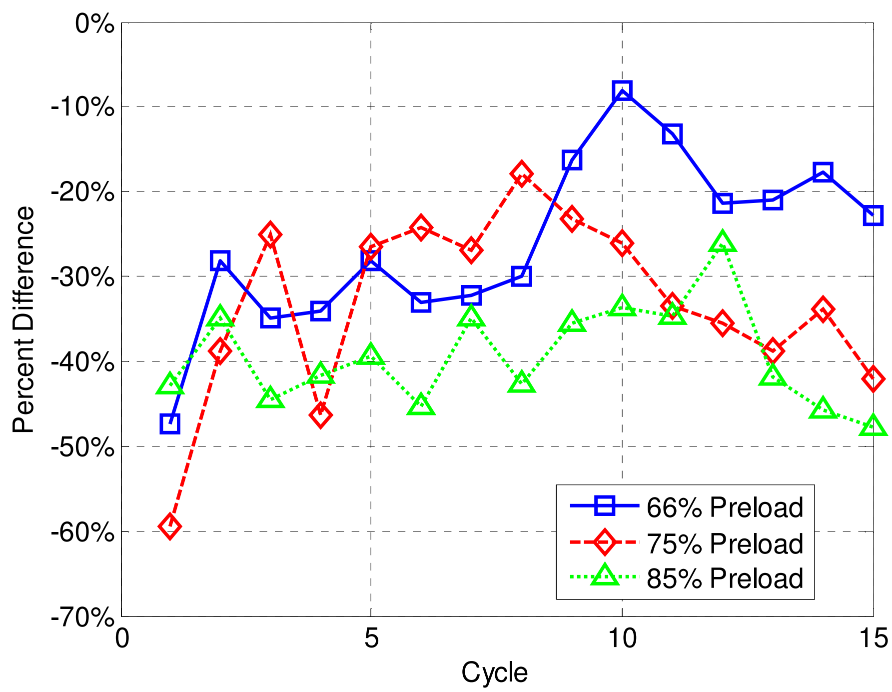

Figure D-27: MS21043-4 Percent Difference; Trial Average

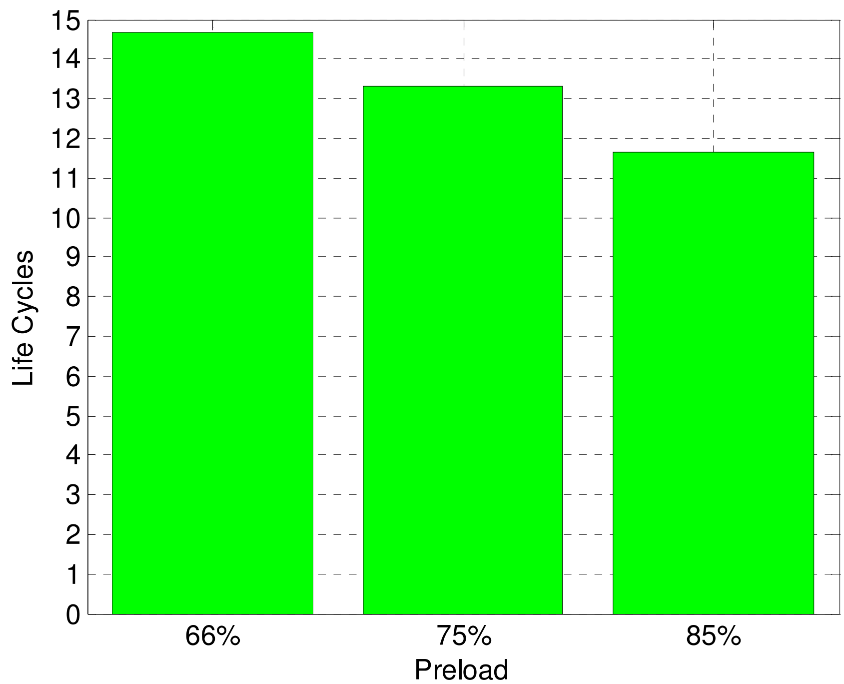

Figure D-28: MS21043-4 Life; Trial Average

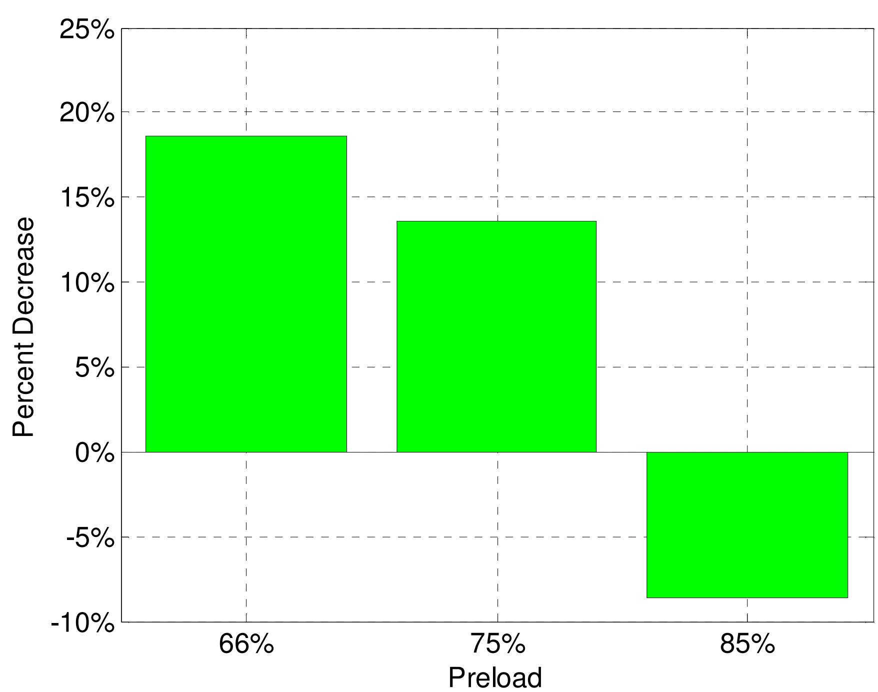

Figure D-29: MS21043-4 Assembly Prevailing Percent Decrease between Cycle 1 and 2; Trial Average

Appendix D (Continued)

D.2 NAS1291-4

D.2.1 Unseated

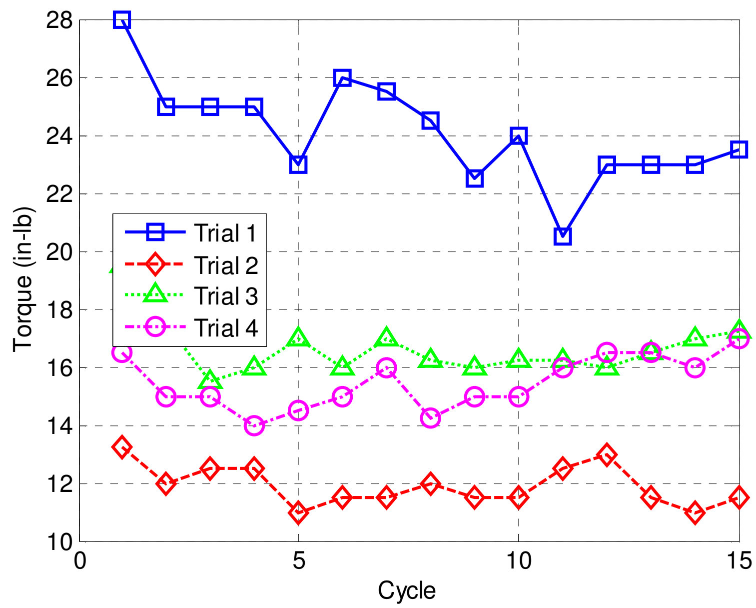

Figure D-30: NAS2191-4 Assembly Prevailing Torque; Unseated

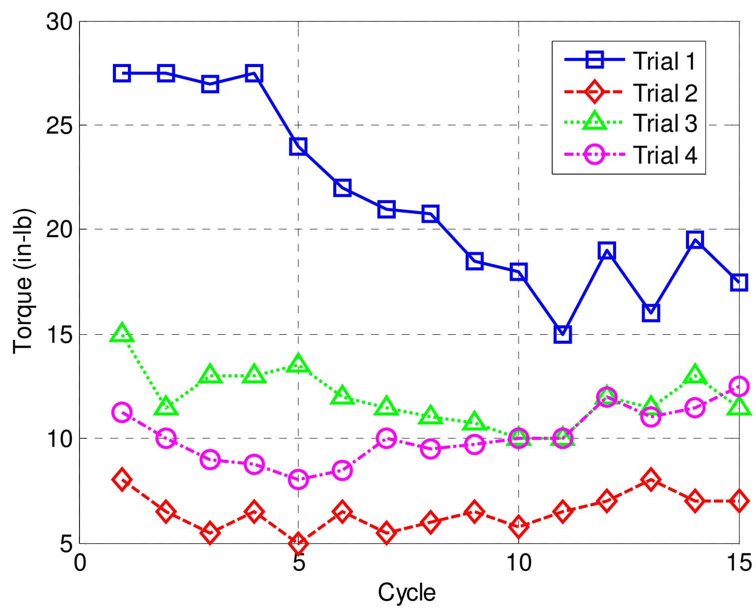

Figure D-31: NAS2191-4 Removal Prevailing Torque; Unseated

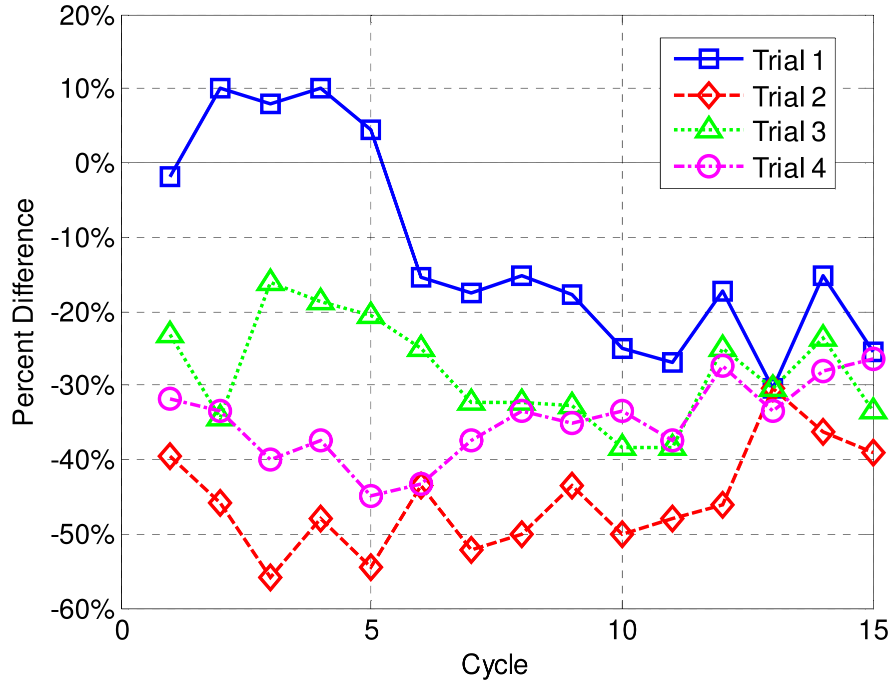

Figure D-32: NAS2191-4 Percent Difference; Unseated

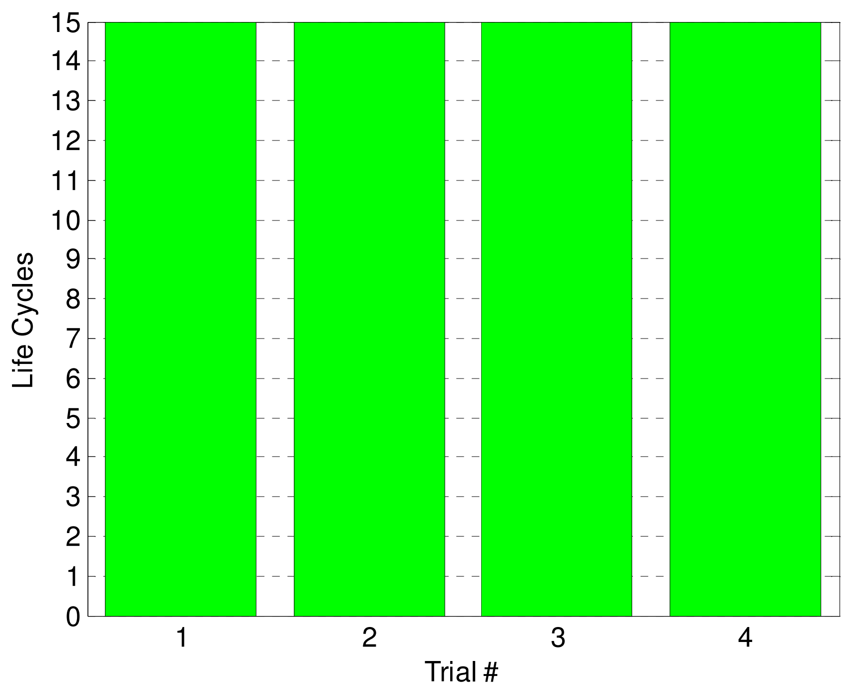

Figure D-33: NAS2191-4 Life; Unseated

Appendix D (Continued)

D.2.2 66% Y Preload

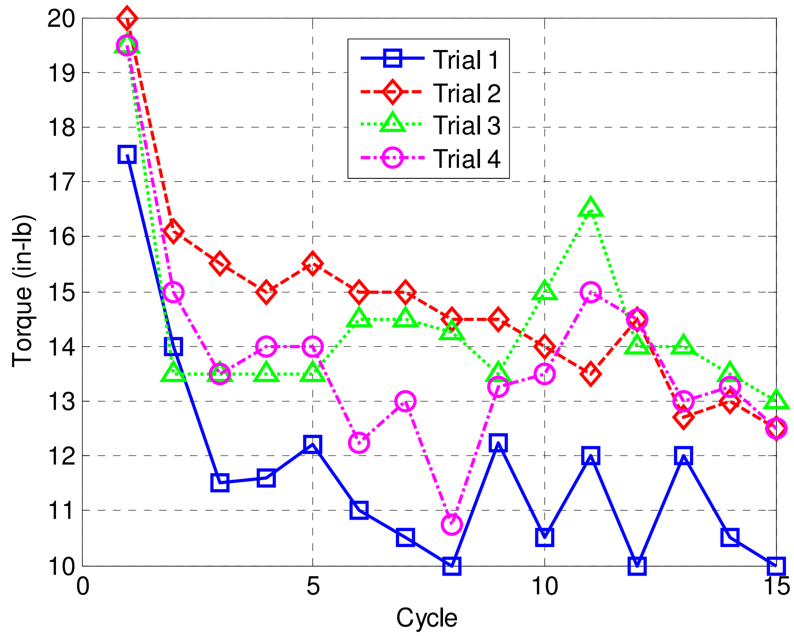

Figure D-34: NAS1291-4 Assembly Prevailing Torque; 66% Y Preload

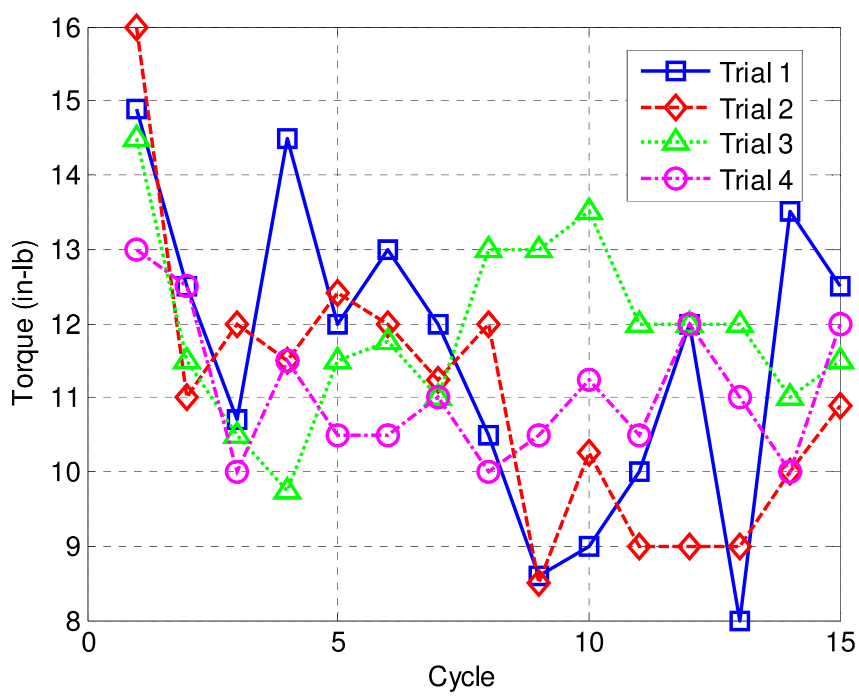

Figure D-35: NAS1291-4 Removal Prevailing Torque; 66% Y Preload

Appendix D (Continued)

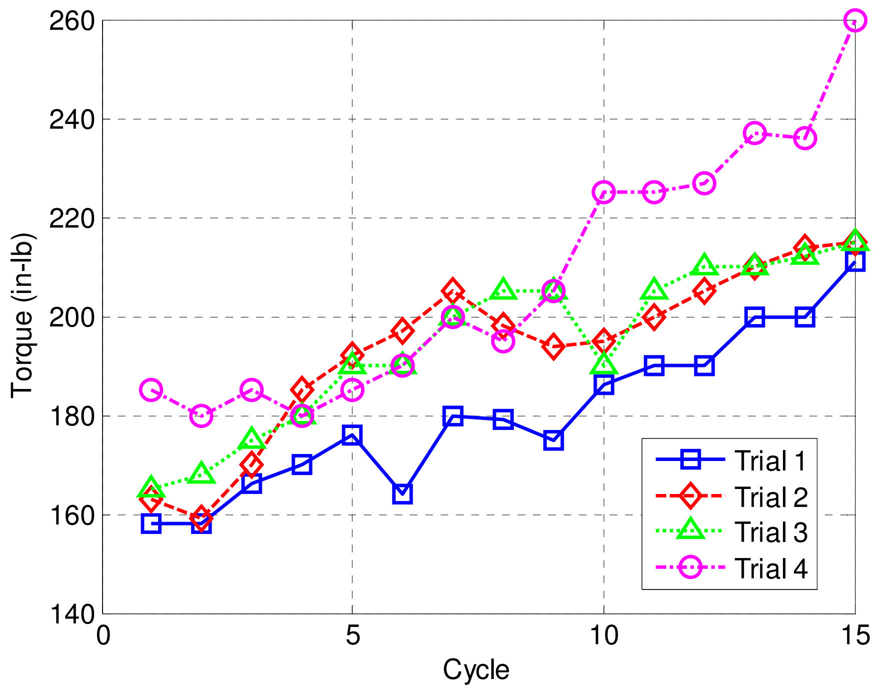

Figure D-36: NAS1291-4 Tightening Torque; 66% Y Preload

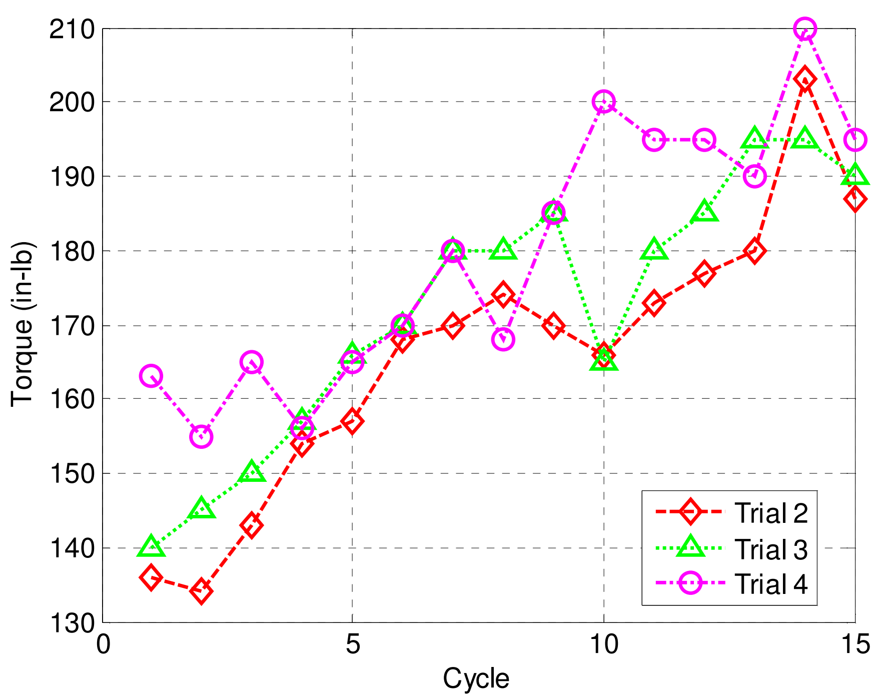

Figure D-37: NAS1291-4 Breakloose Torque; 66% Y Preload

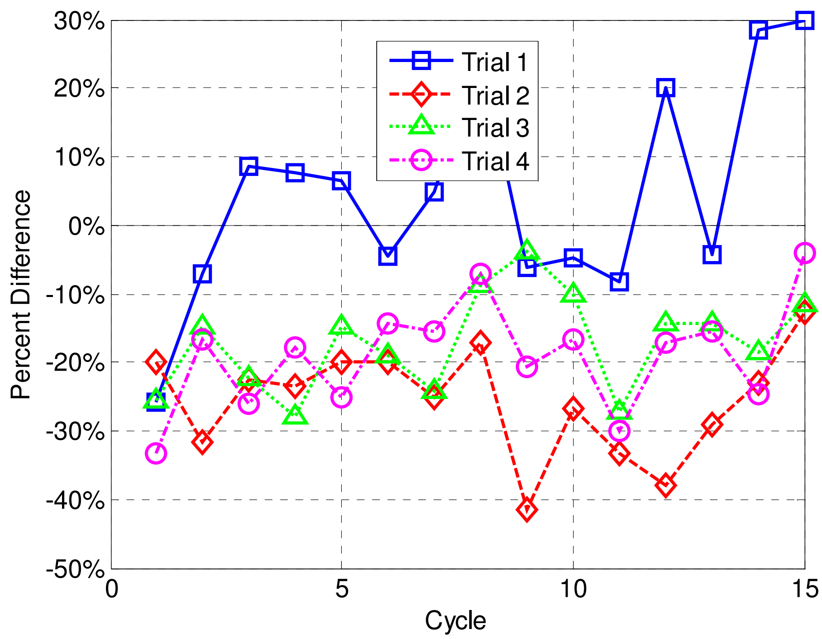

Figure D-38: NAS1291-4 Percent Difference; 66% Y Preload

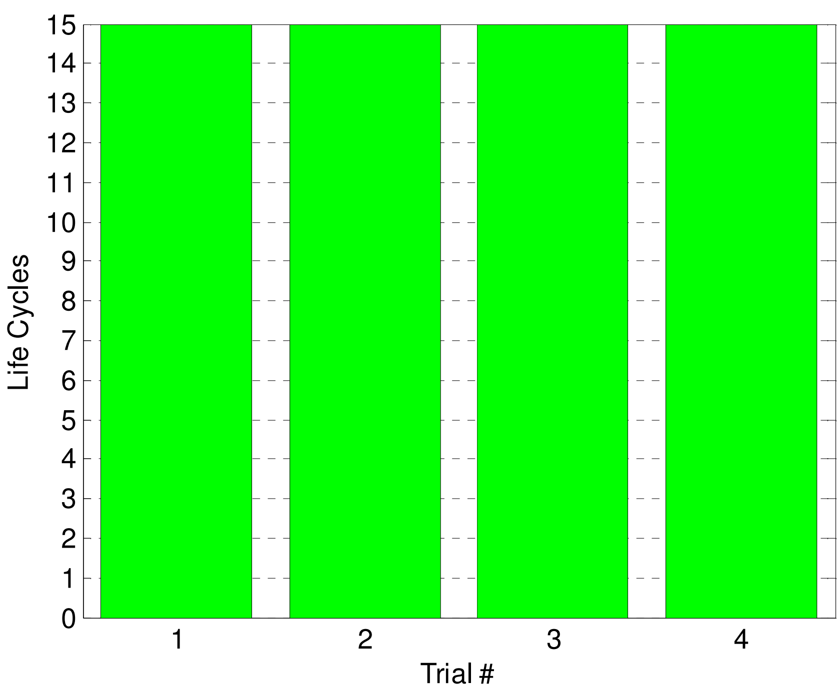

Figure D-39: NAS1291-4 Life; 66% Y Preload

Appendix D (Continued)

D.2.3 75% Y Preload

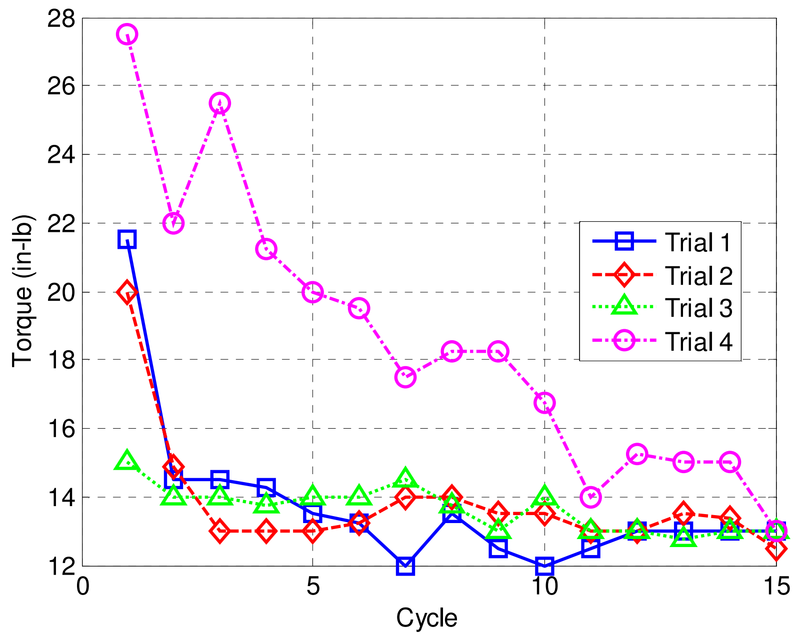

Figure D-40: NAS1291-4 Assembly Prevailing Torque; 75% Y Preload

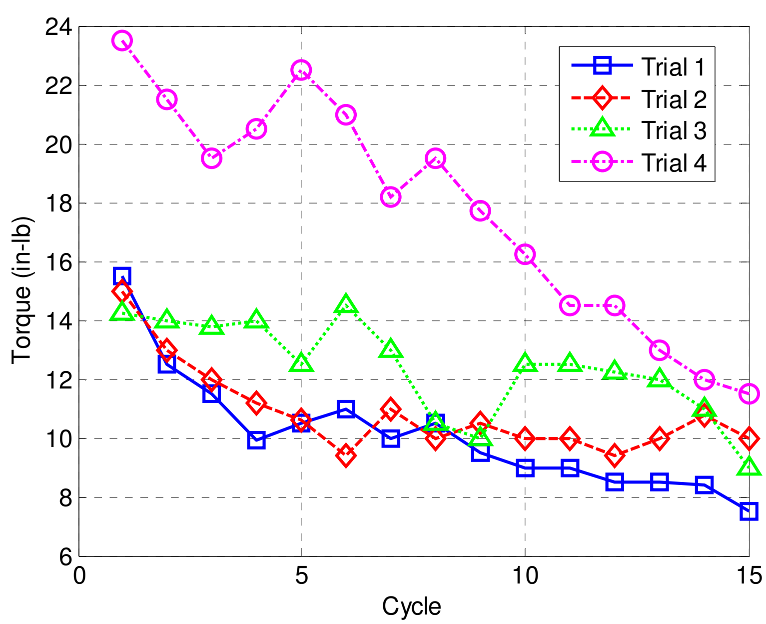

Figure D-41: NAS1291-4 Removal Prevailing Torque; 75% Y Preload

Appendix D (Continued)

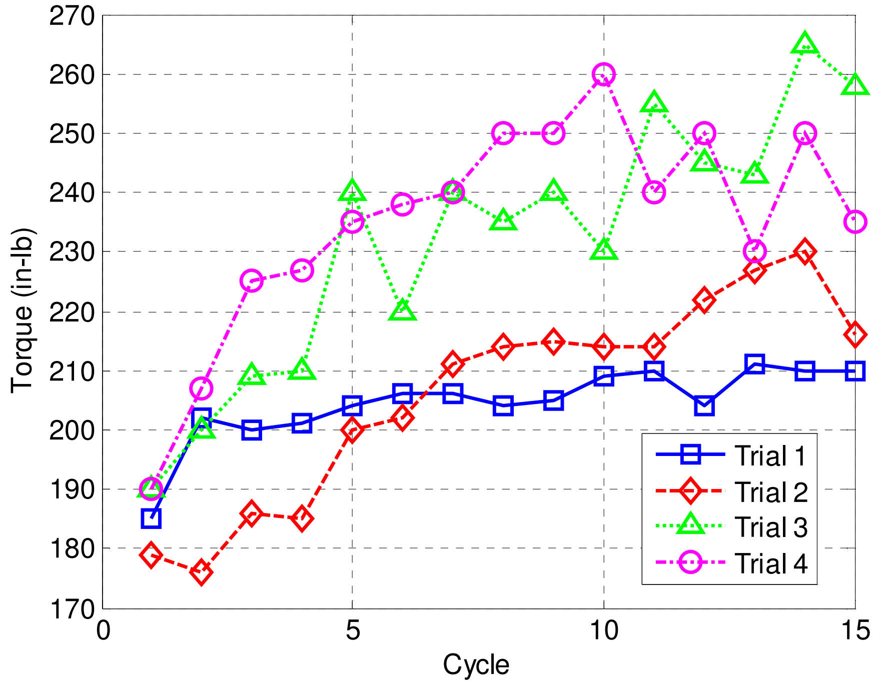

Figure D-42: NAS1291-4 Tightening Torque; 75% Y Preload

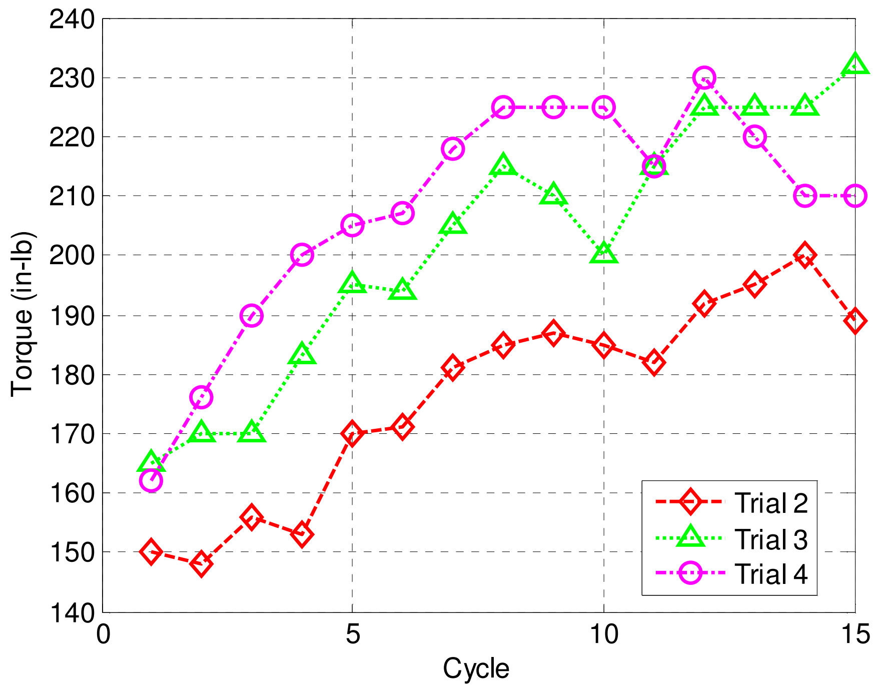

Figure D-43: NAS1291-4 Breakloose Torque; 75% Y Preload

Appendix D (Continued)

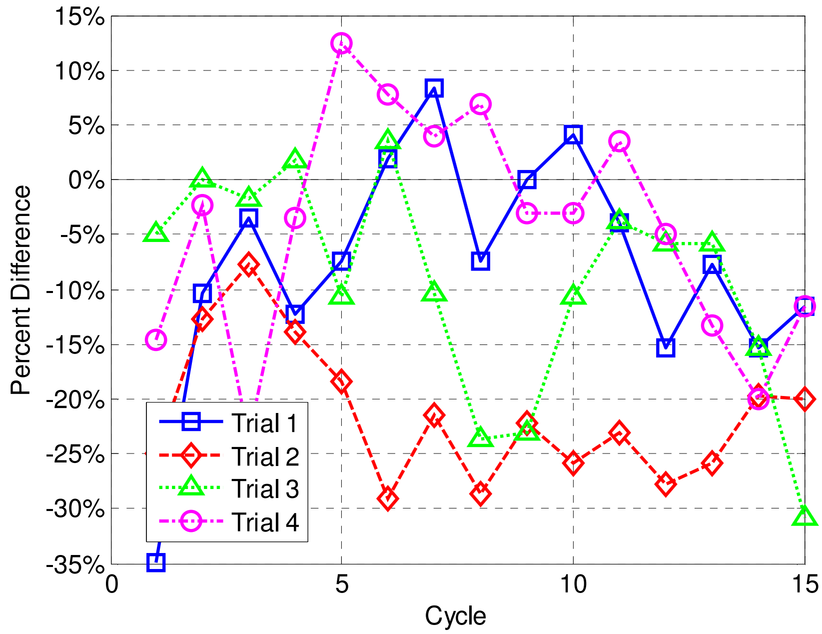

Figure D-44: NAS1291-4 Percent Difference; 75% Y Preload

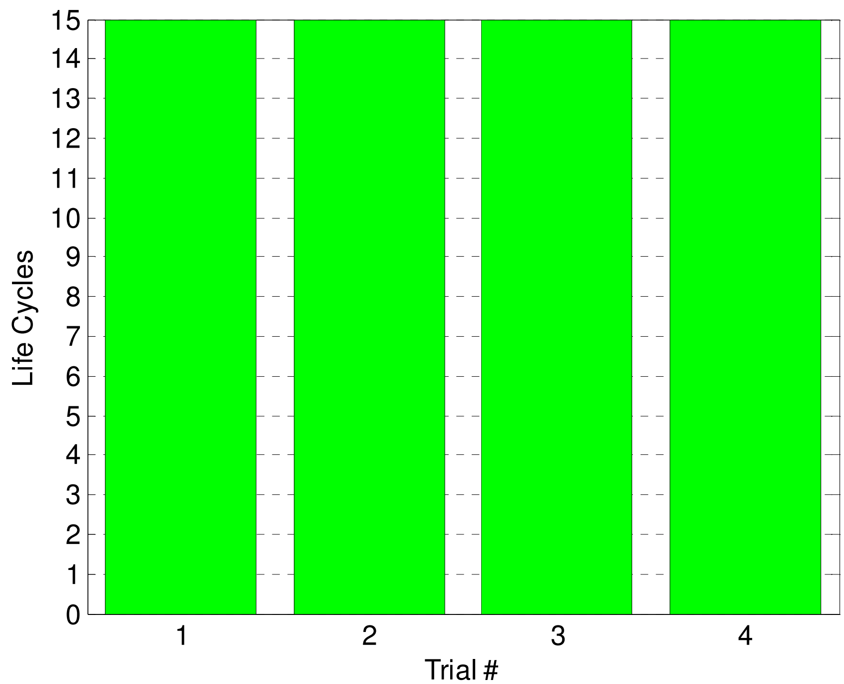

Figure D-45: NAS1291-4 Life; 75% Y Preload

Appendix D (Continued)

D.2.4 85% Y Preload

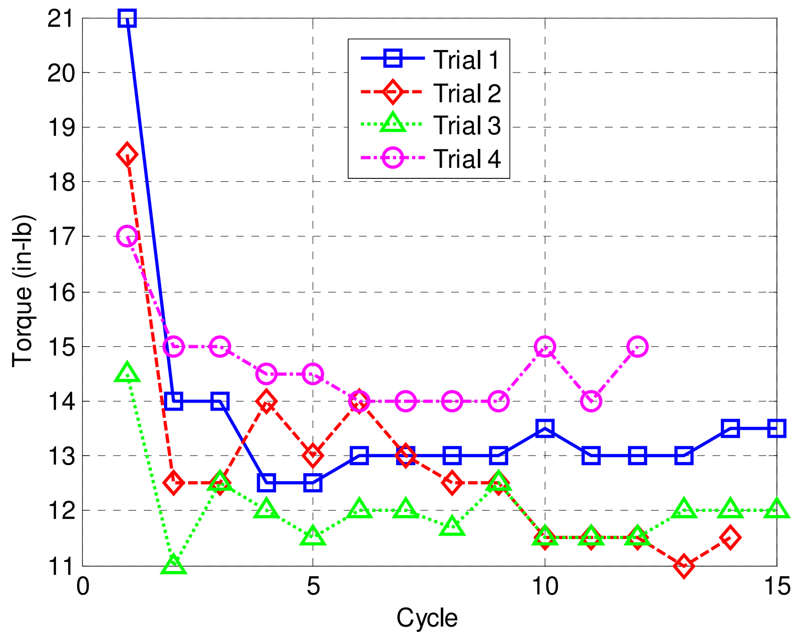

Figure D-46: NAS1291-4 Assembly Prevailing Torque; 85% Y Preload

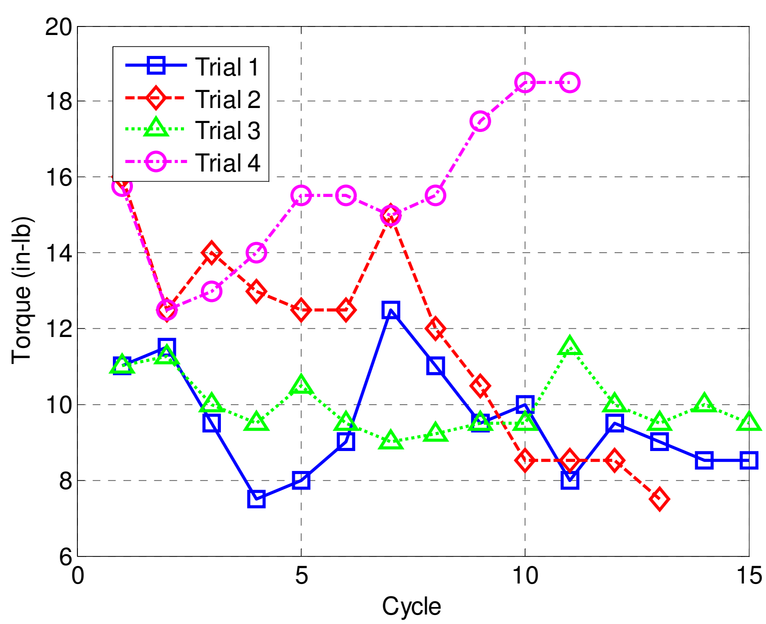

Figure D-47: NAS1291-4 Removal Prevailing Torque; 85% Y Preload

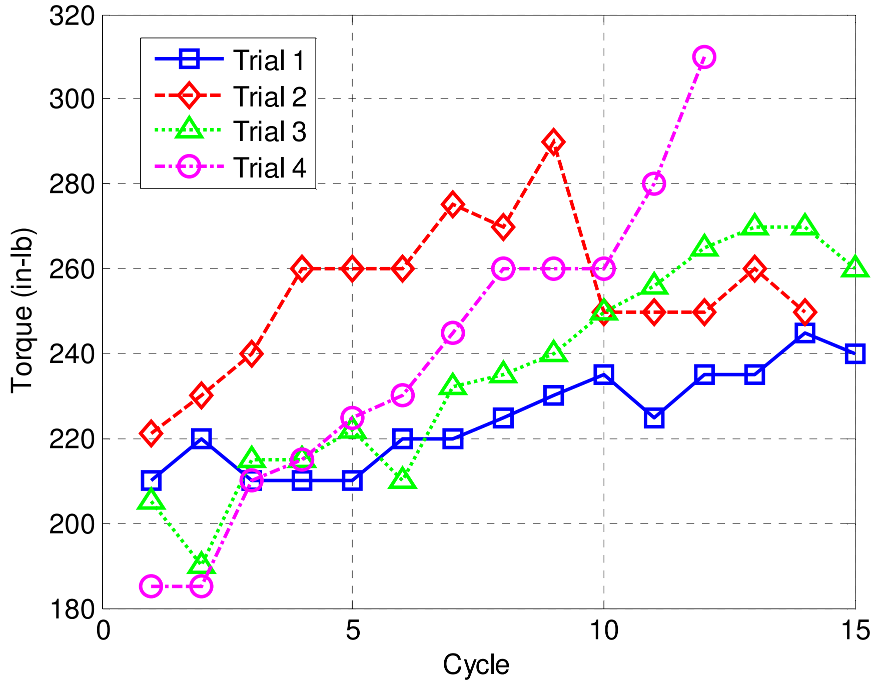

Figure D-48: NAS1291-4 Tightening Torque; 85% Y Preload

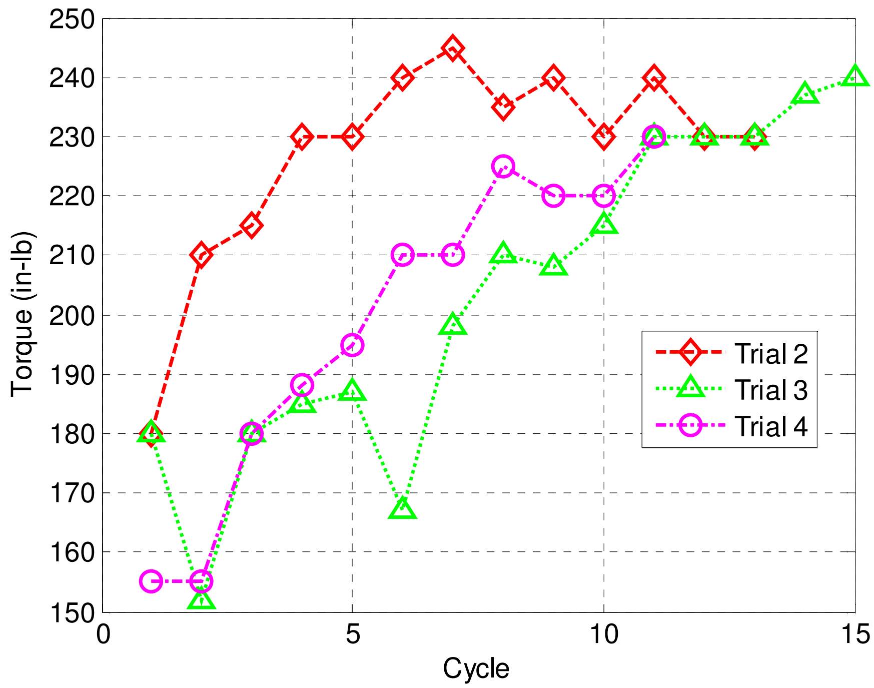

Figure D-49: NAS1291-4 Breakloose Torque; 85% Y Preload

Appendix D (Continued)

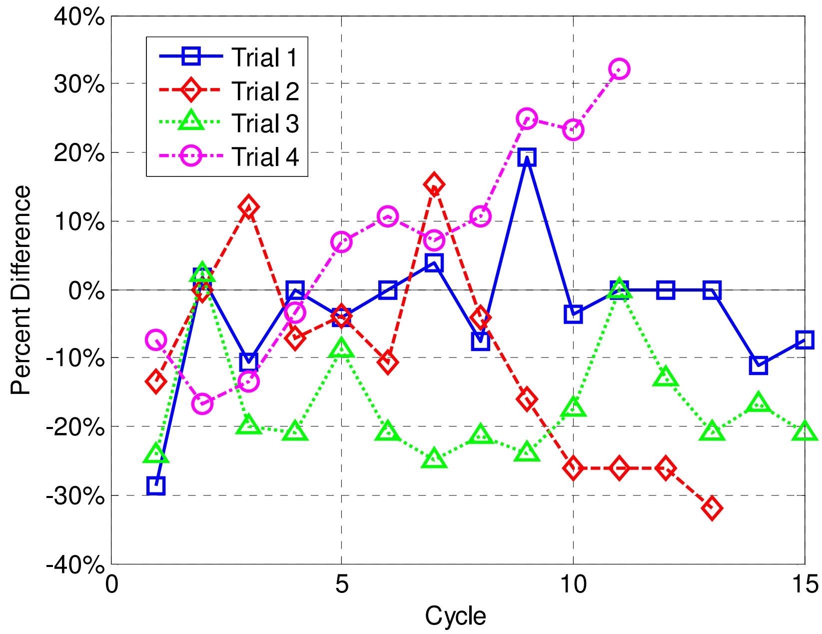

Figure D-50: NAS1291-4 Percent Difference; 85% Y Preload

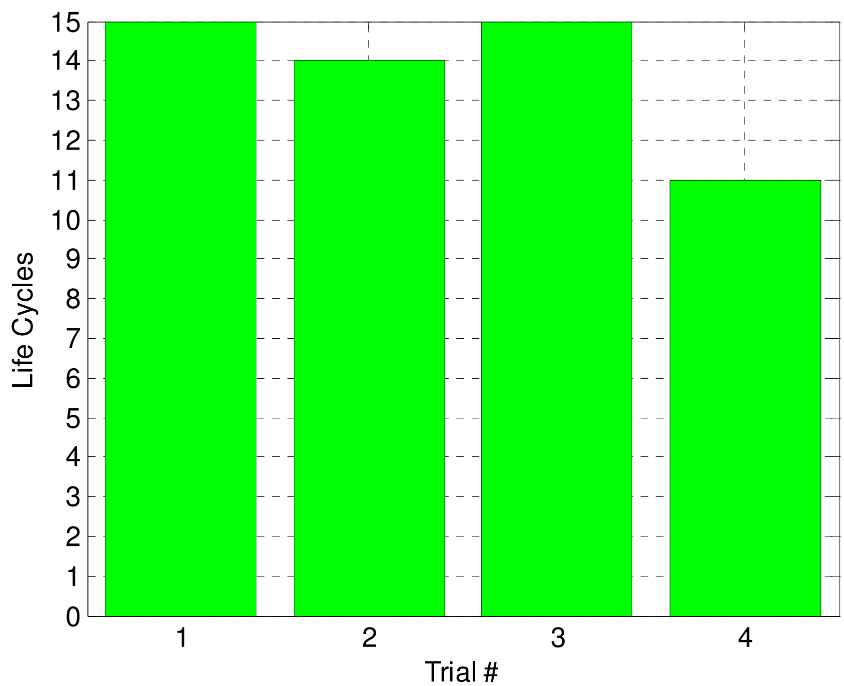

Figure D-51: NAS1291-4 Life; 85% Y Preload

Appendix D (Continued)

D.2.5 Preload Averages

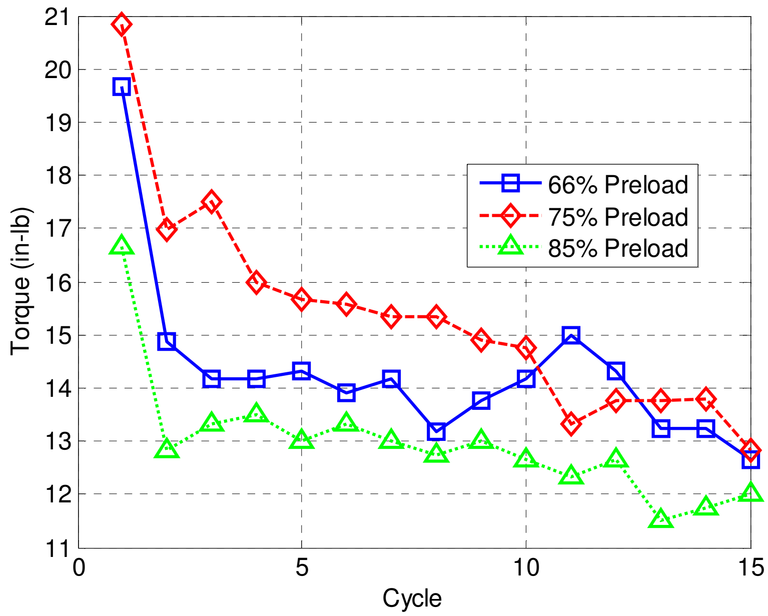

Figure D-52: NAS1291-4 Assembly Prevailing Torque; Preload Average

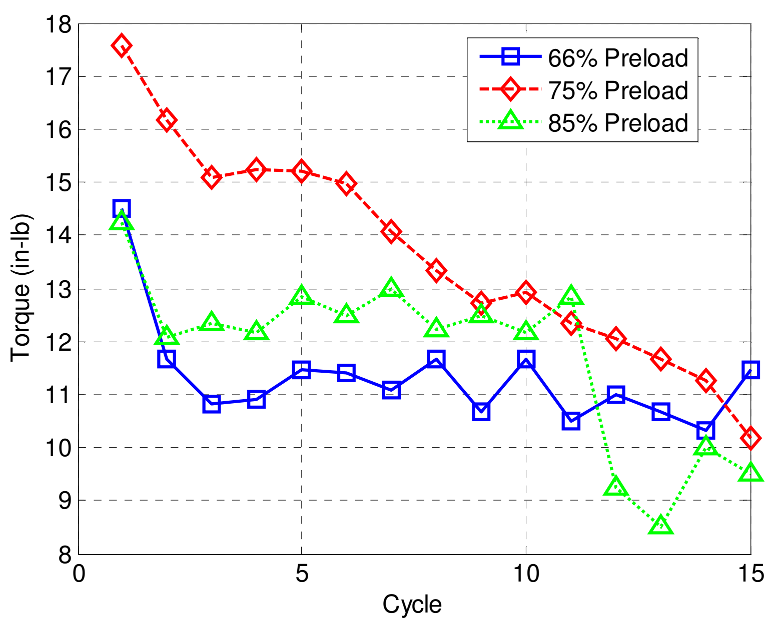

Figure D-53: NAS1291-4 Removal Prevailing Torque; Preload Average

Appendix D (Continued)

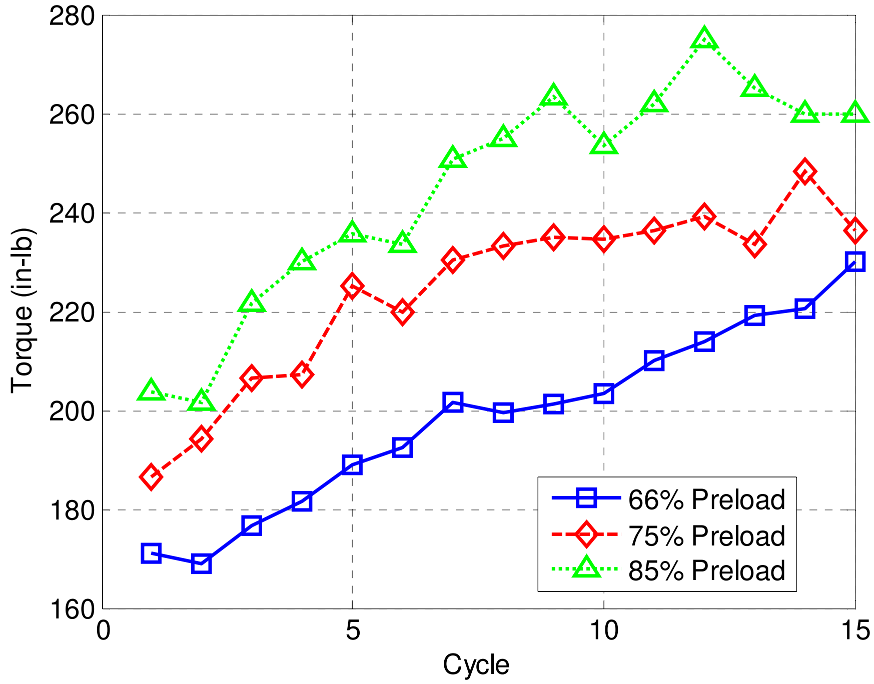

Figure D-54: NAS1291-4 Tightening Torque; Preload Average

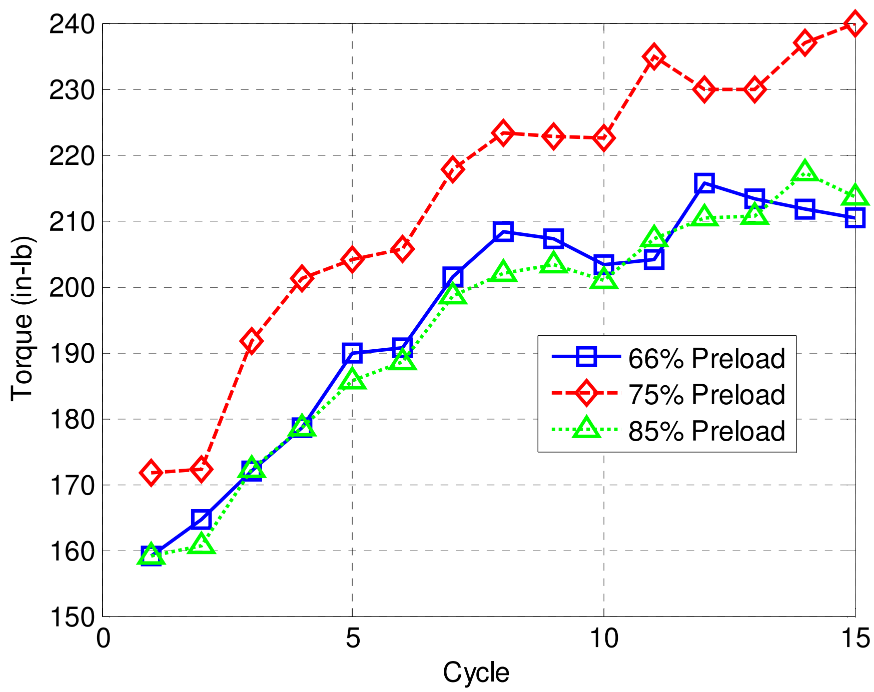

Figure D-55: NAS1291-4 Breakloose Torque; Preload Average

Appendix D (Continued)

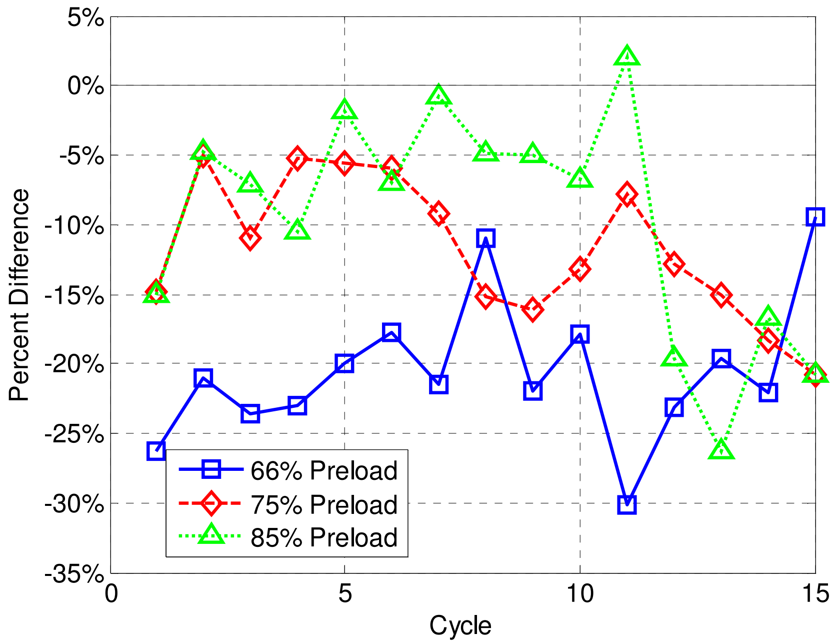

Figure D-56: NAS1291-4 Percent Difference; Preload Average

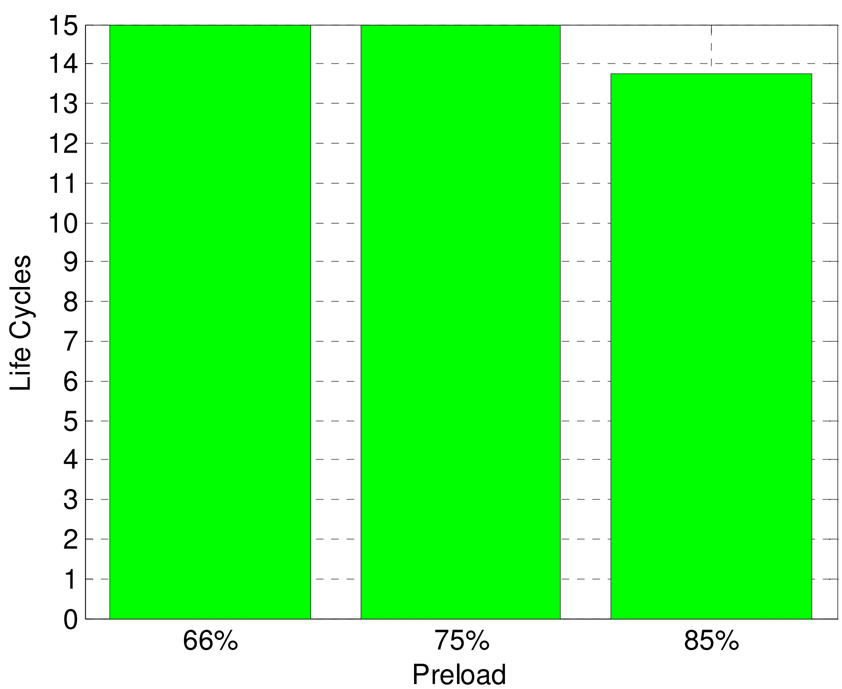

Figure D-57: NAS1291-4 Life; Preload Average

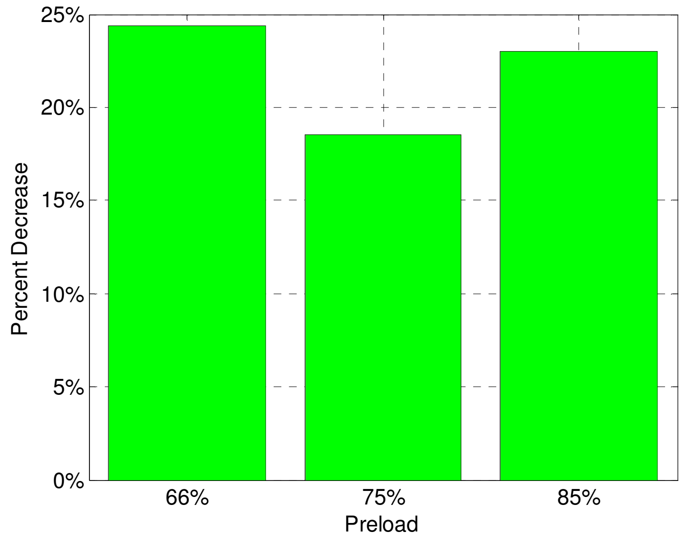

Figure D-58: NAS1291-4 Percent Decrease of Assembly Prevailing Torque from Cycle 1 to 2; Preload Average

D.3 NAS1805-4

D.3.1 Unseated

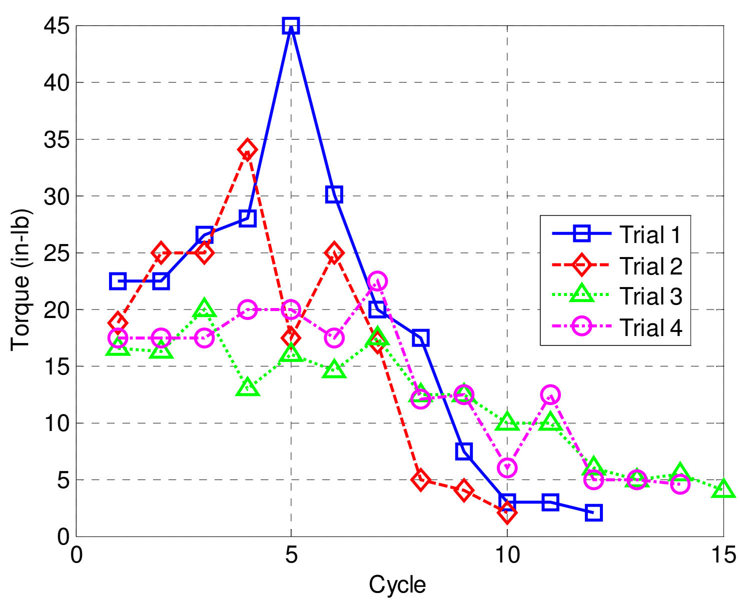

Figure D-59: NAS1805-4 Assembly Prevailing Torque; Unseated

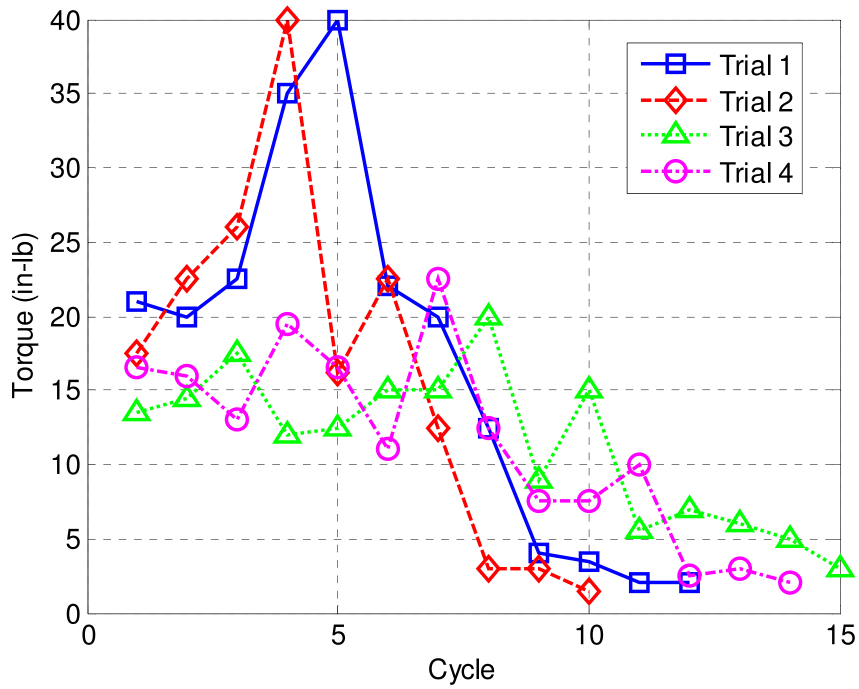

Figure D-60: NAS1805-4 Removal Prevailing Torque; Unseated

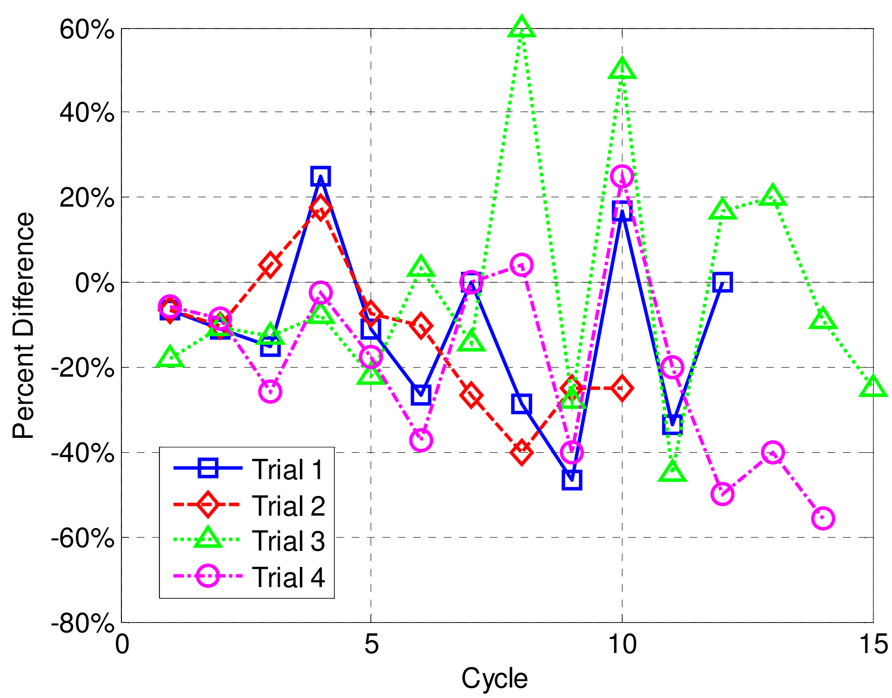

Figure D-61: NAS1805-4 Percent Difference; Unseated

Appendix D (Continued)

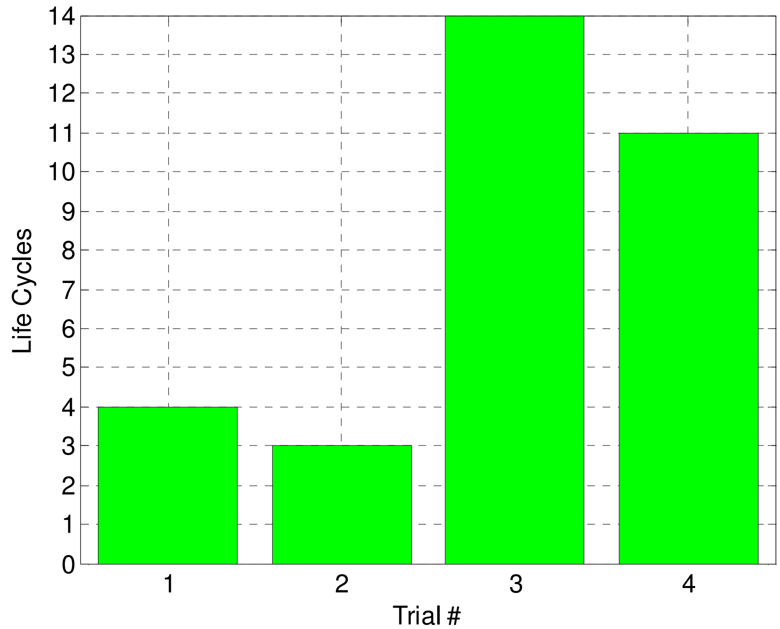

Figure D-62: NAS1805-4 Life; Unseated

D.3.2 66% Y Preload

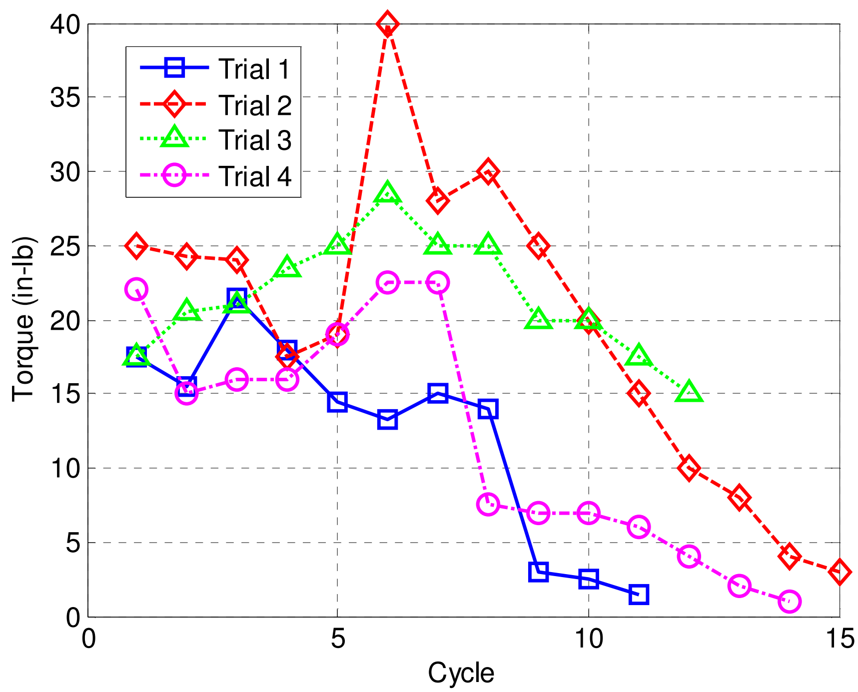

Figure D-63: NAS1805-4 Assembly Prevailing Torque; 66% Y Preload

Appendix D (Continued)

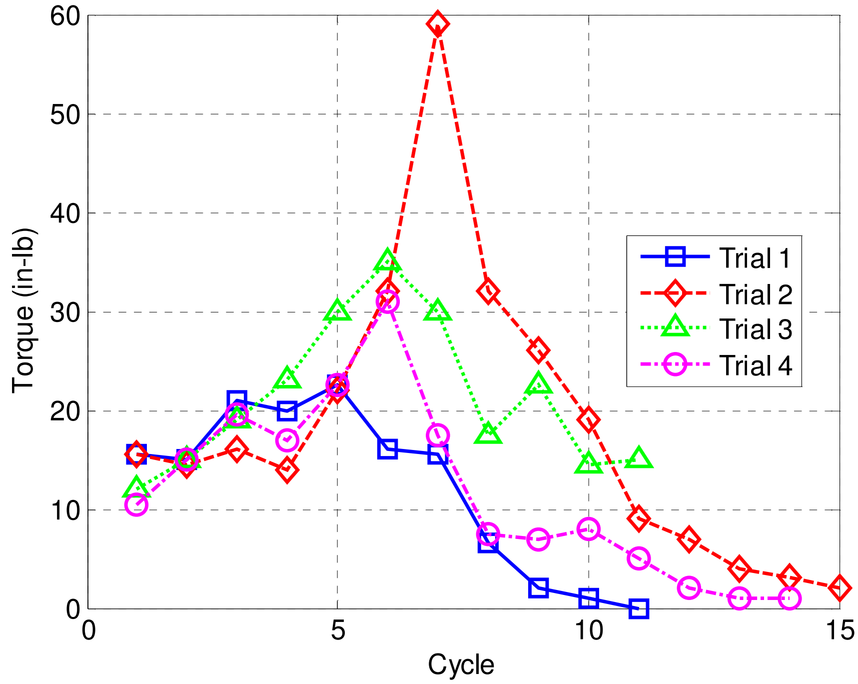

Figure D-64: NAS1805-4 Removal Prevailing Torque; 66% Y Preload

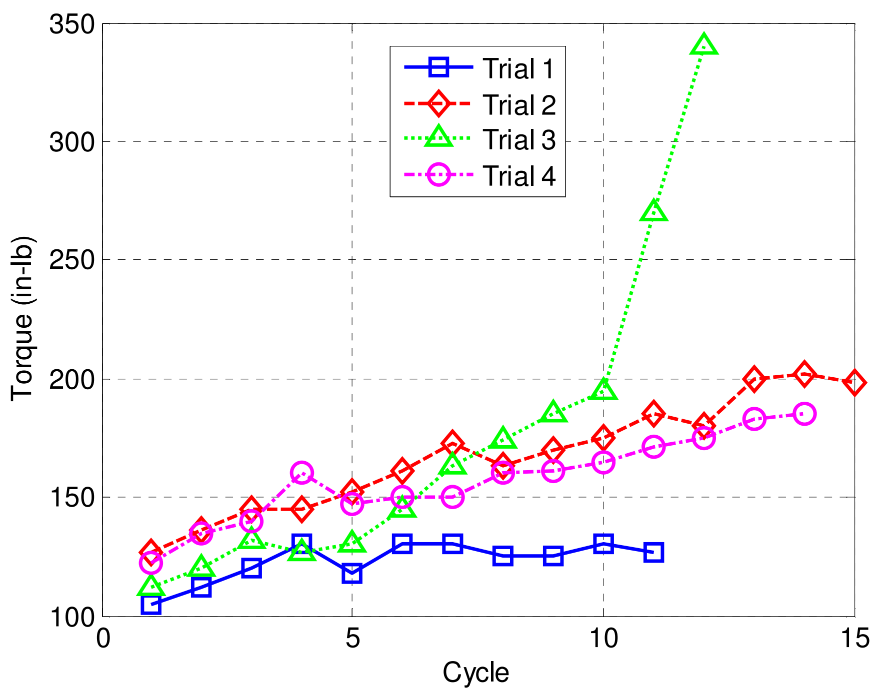

Figure D-65: NAS1805-4 Tightening Torque; 66% Y Preload

Appendix D (Continued)

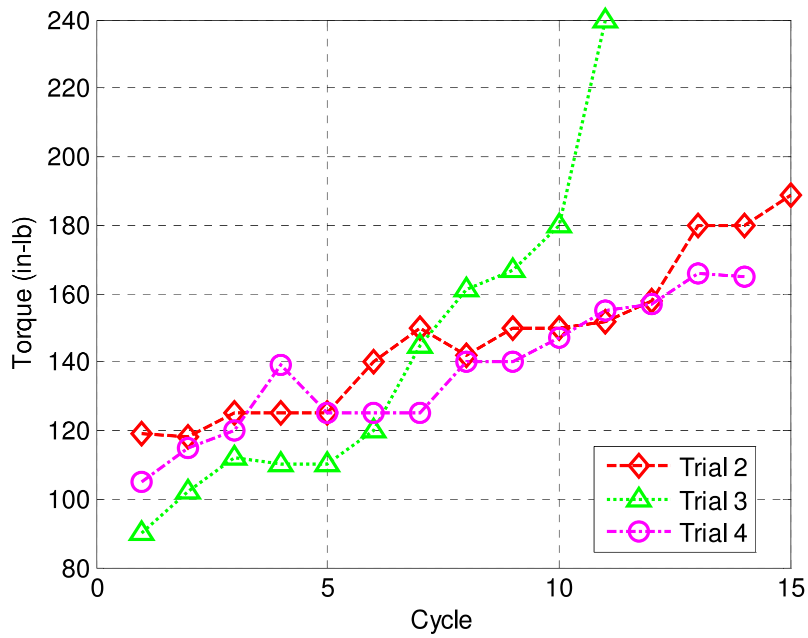

Figure D-66: NAS1805-4 Breakloose Torque; 66% Y Preload

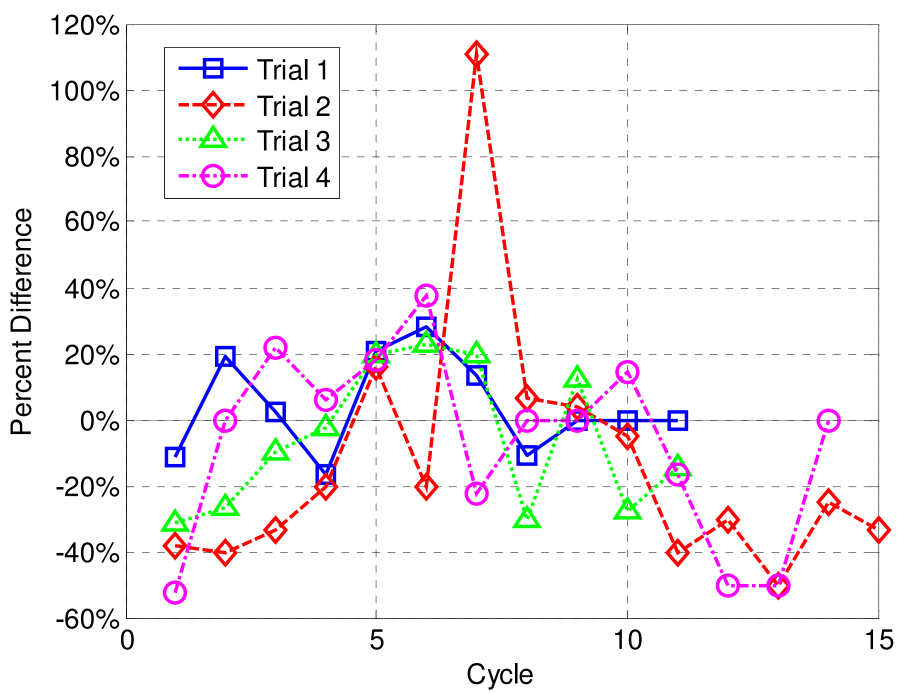

Figure D-67: NAS1805-4 Percent Difference; 66% Y Preload

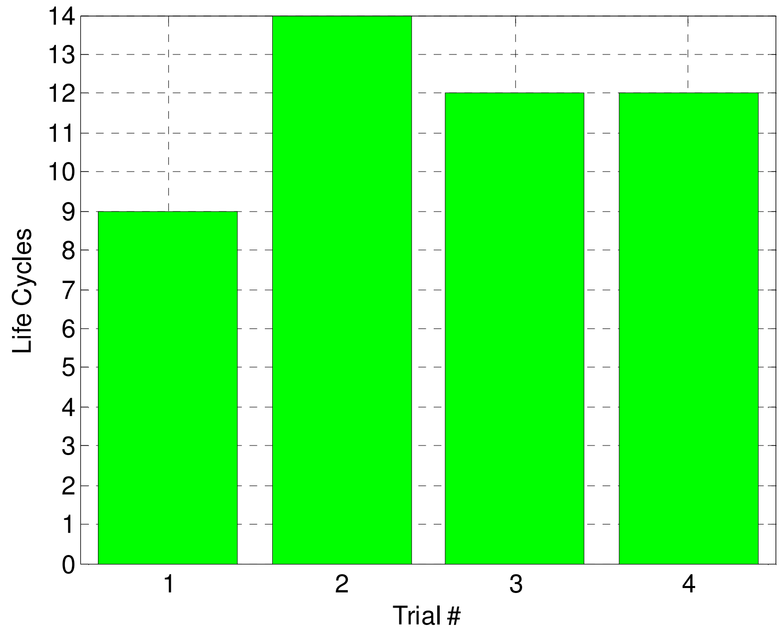

Figure D-68: NAS1805-4 Life; 66% Y Preload

D.3.3 75% Y Preload

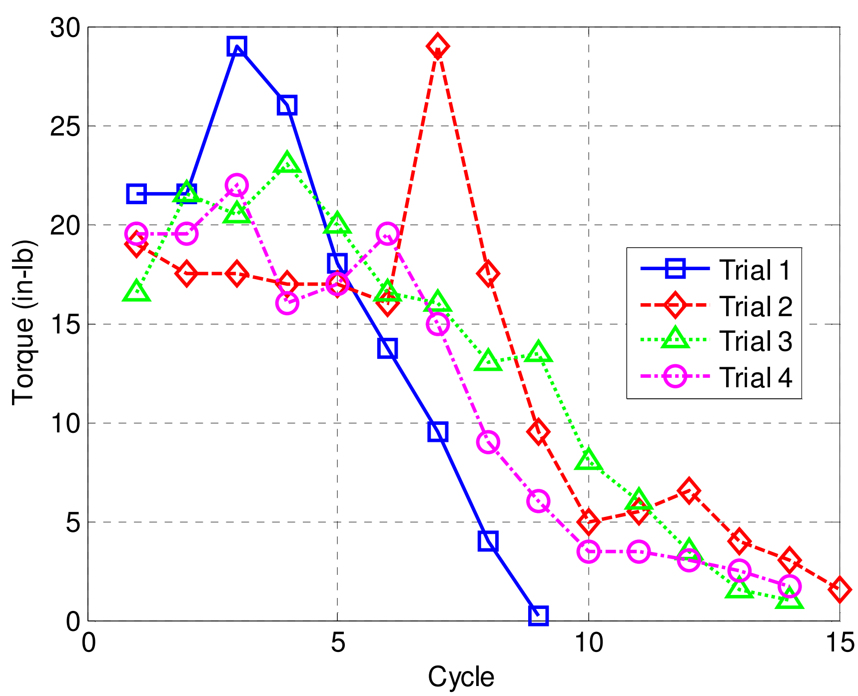

Figure D-69: NAS1805-4 Assembly Prevailing Torque; 75% Y Preload

Appendix D (Continued)

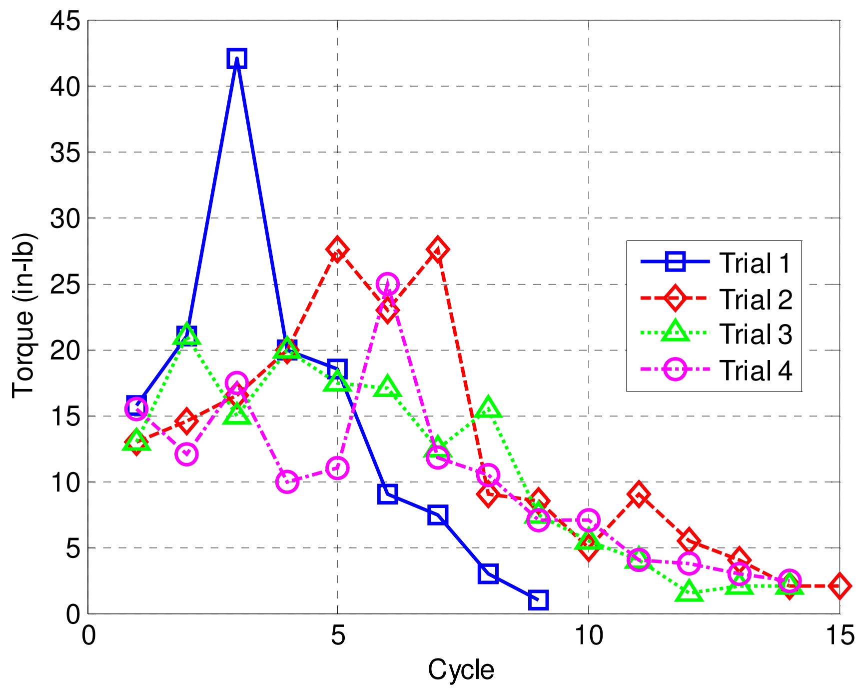

Figure D-70: NAS1805-4 Removal Prevailing Torque; 75% Y Preload

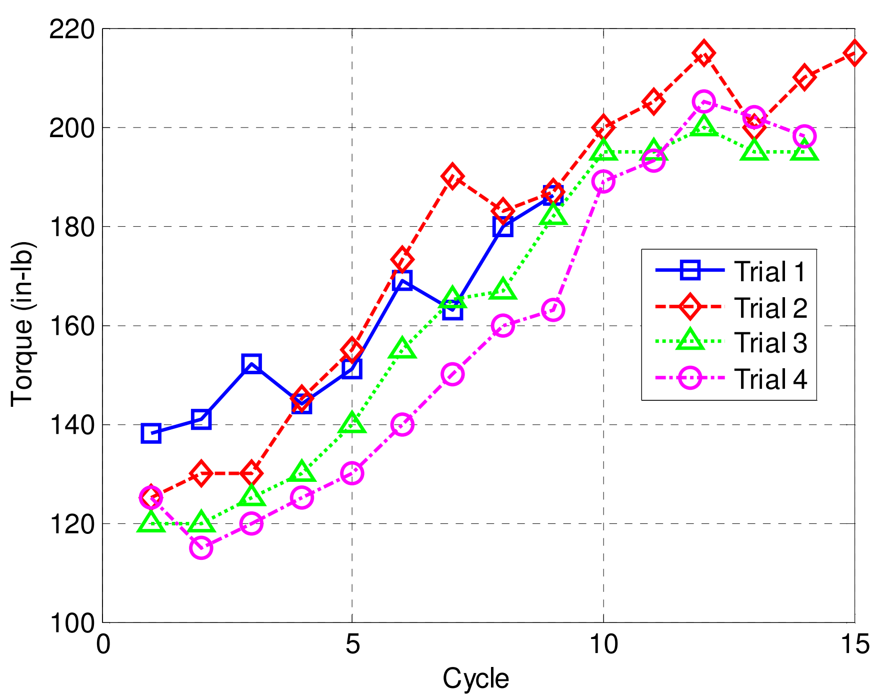

Figure D-71: NAS1805-4 Tightening Torque; 75% Y Preload

Appendix D (Continued)

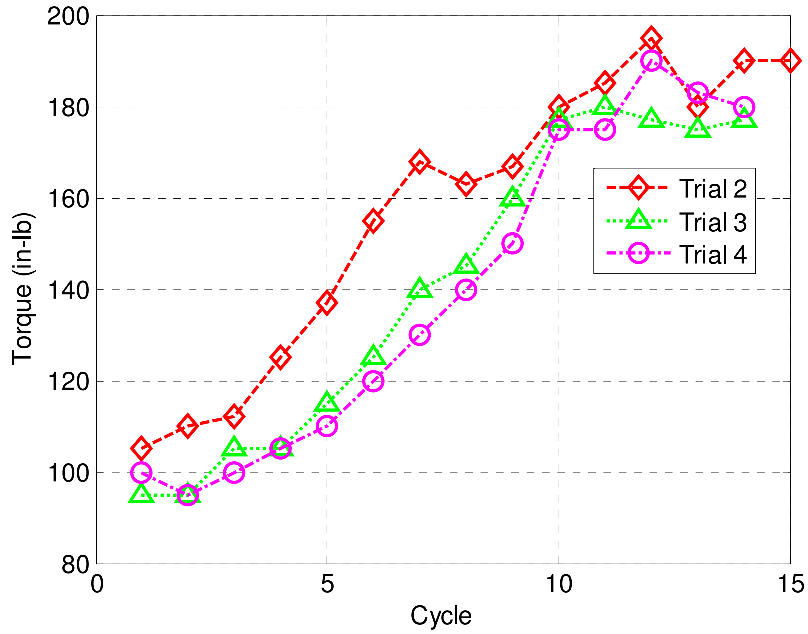

Figure D-72: NAS1805-4 Breakloose Torque; 75% Y Preload

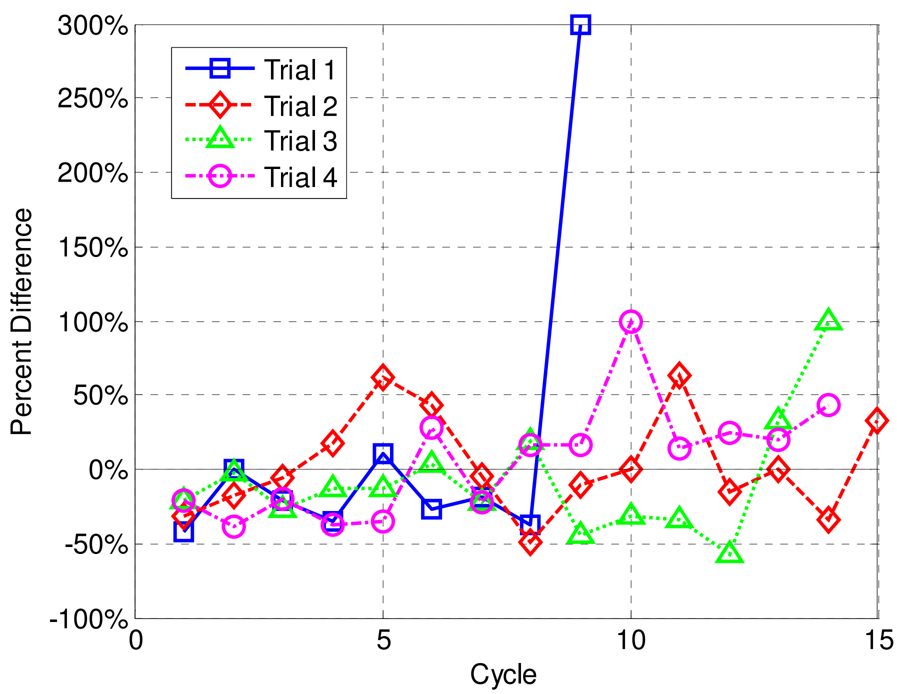

Figure D-73: NAS1805-4 Percent Difference; 75% Y Preload

Appendix D (Continued)

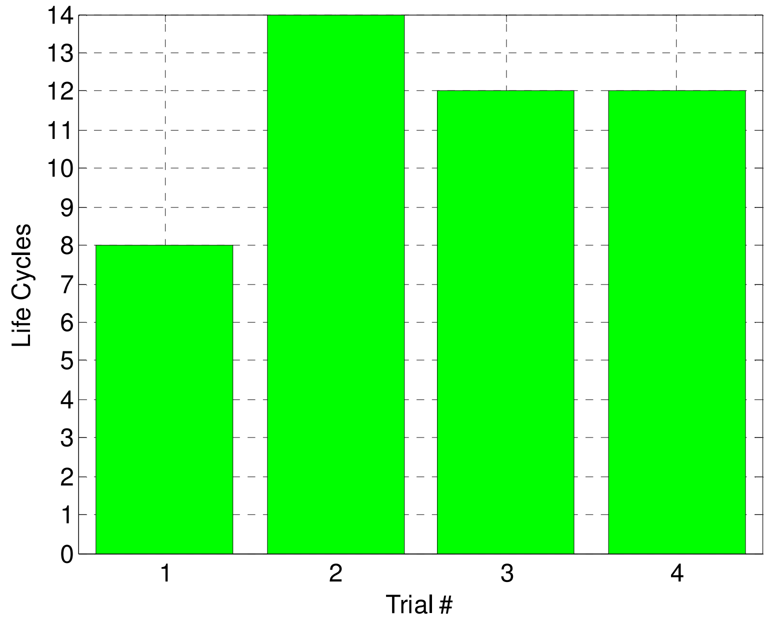

Figure D-74: NAS1805-4 Life; 75% Y Preload

D.3.4 85% Y Preload

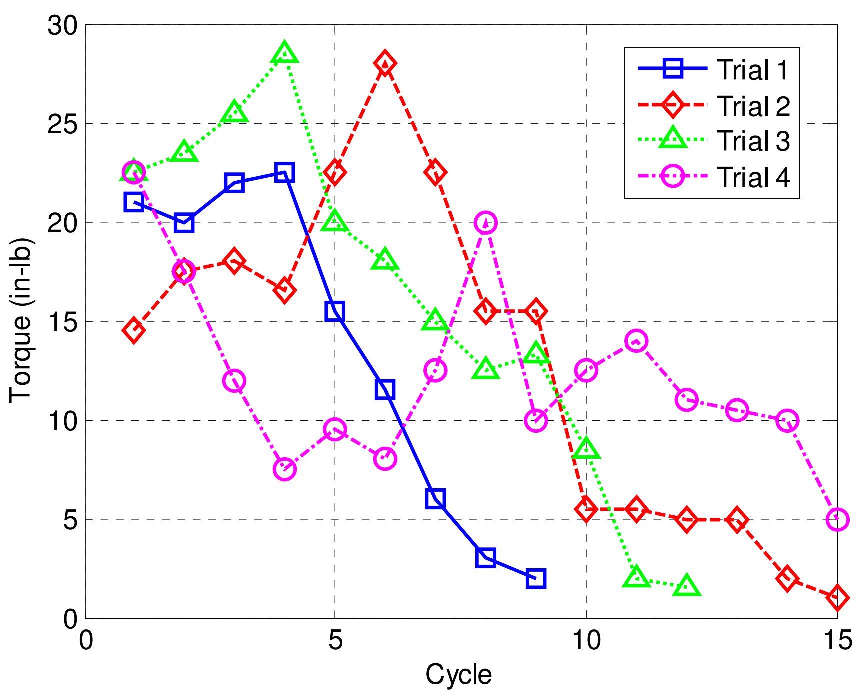

Figure D-75: NAS1805-4 Assembly Prevailing Torque; 85% Y Preload

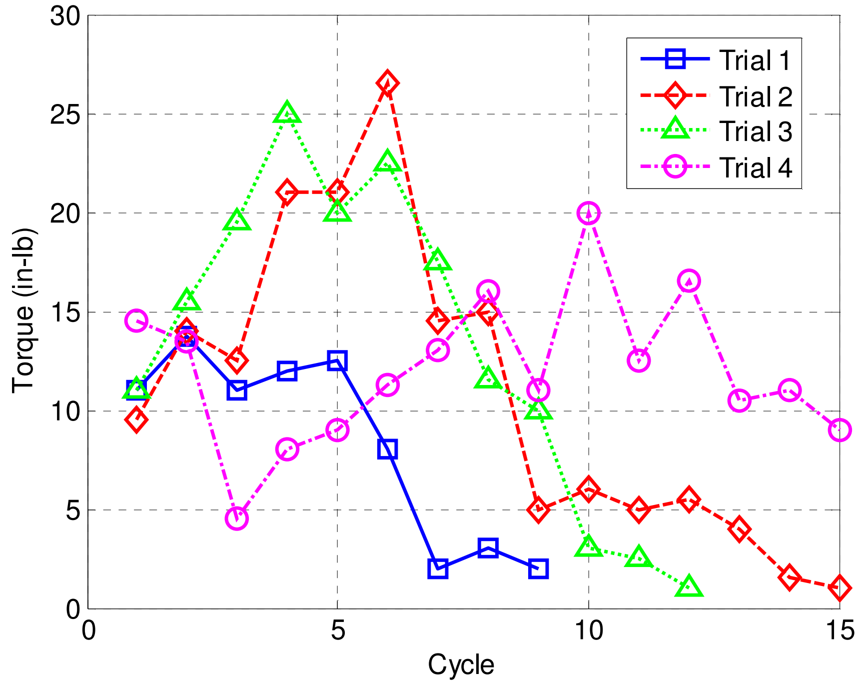

Figure D-76: NAS1805-4 Removal Prevailing Torque; 85% Y Preload

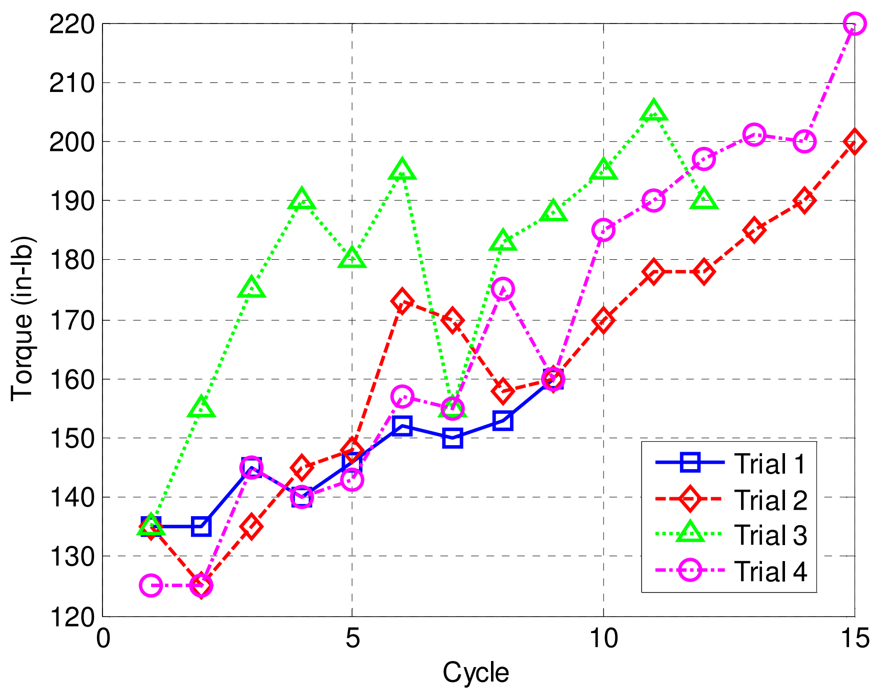

Figure D-77: NAS1805-4 Tightening Torque; 85% Y Preload

Appendix D (Continued)

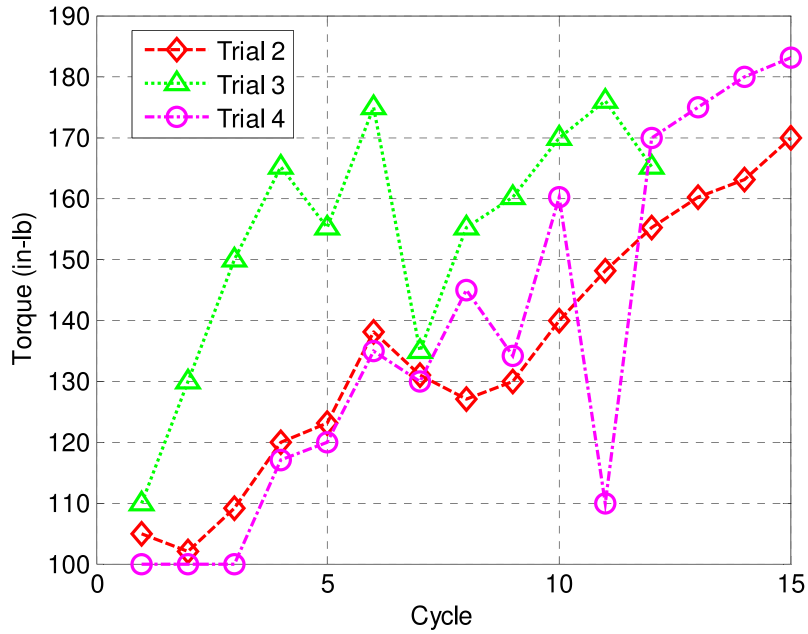

Figure D-78: NAS1805-4 Breakloose Torque; 85% Y Preload

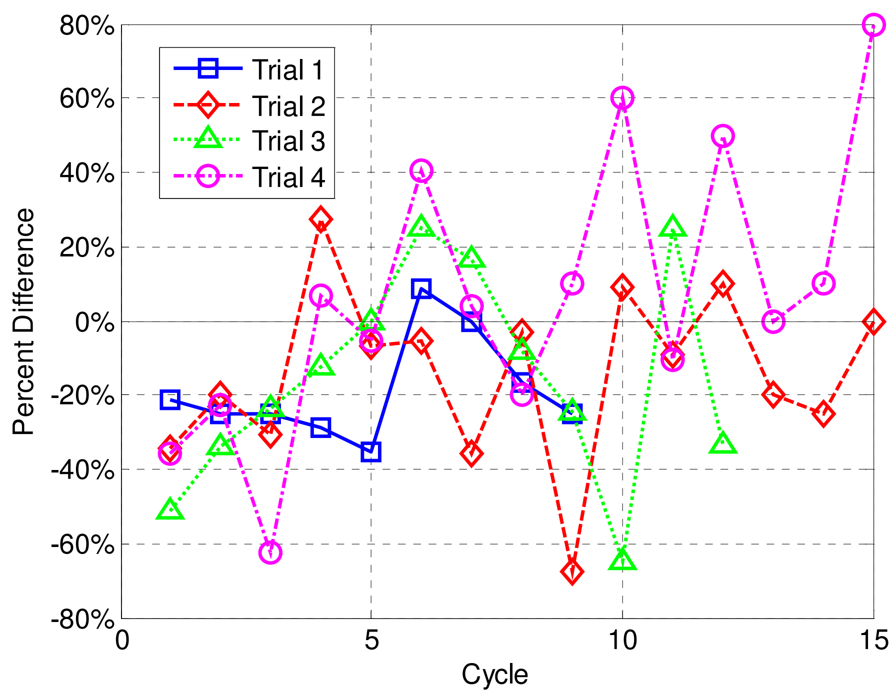

Figure D-79: NAS1805-4 Percent Difference; 85% Y Preload

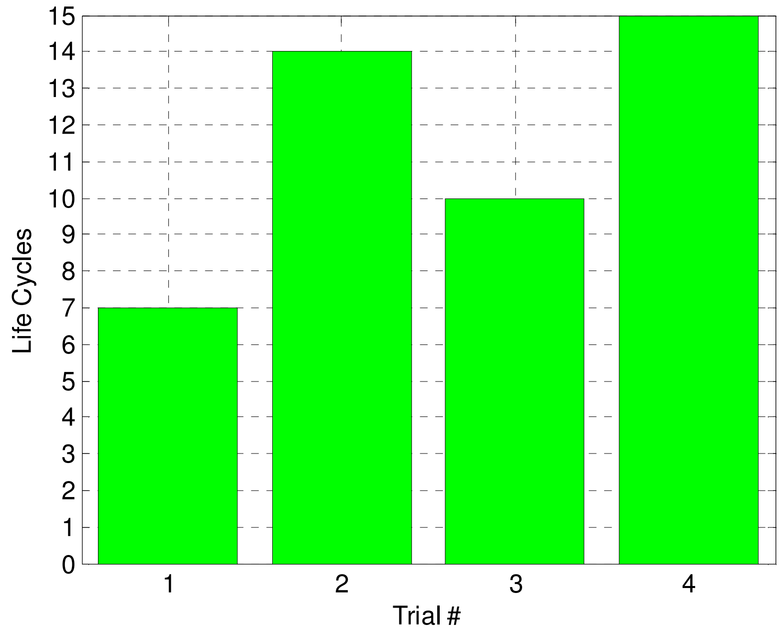

Figure D-80: NAS1805-4 Life; 85% Y Preload

D.3.5 Preload Averages

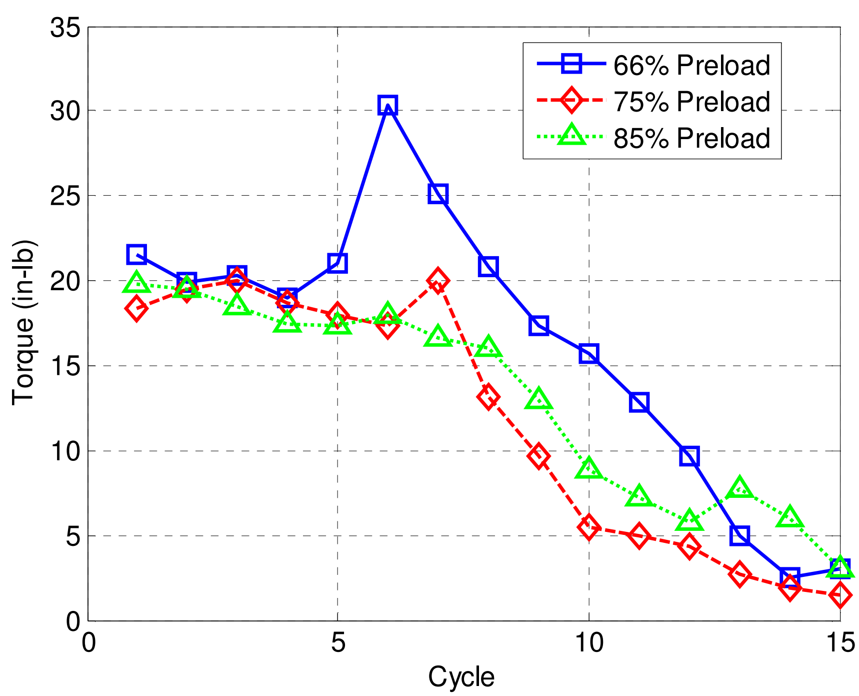

Figure D-81: NAS1805-4 Assembly Prevailing Torque; Preload Average

Appendix D (Continued)

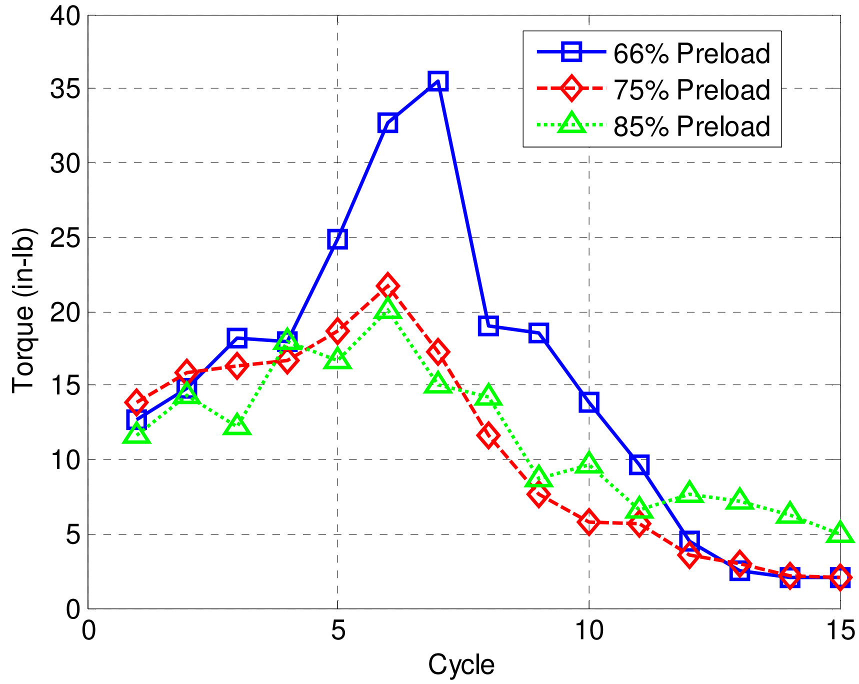

Figure D-82: NAS1805-4 Removal Prevailing Torque; Preload Average

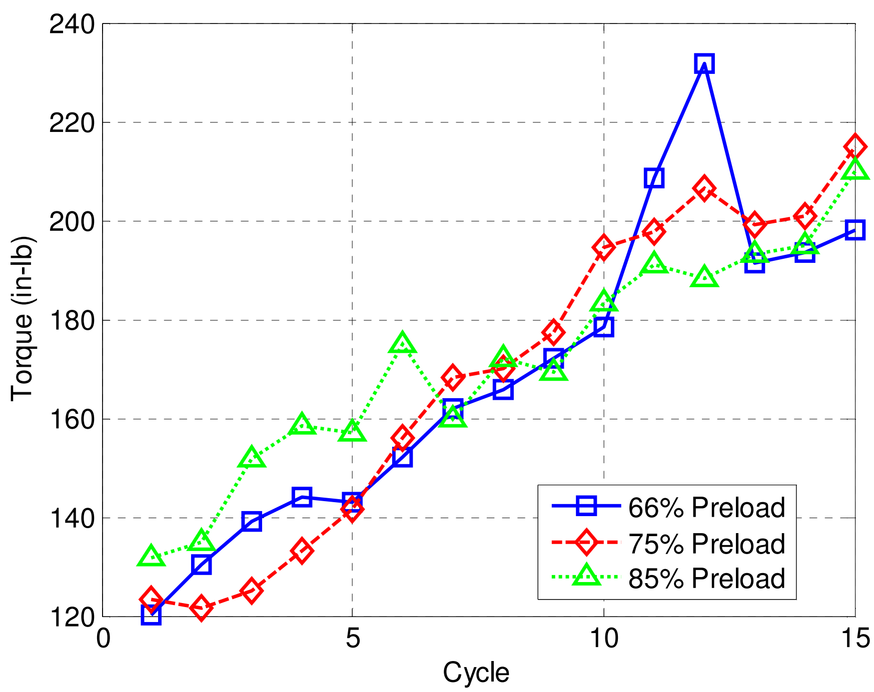

Figure D-83: NAS1805-4 Tightening Torque; Preload Average

Appendix D (Continued)

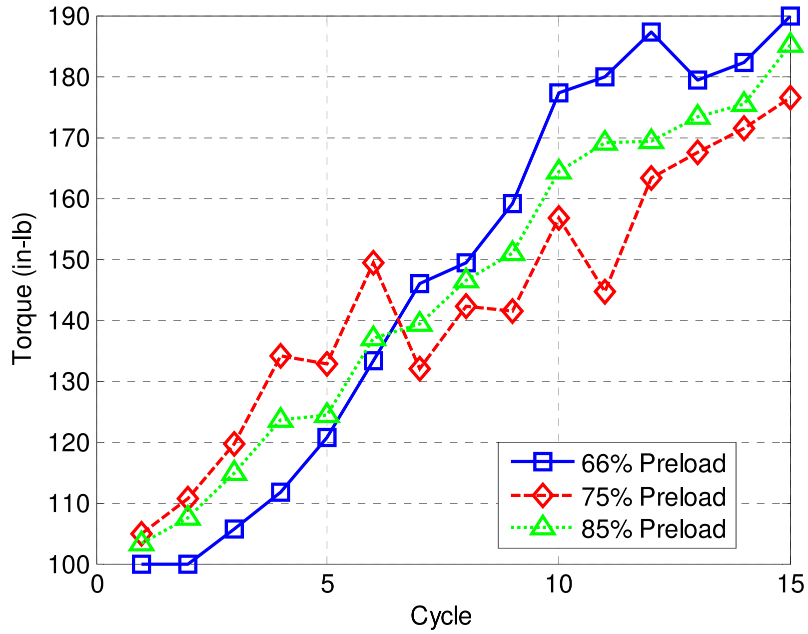

Figure D-84: NAS1805-4 Breakloose Torque; Preload Average

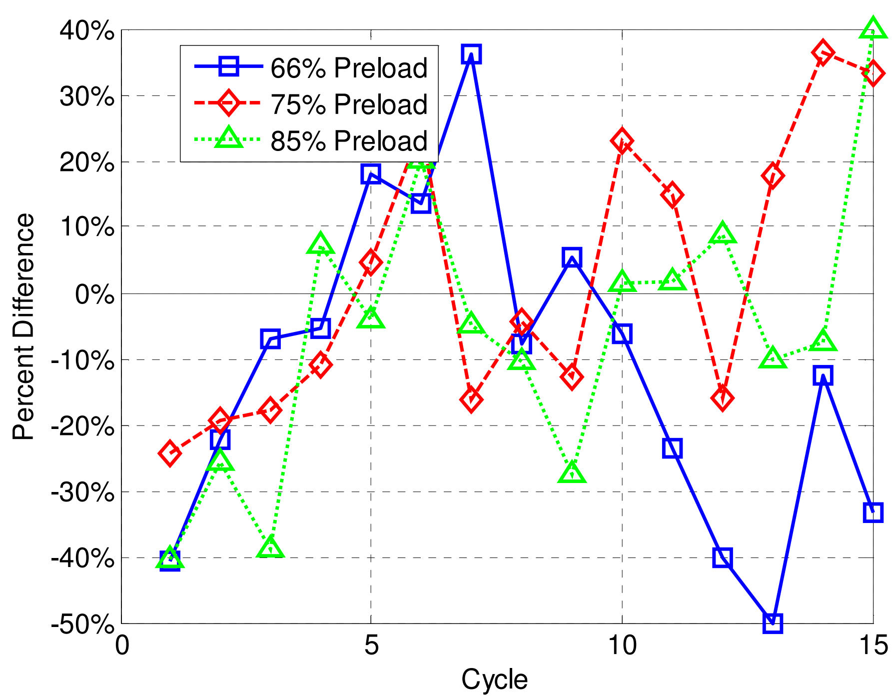

Figure D-85: NAS1805-4 Percent Difference; Preload Average

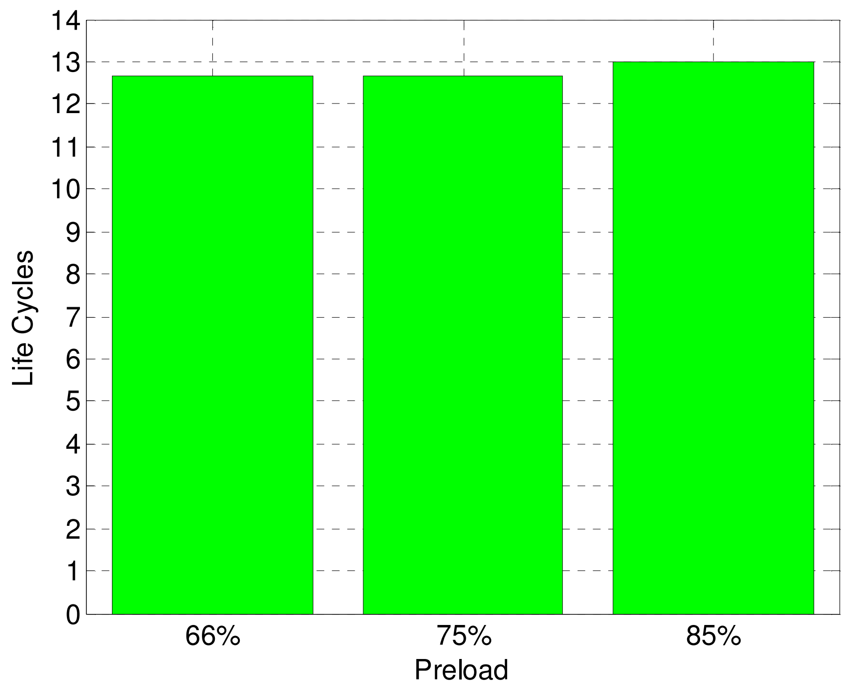

Figure D-86: NAS1805-4 Life; Preload Average

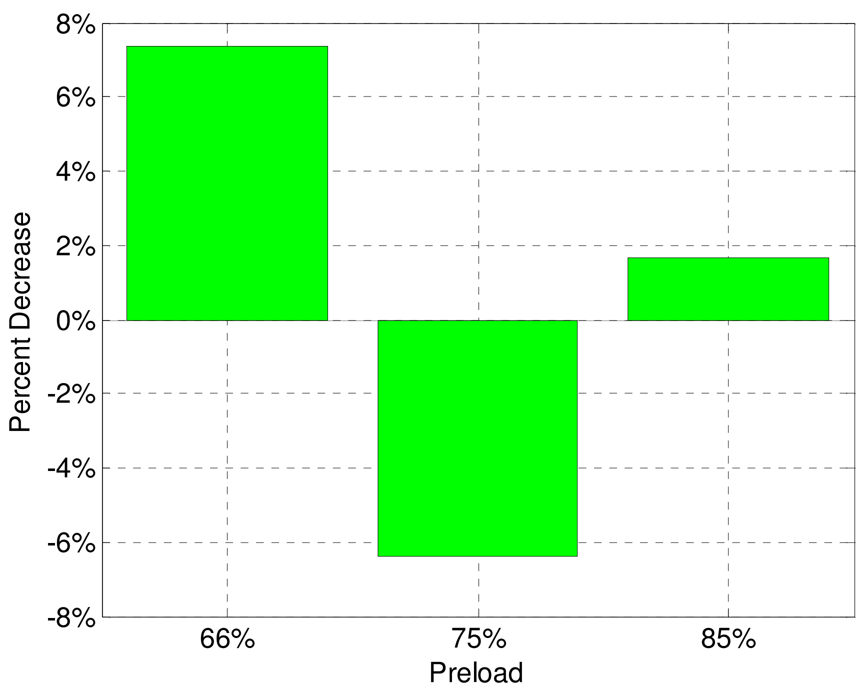

Figure D-87: NAS1805-4 Percent Decrease of Assembly Prevailing Torque from Cycle 1 to 2; Preload Average

Appendix D (Continued)

D.4 MS17825-4

D.4.1 Unseated

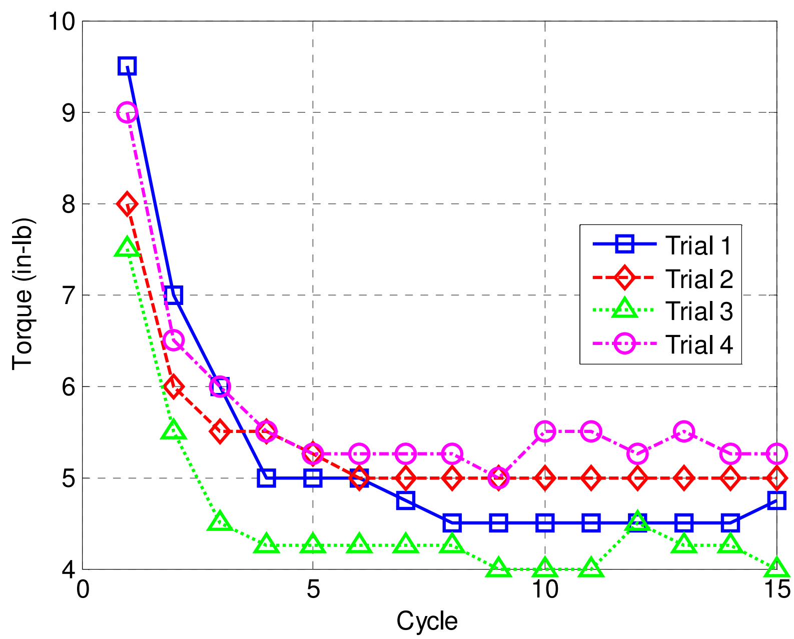

Figure D-88: MS17825-4 Assembly Prevailing Torque; Unseated

Appendix D (Continued)

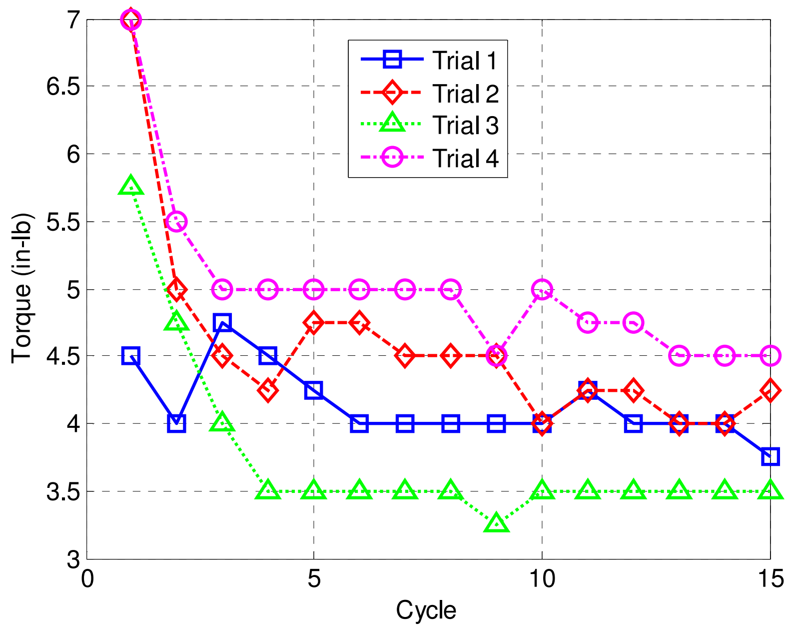

Figure D-89: MS17825-4 Removal Prevailing Torque; Unseated

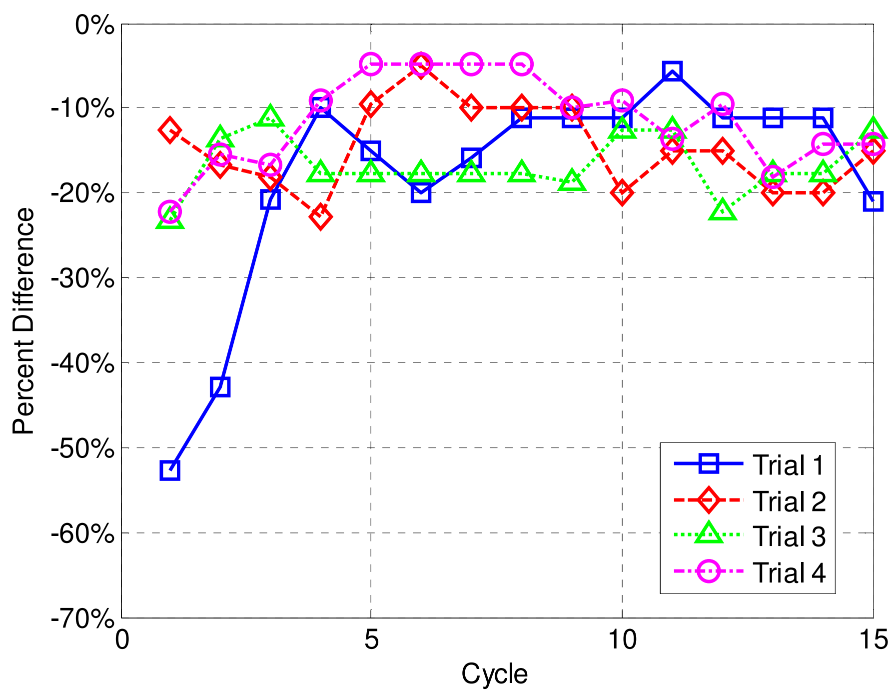

Figure D-90: MS17825-4 Percent Difference; Unseated

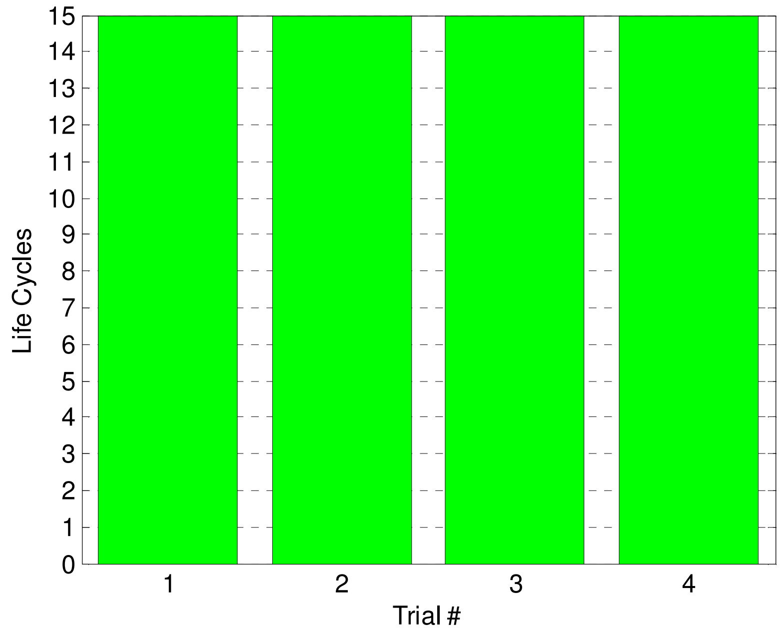

Figure D-91: MS17825-4 Life; Unseated

D.4.2 66% Y Preload

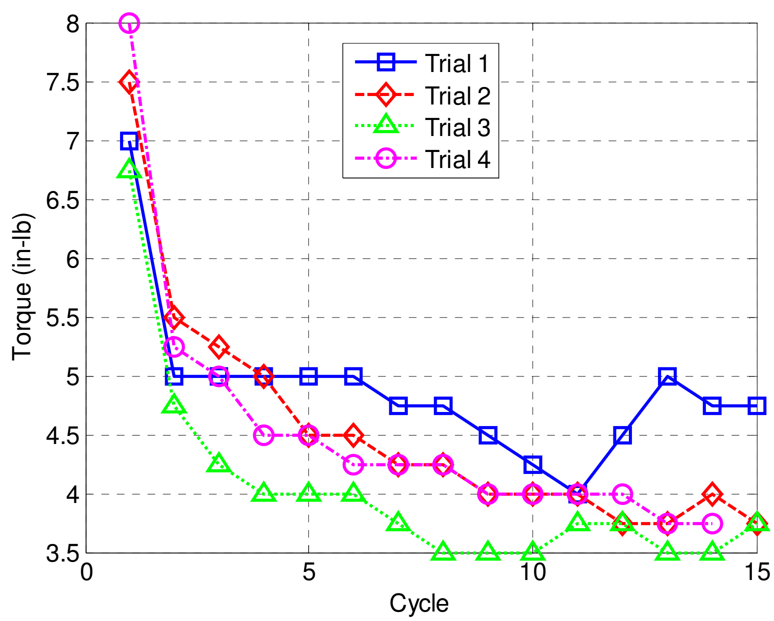

Figure D-92: MS17825-4 Assembly Prevailing Torque; 66% Y Preload

Appendix D (Continued)

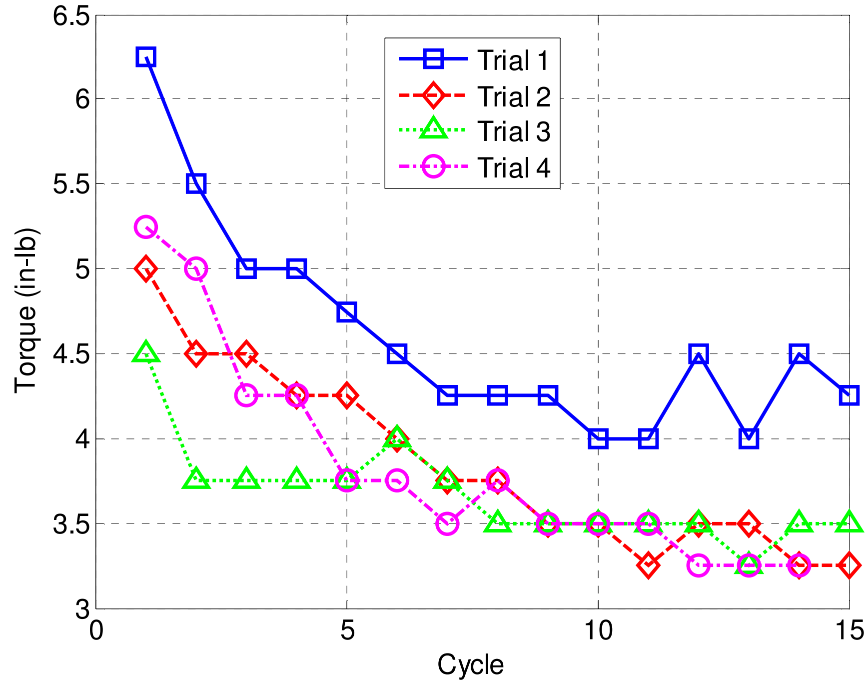

Figure D-93: MS17825-4 Removal Prevailing Torque; 66% Y Preload

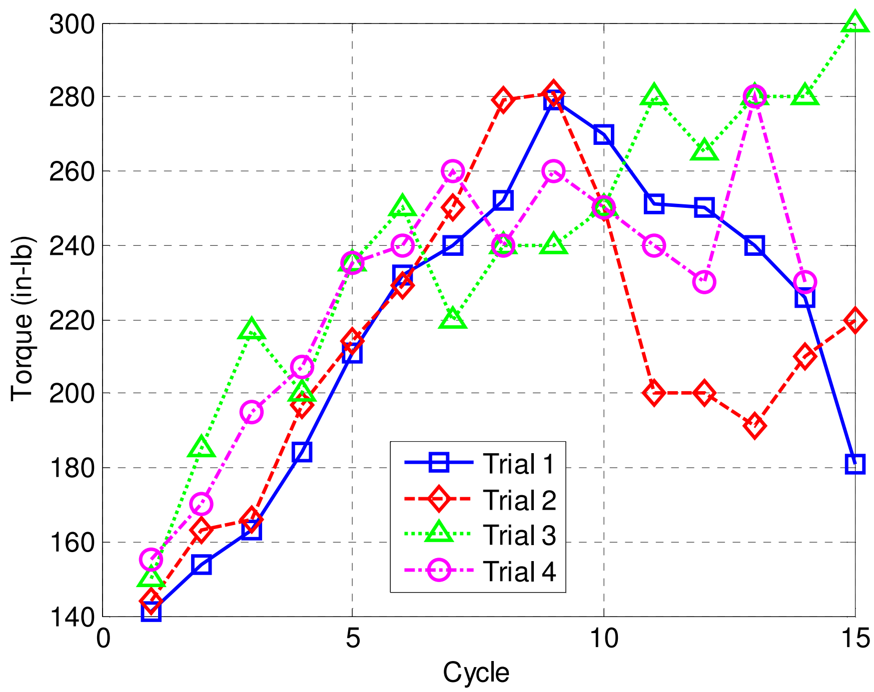

Figure D-94: MS17825-4 Tightening Torque; 66% Y Preload

Appendix D (Continued)

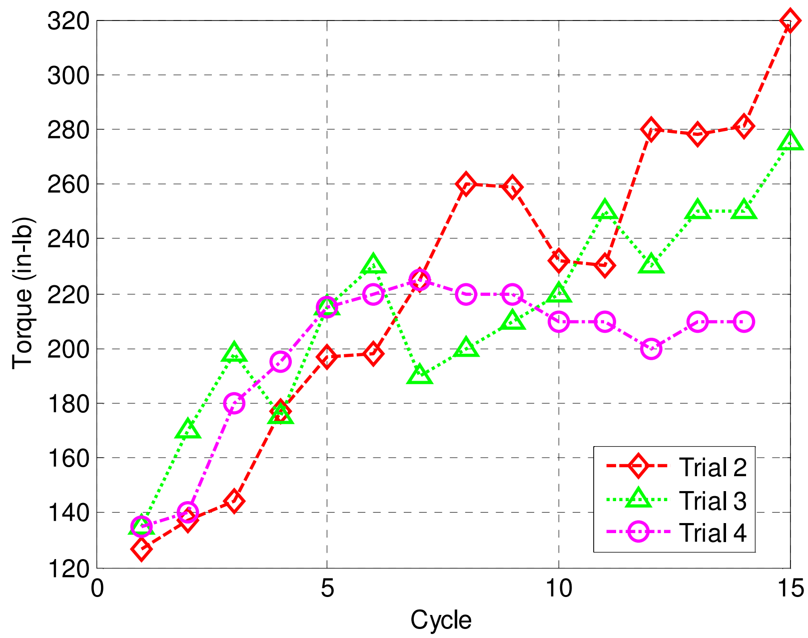

Figure D-95: MS17825-4 Breakloose Torque; 66% Y Preload

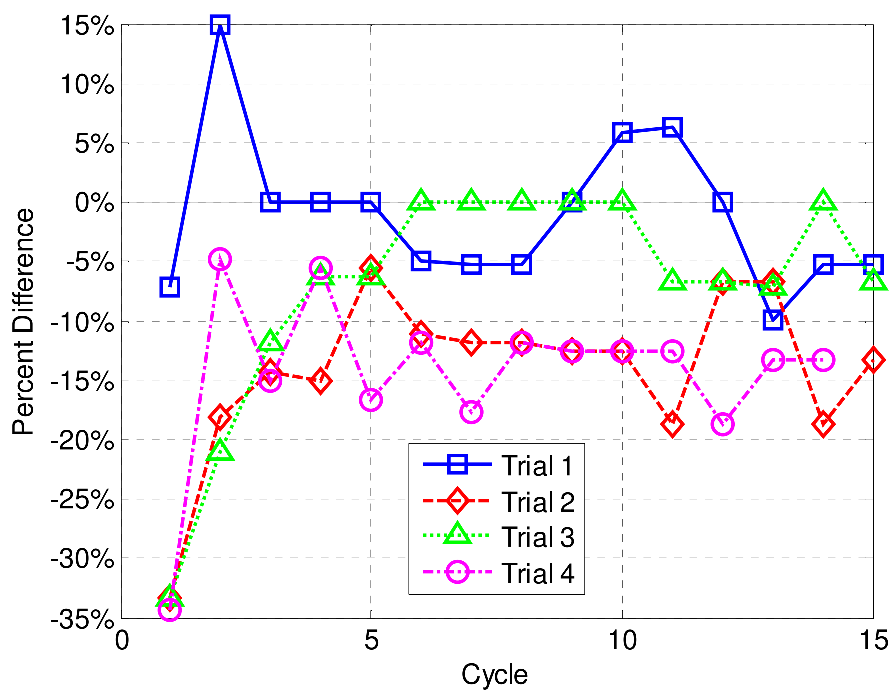

Figure D-96: MS17825-4 Percent Difference; 66% Y Preload

Appendix D (Continued)

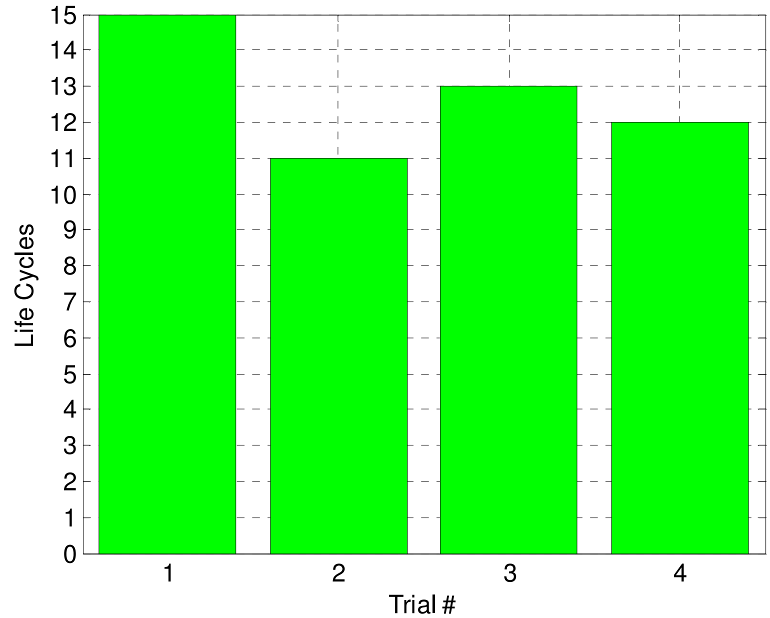

Figure D-97: MS17825-4 Life; 66% Y Preload

D.4.3 75% Y Preload

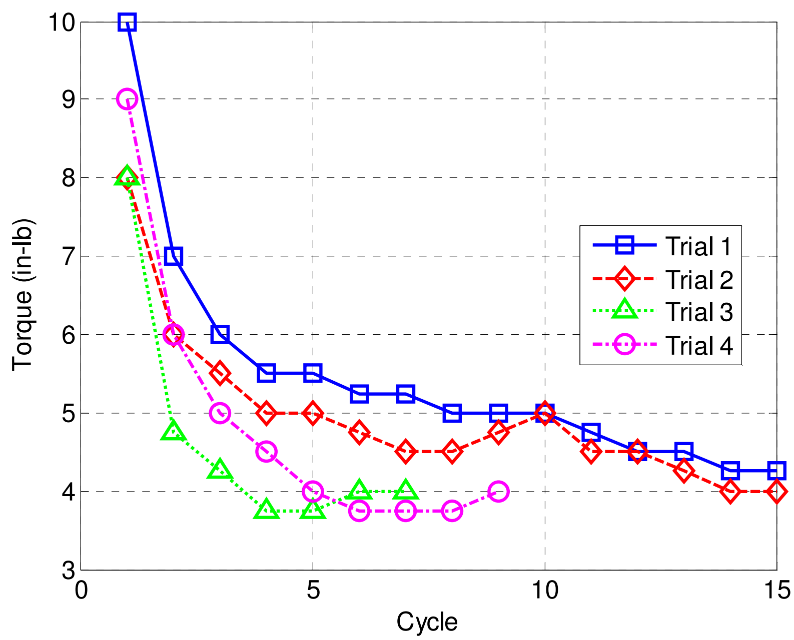

Figure D-98: MS17825-4 Assembly Prevailing Torque; 75% Y Preload

Appendix D (Continued)

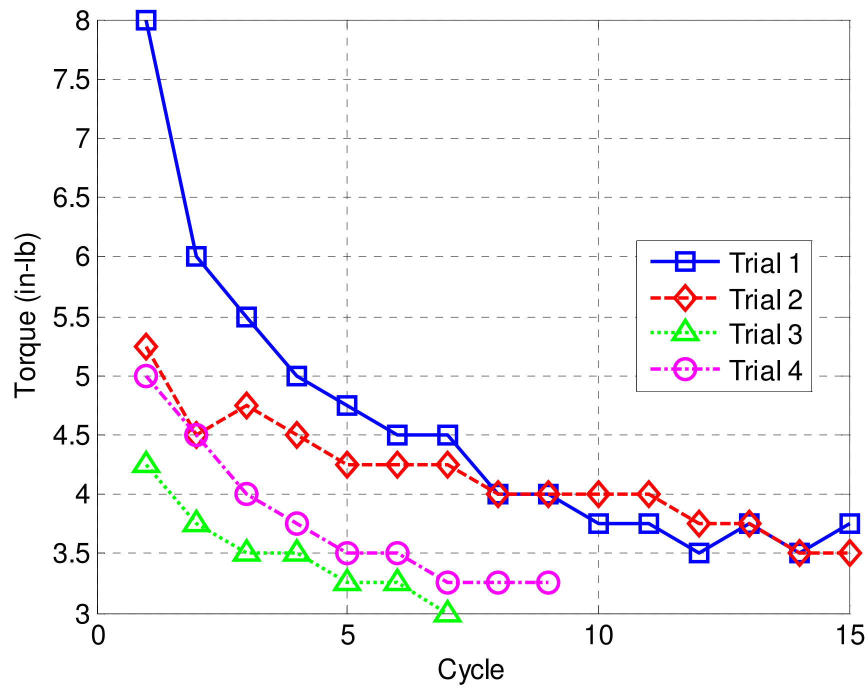

Figure D-99: MS17825-4 Removal Prevailing Torque; 75% Y Preload

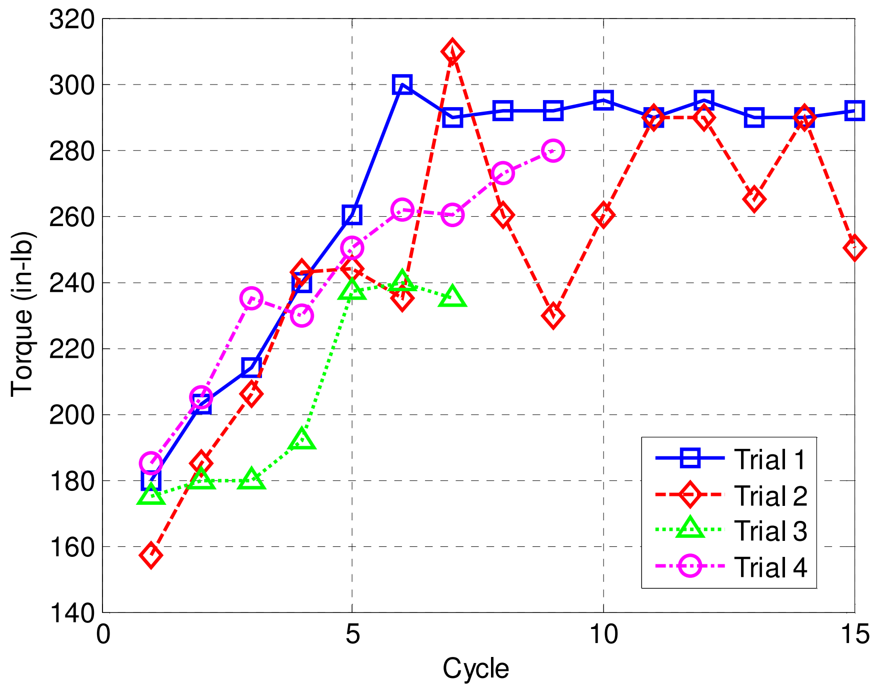

Figure D-100: MS17825-4 Tightening Torque; 75% Y Preload

Appendix D (Continued)

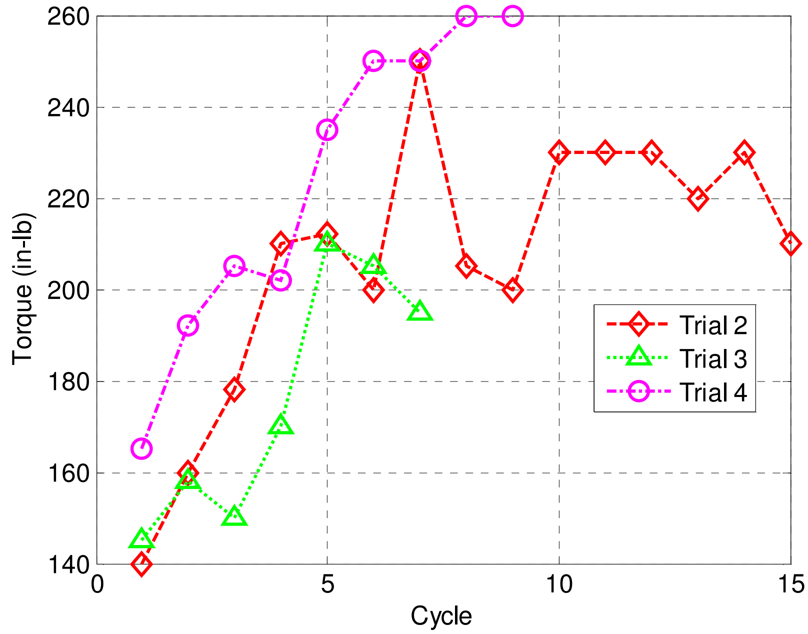

Figure D-101: MS17825-4 Breakloose Torque; 75% Y Preload

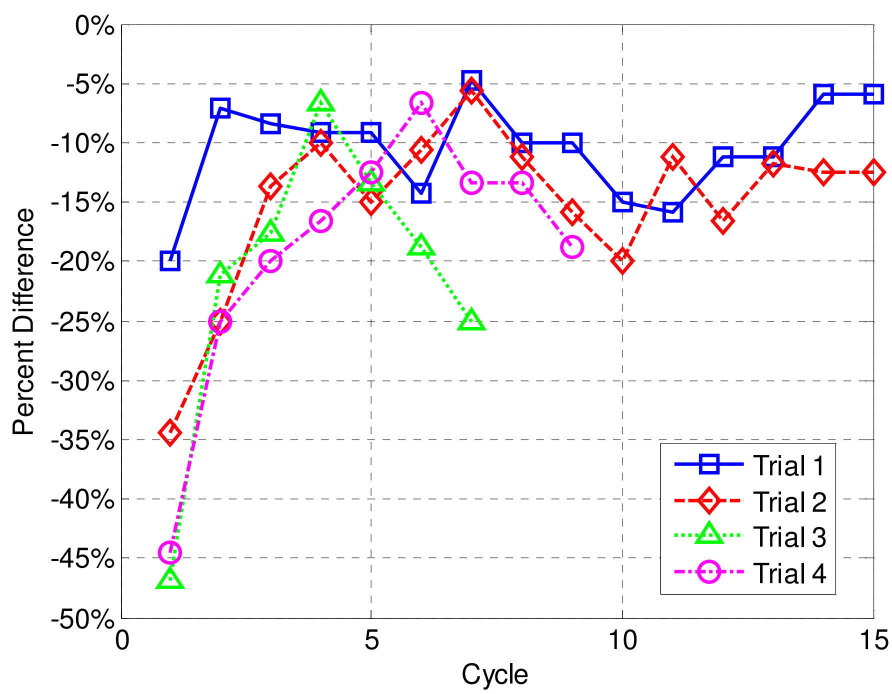

Figure D-102: MS17825-4 Percent Difference; 75% Y Preload

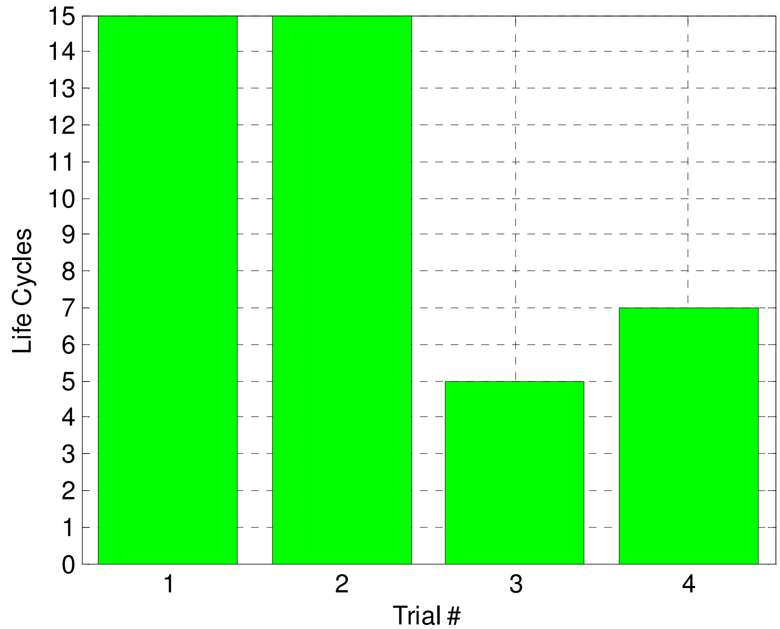

Figure D-103: MS17825-4 Life; 75% Y Preload

D.4.4 85% Y Preload

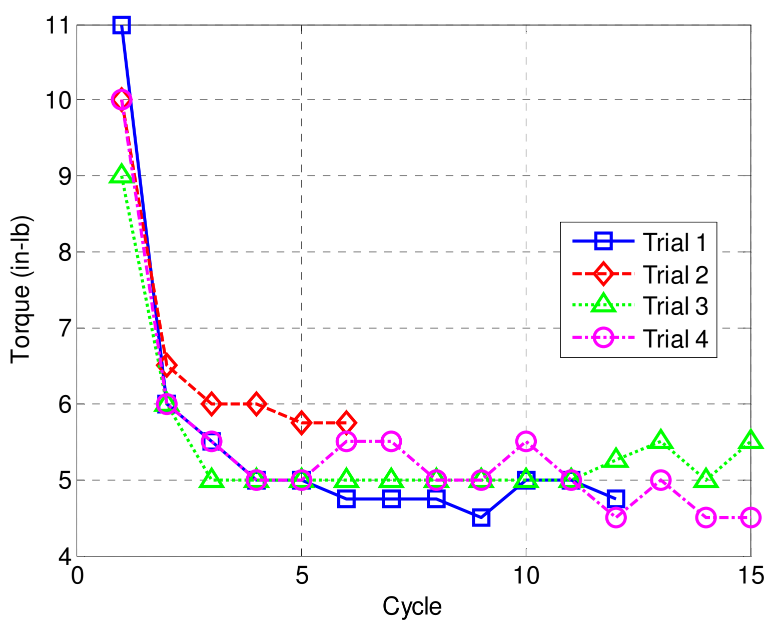

Figure D-104: MS17825-4 Assembly Prevailing Torque; 85% Y Preload

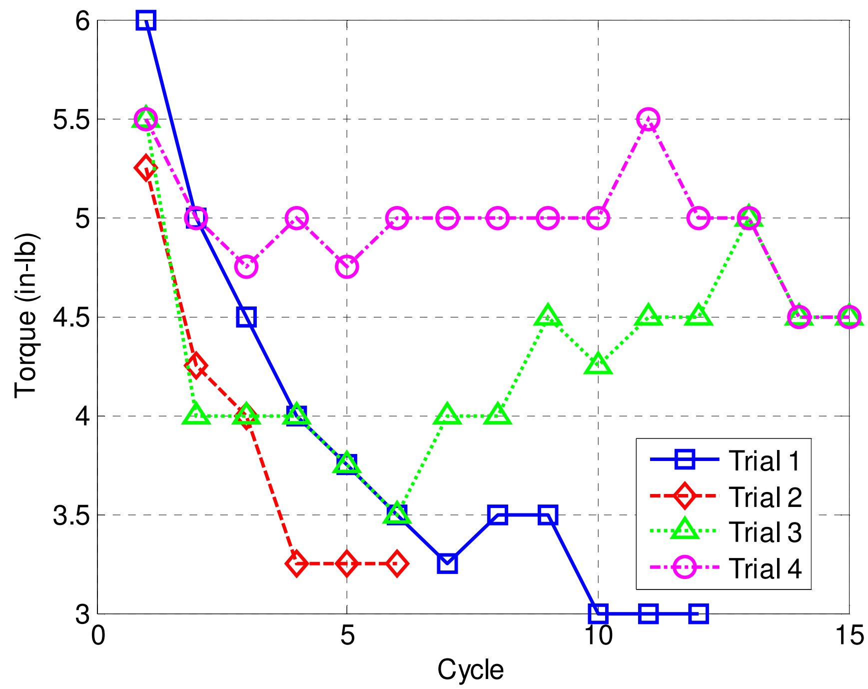

Figure D-105: MS17825-4 Removal Prevailing Torque; 85% Y Preload

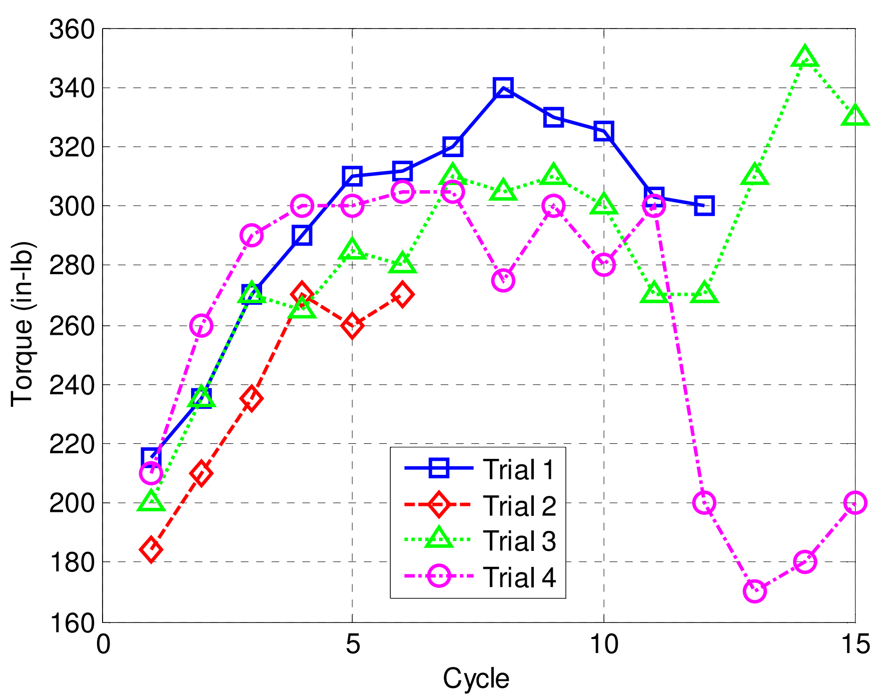

Figure D-106: MS17825-4 Tightening Torque; 85% Y Preload

Appendix D (Continued)

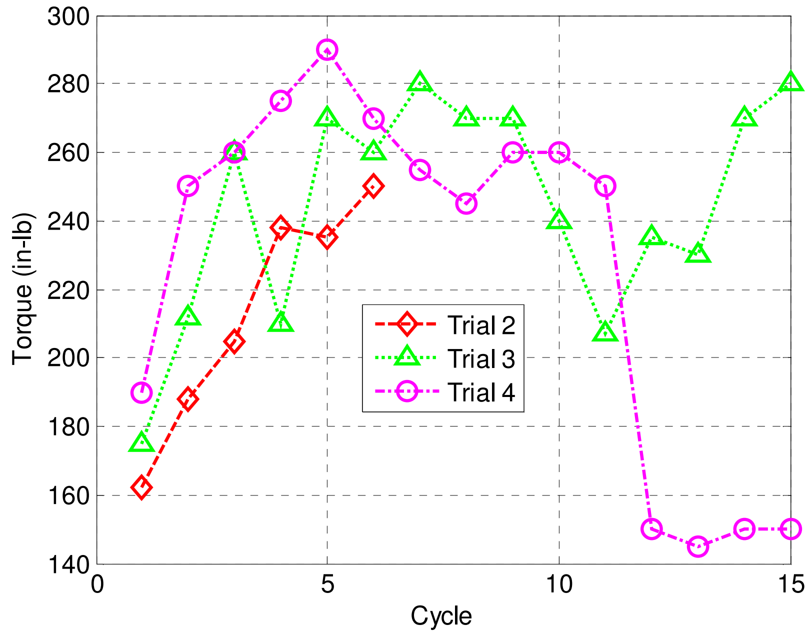

Figure D-107: MS17825-4 Breakloose Torque; 85% Y Preload

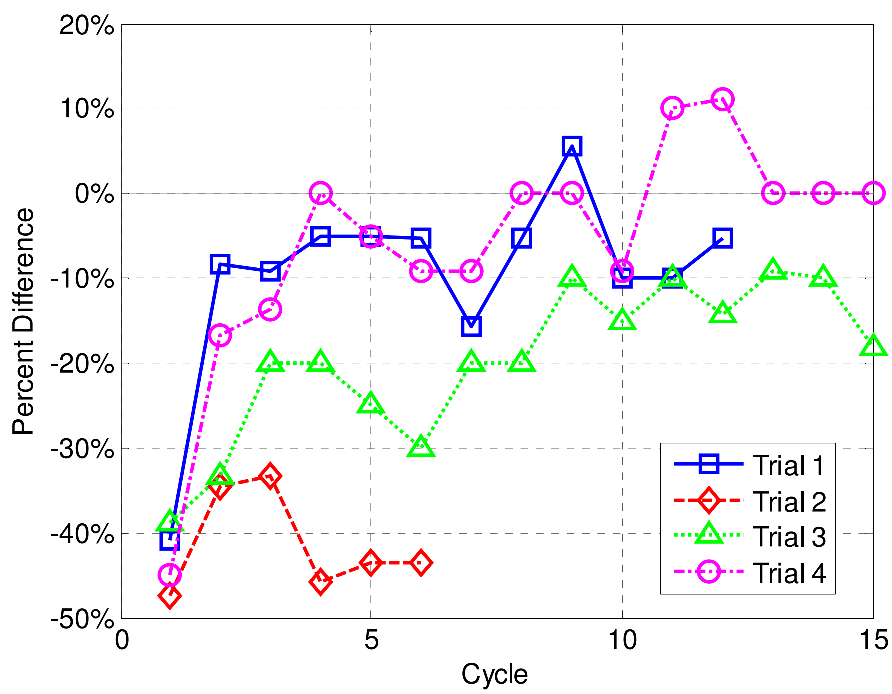

Figure D-108: MS17825-4 Percent Difference; 85% Y Preload

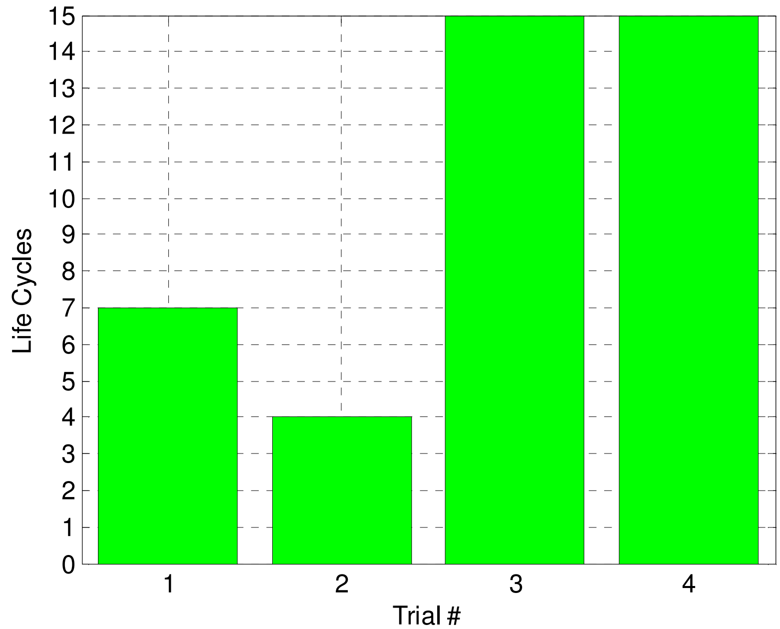

Figure D-109: MS17825-4 Life; 85% Y Preload

D.4.5 Preload Averages

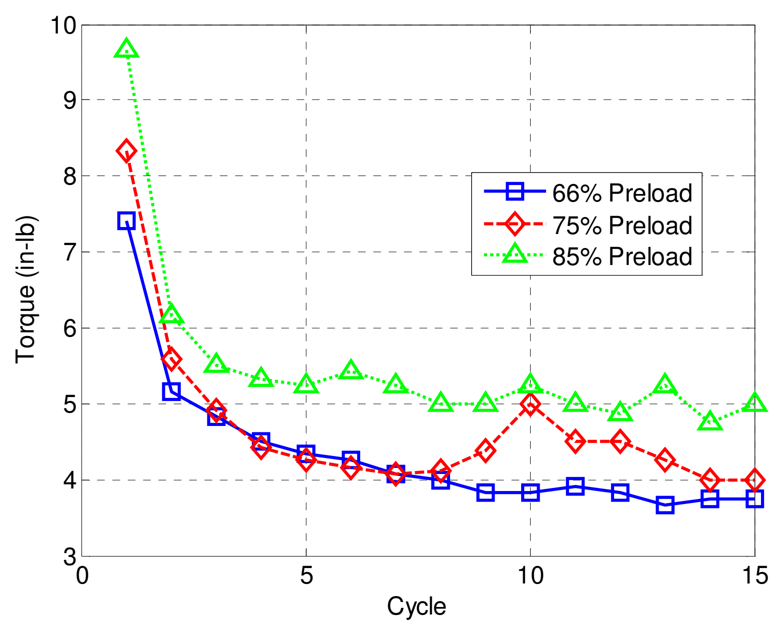

Figure D-110: MS17825-4 Assembly Prevailing Torque; Preload Average

Appendix D (Continued)

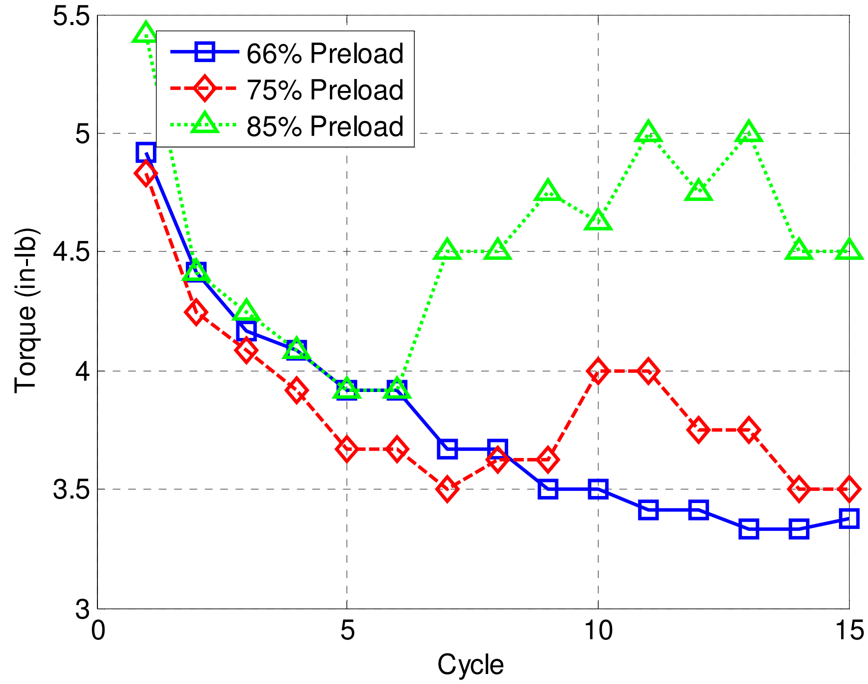

Figure D-111: MS17825-4 Removal Prevailing Torque; Preload Average

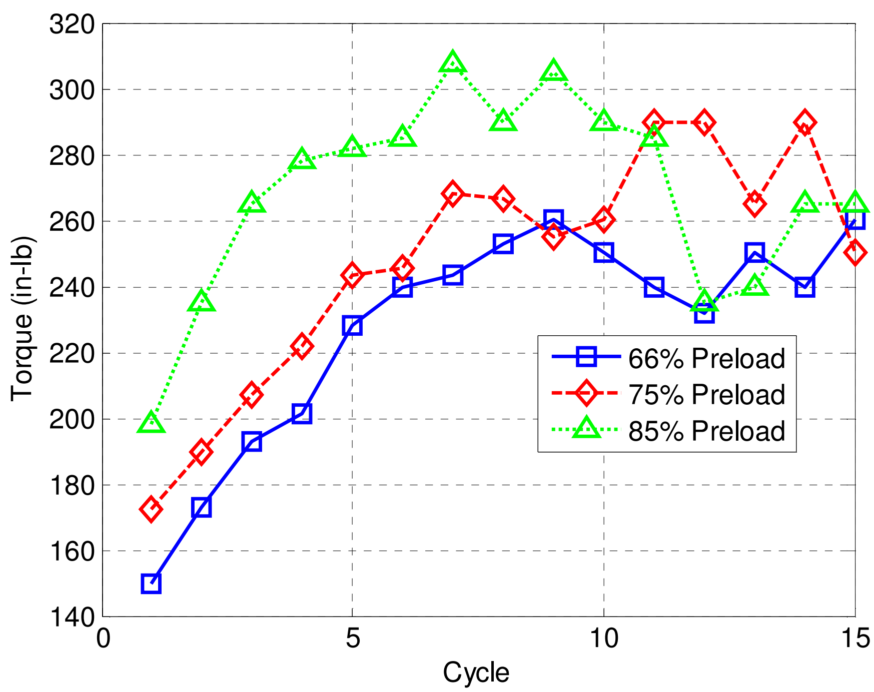

Figure D-112: MS17825-4 Tightening Torque; Preload Average

Appendix D (Continued)

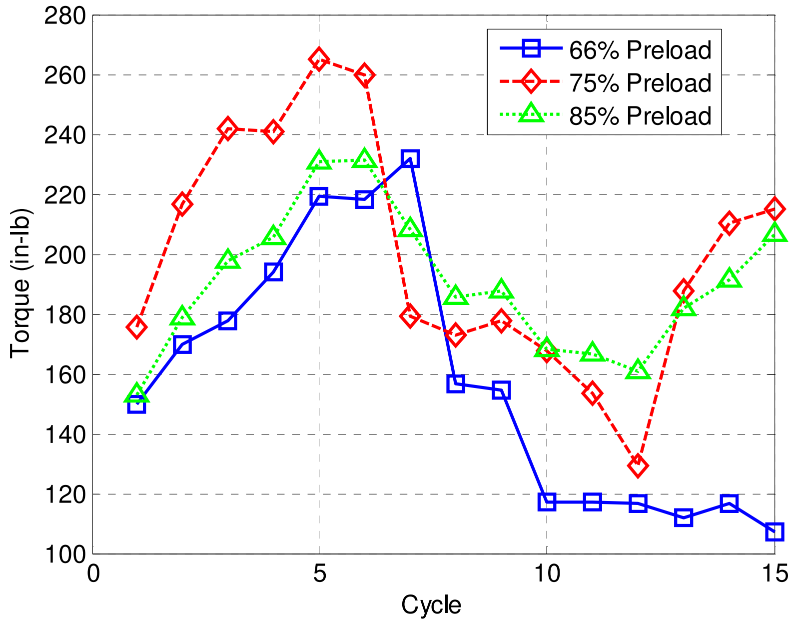

Figure D-113: MS17825-4 Breakloose Torque; Preload Average

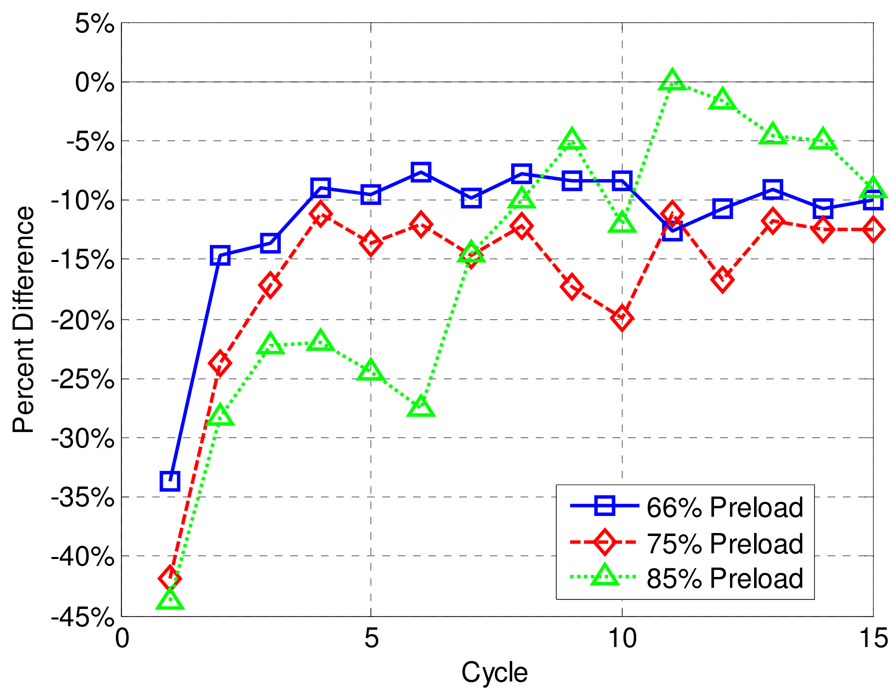

Figure D-114: MS17825-4 Percent Difference; Preload Average

Appendix D (Continued)

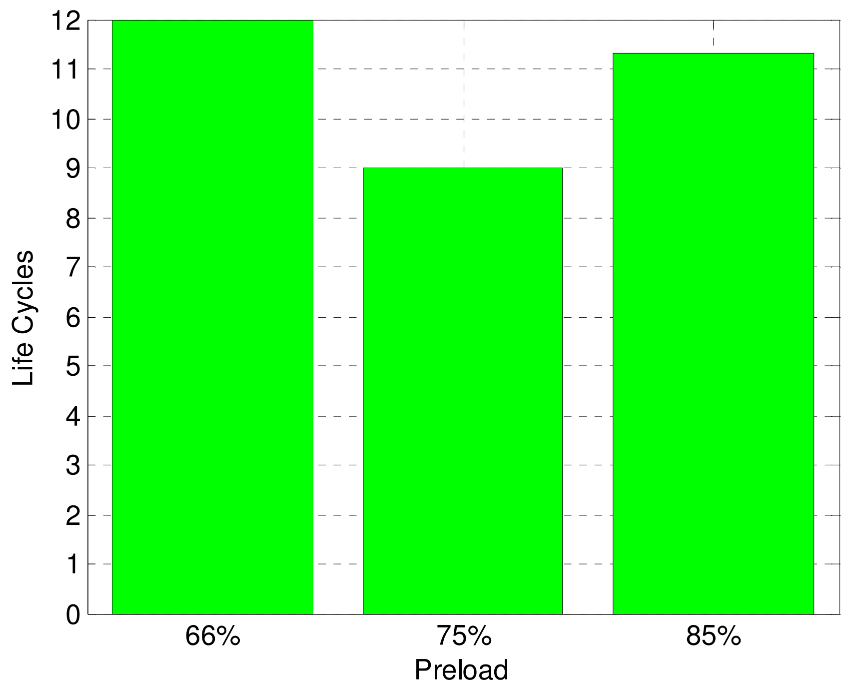

Figure D-115: MS17825-4 Life; Preload Average

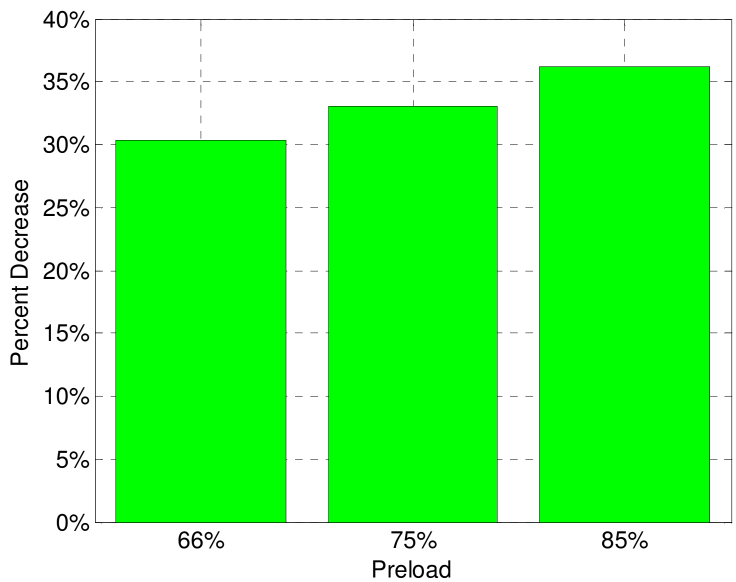

Figure D-116: MS17825-4 Percent Decrease of Assembly Prevailing Torque from Cycle 1 to 2; Preload Average

Appendix D (Continued)

D.5 MS21044D4

D.5.1 Unseated

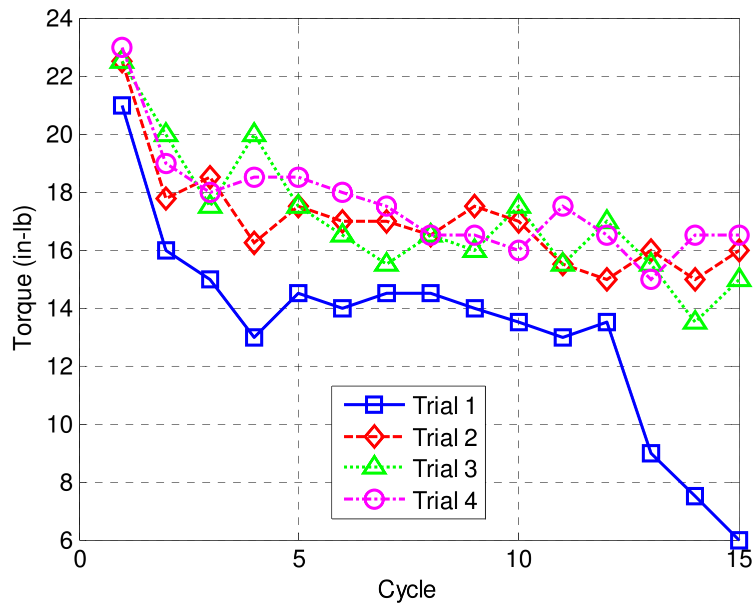

Figure D-117: MS21044D4 Assembly Prevailing Torque; Unseated

Appendix D (Continued)

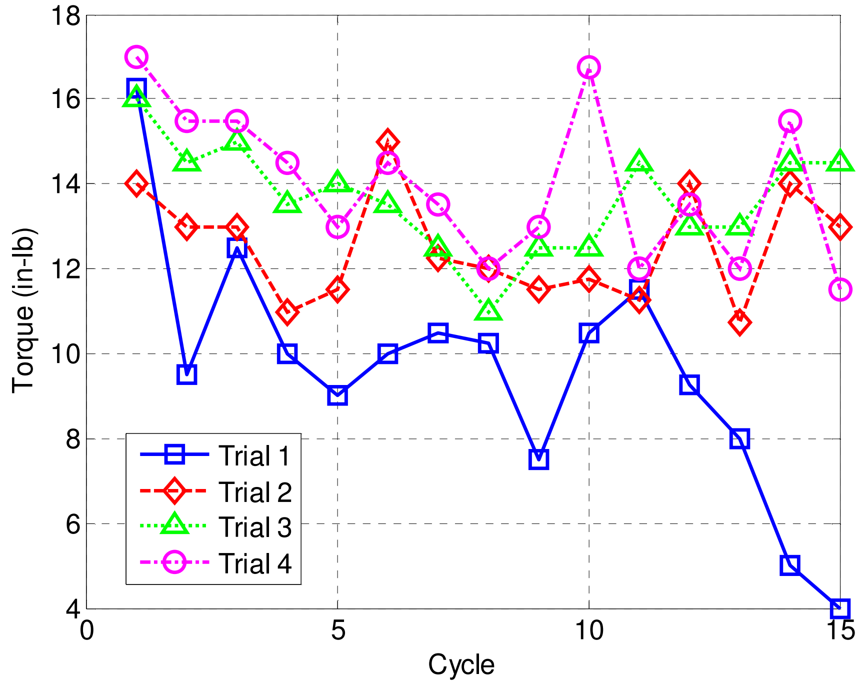

Figure D-118: MS21044D4 Removal Prevailing Torque; Unseated

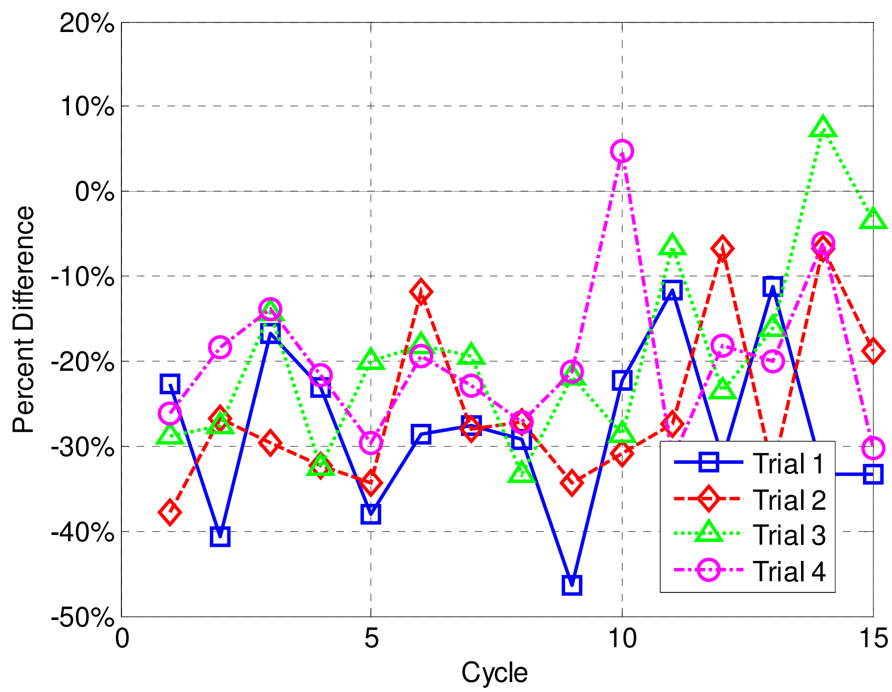

Figure D-119: MS21044D4 Percent Difference; Unseated

Appendix D (Continued)

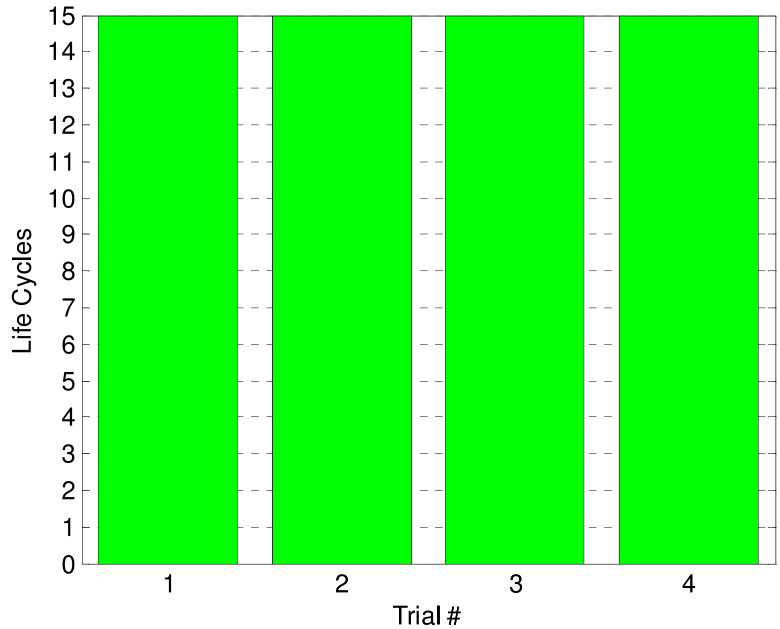

Figure D-120: MS21044D4 Life; Unseated

D.5.2 66% Y Preload

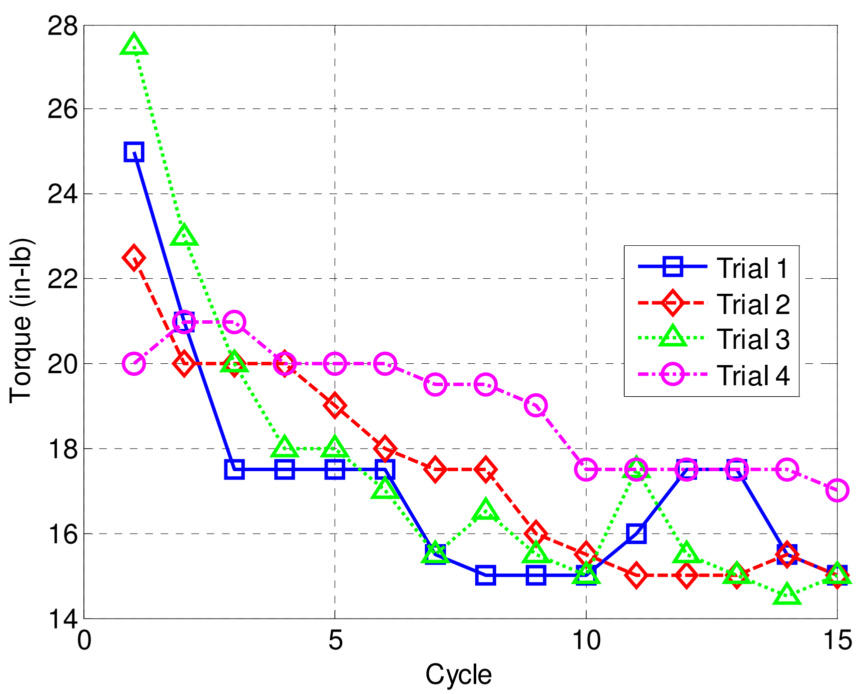

Figure D-121: MS21044D4 Assembly Prevailing Torque; 66% Y Preload

Appendix D (Continued)

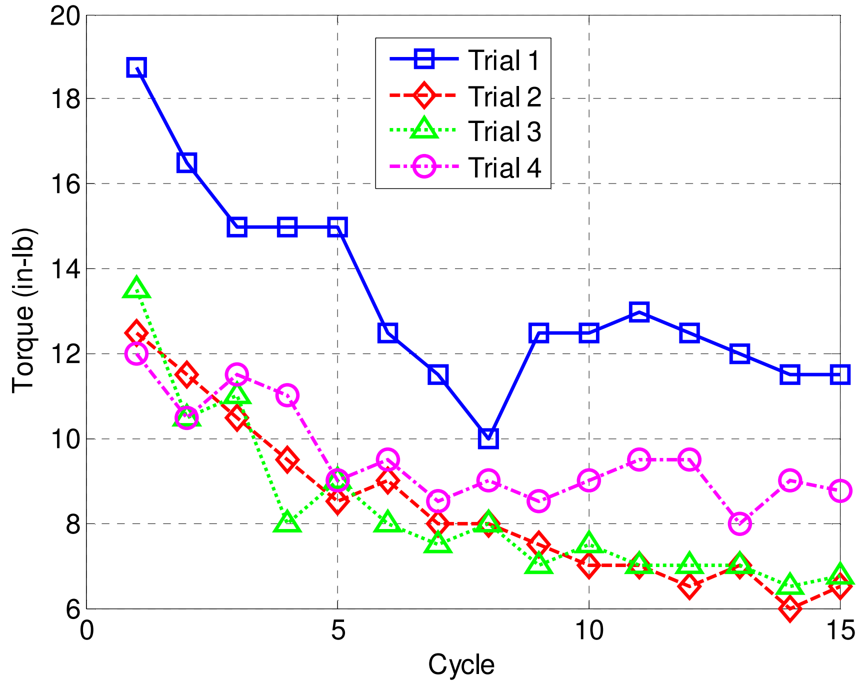

Figure D-122: MS21044D4 Removal Prevailing Torque; 66% Y Preload

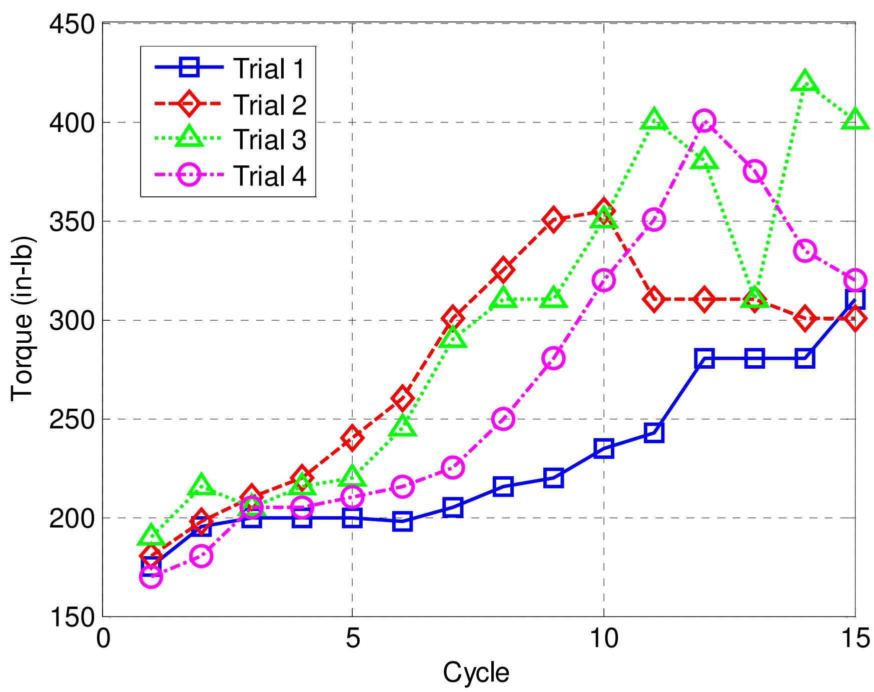

Figure D-123: MS21044D4 Tightening Torque; 66% Y Preload

Appendix D (Continued)

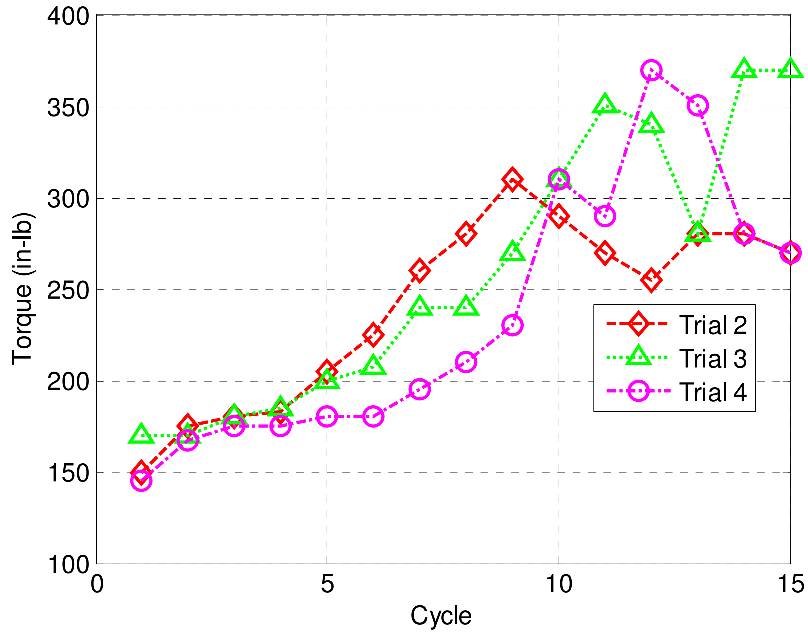

Figure D-124: MS21044D4 Breakloose Torque; 66% Y Preload

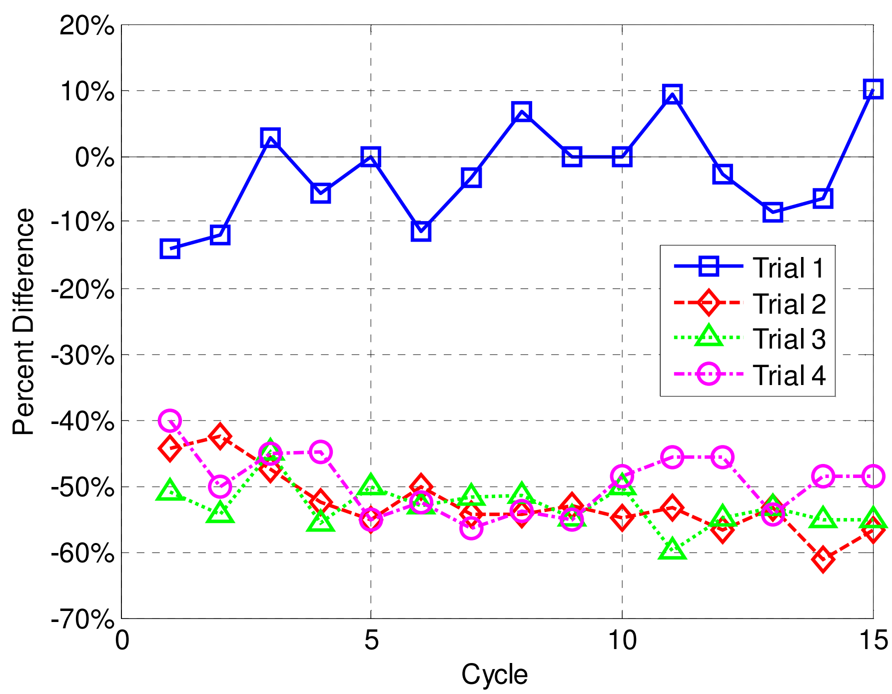

Figure D-125: MS21044D4 Percent Difference; 66% Y Preload

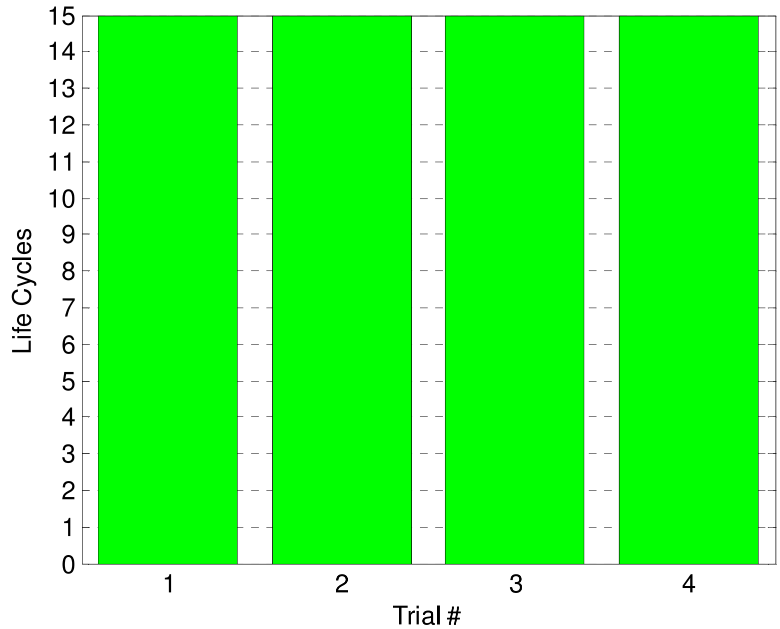

Figure D-126: MS21044D4 Life; 66% Y Preload

D.5.3 75% Y Preload

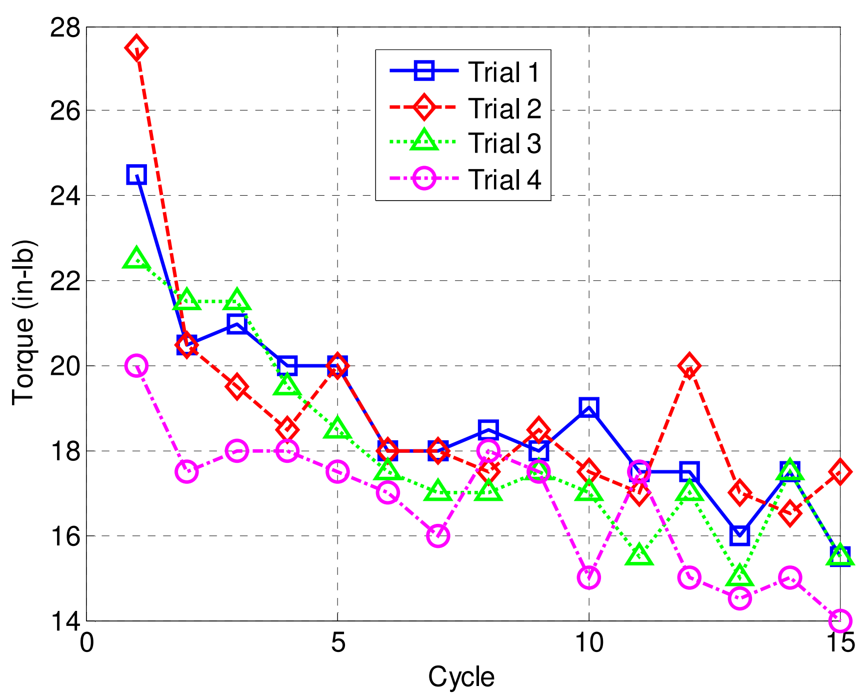

Figure D-127: MS21044D4 Assembly Prevailing Torque; 75% Y Preload

Appendix D (Continued)

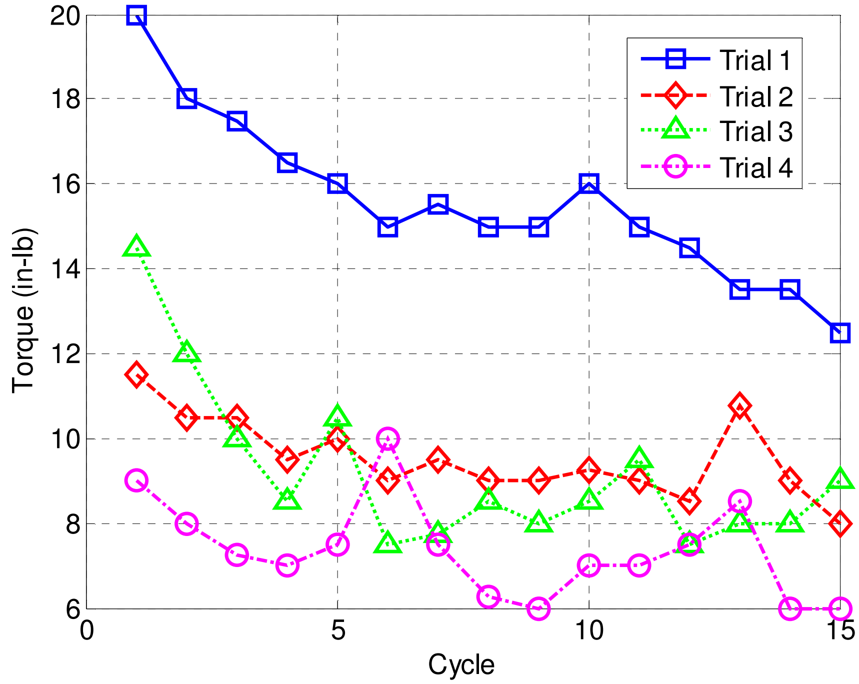

Figure D-128: MS21044D4 Removal Prevailing Torque; 75% Y Preload

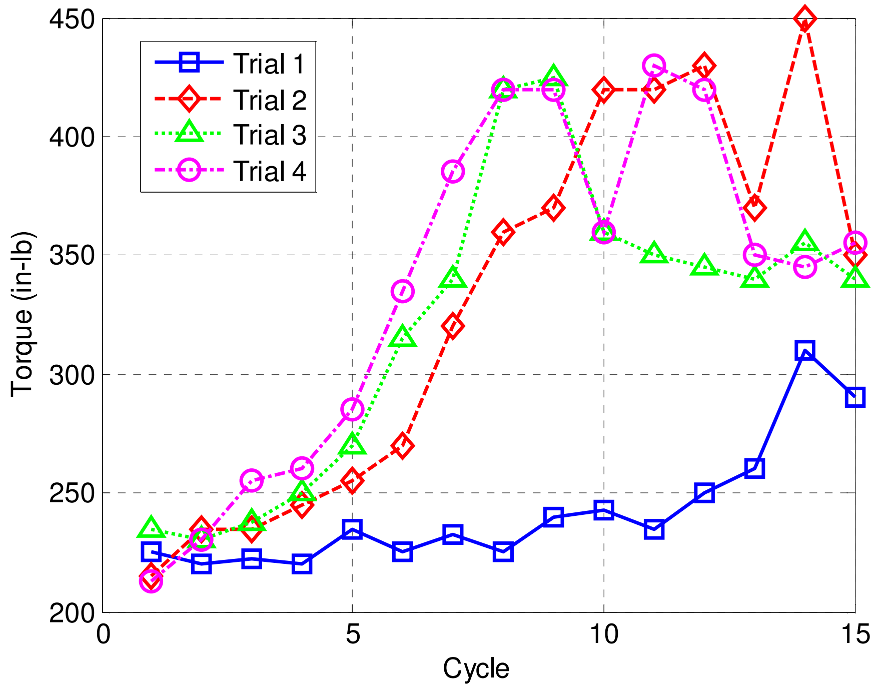

Figure D-129: MS21044D4 Tightening Torque; 75% Y Preload

Appendix D (Continued)

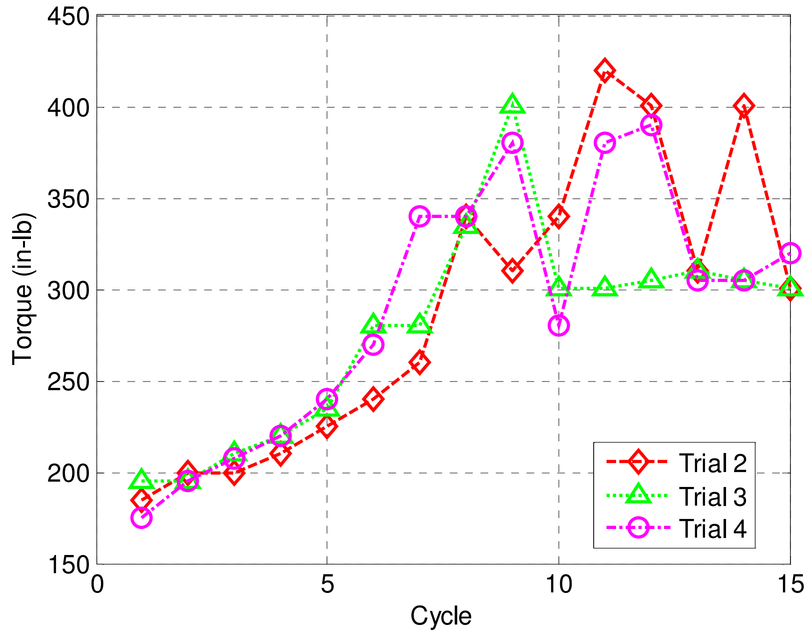

Figure D-130: MS21044D4 Breakloose Torque; 75% Y Preload

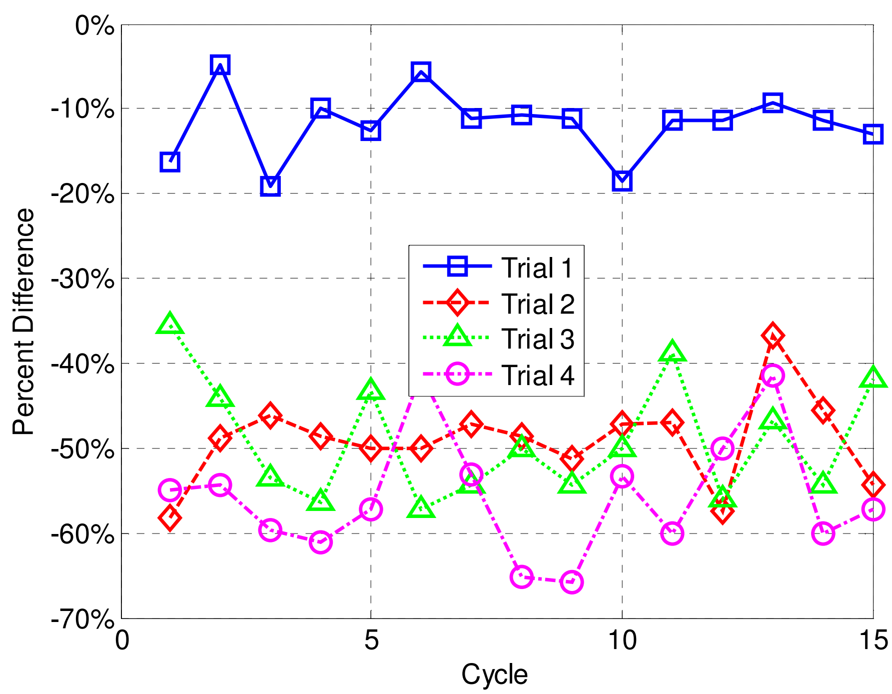

Figure D-131: MS21044D4 Percent Difference; 75% Y Preload

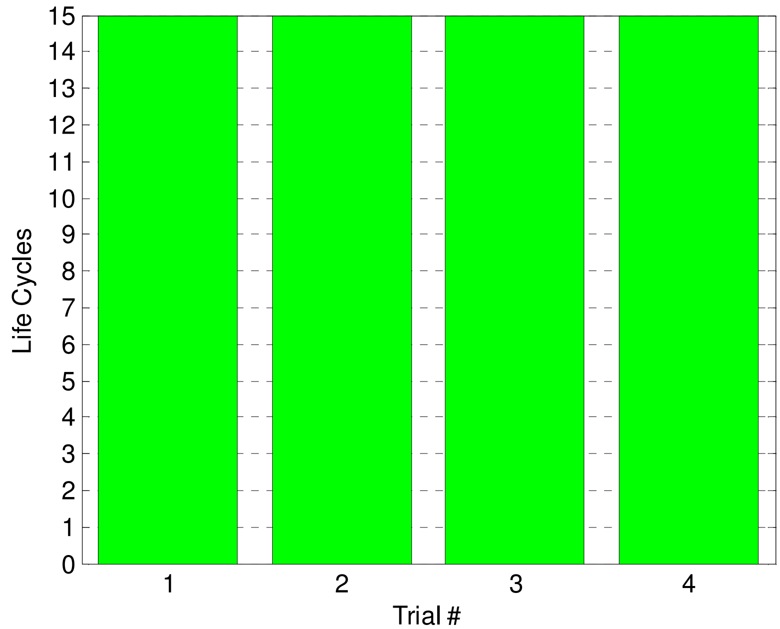

Figure D-132: MS21044D4 Life; 75% Y Preload

D.5.4 85% Y Preload

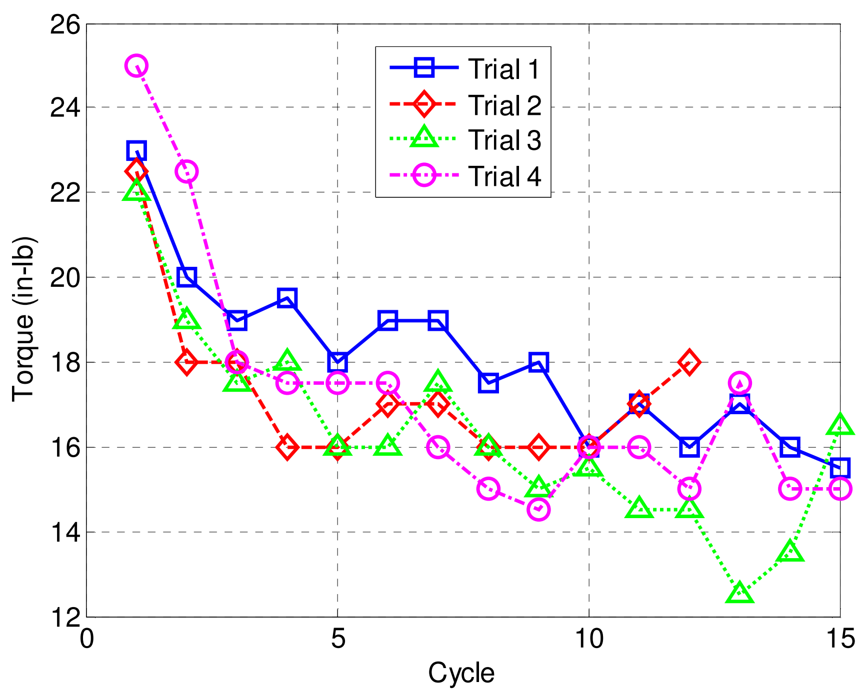

Figure D-133: MS21044D4 Assembly Prevailing Torque; 85% Y Preload

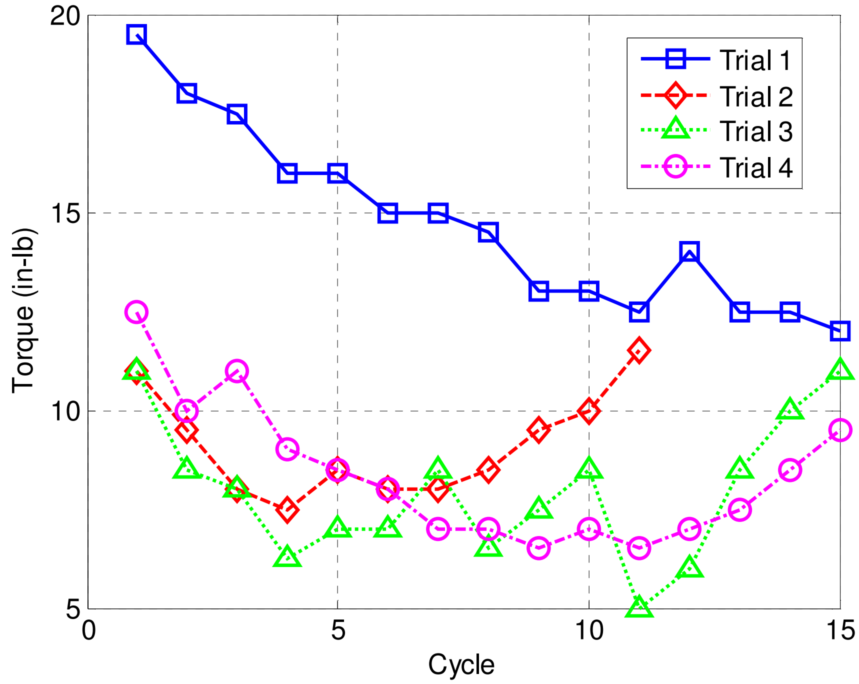

Figure D-134: MS21044D4 Removal Prevailing Torque; 85% Y Preload

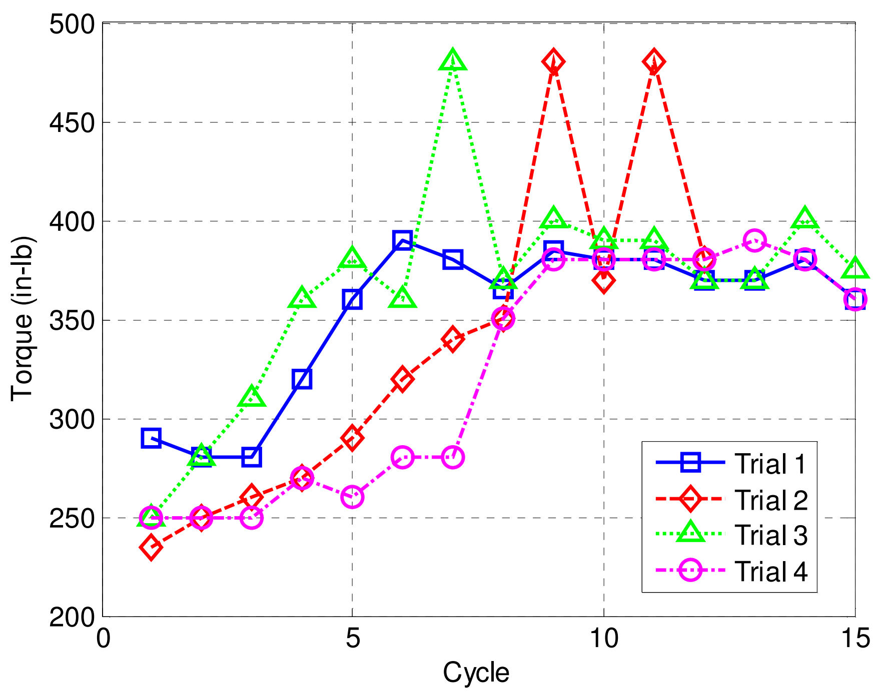

Figure D-135: MS21044D4 Tightening Torque; 85% Y Preload

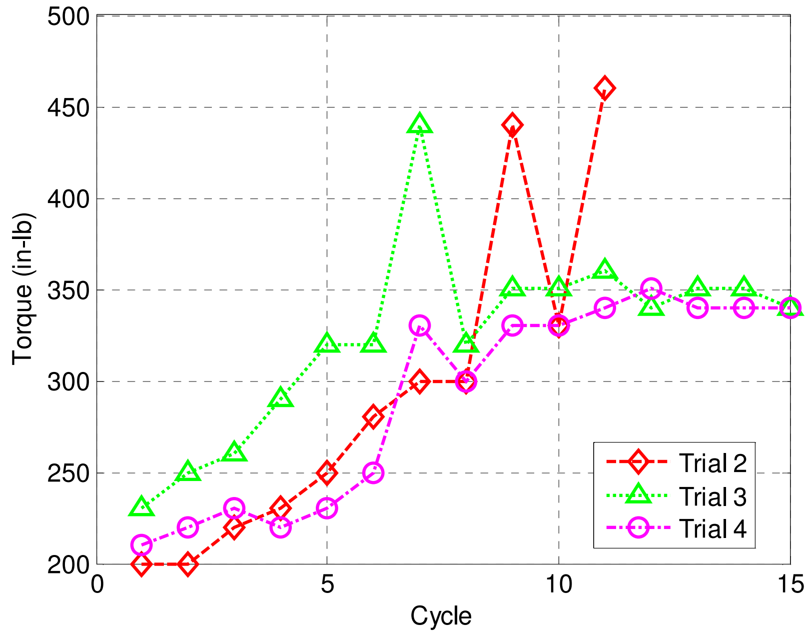

Figure D-136: MS21044D4 Breakloose Torque; 85% Y Preload

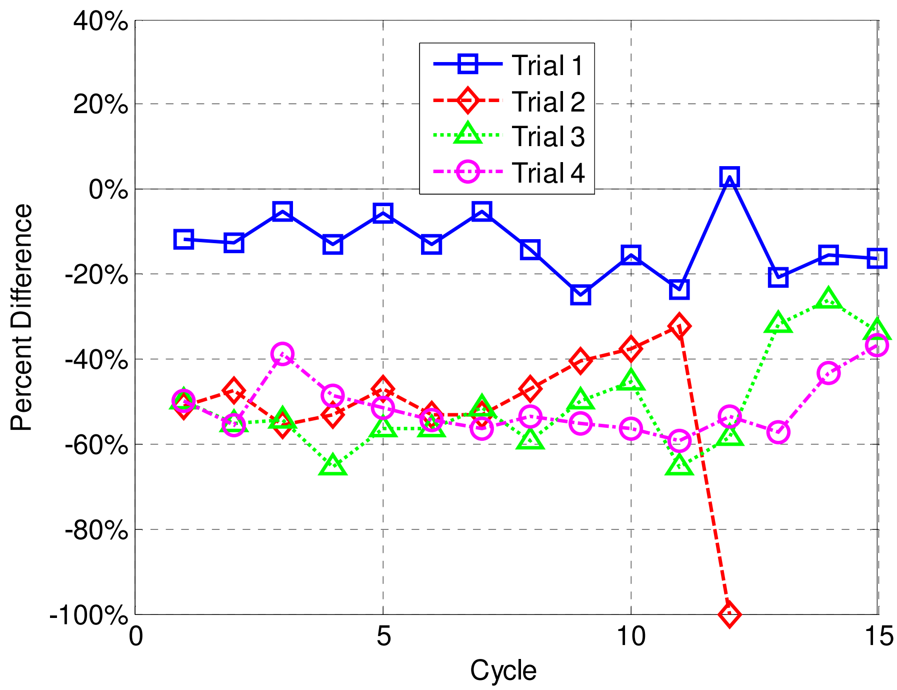

Figure D-137: MS21044D4 Percent Difference; 85% Y Preload

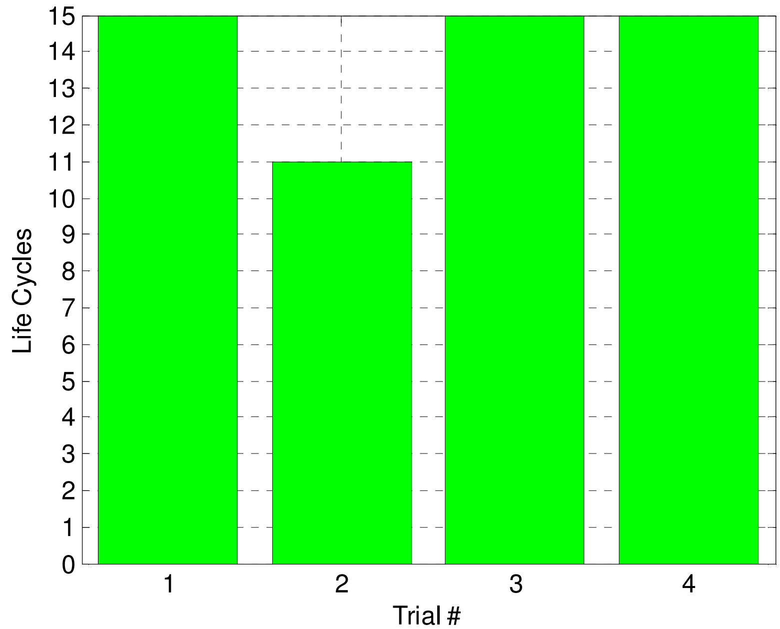

Figure D-138: MS21044D4 Life; 85% Y Preload

D.5.5 Preload Averages

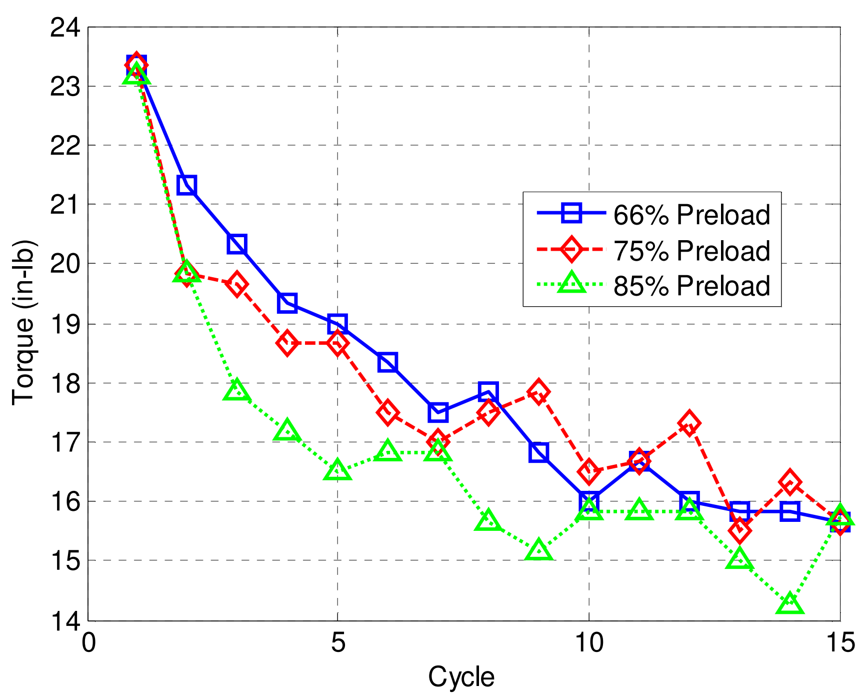

Figure D-139: MS21044D4 Assembly Prevailing Torque; Preload Average

Appendix D (Continued)

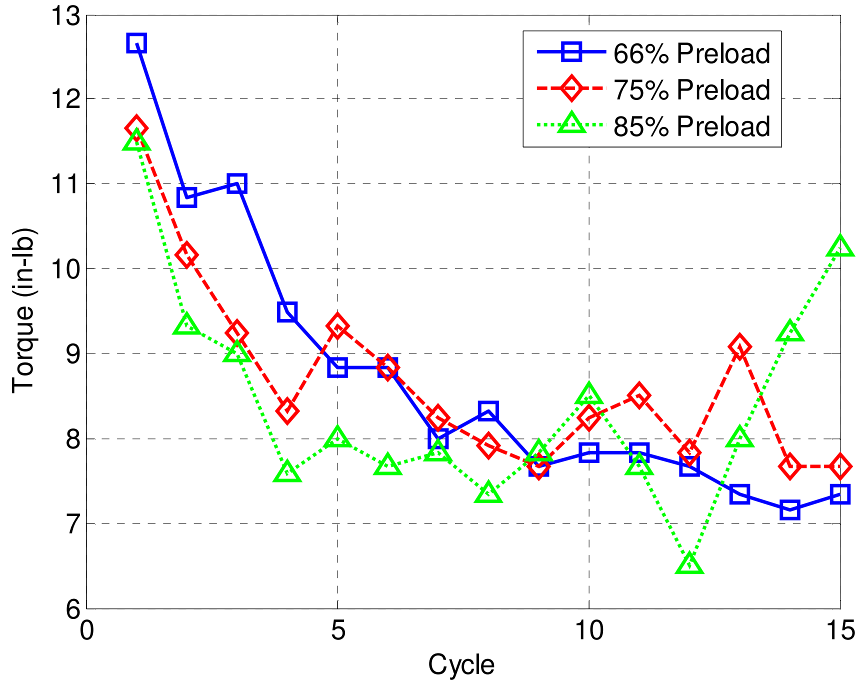

Figure D-140: MS21044D4 Removal Prevailing Torque; Preload Average

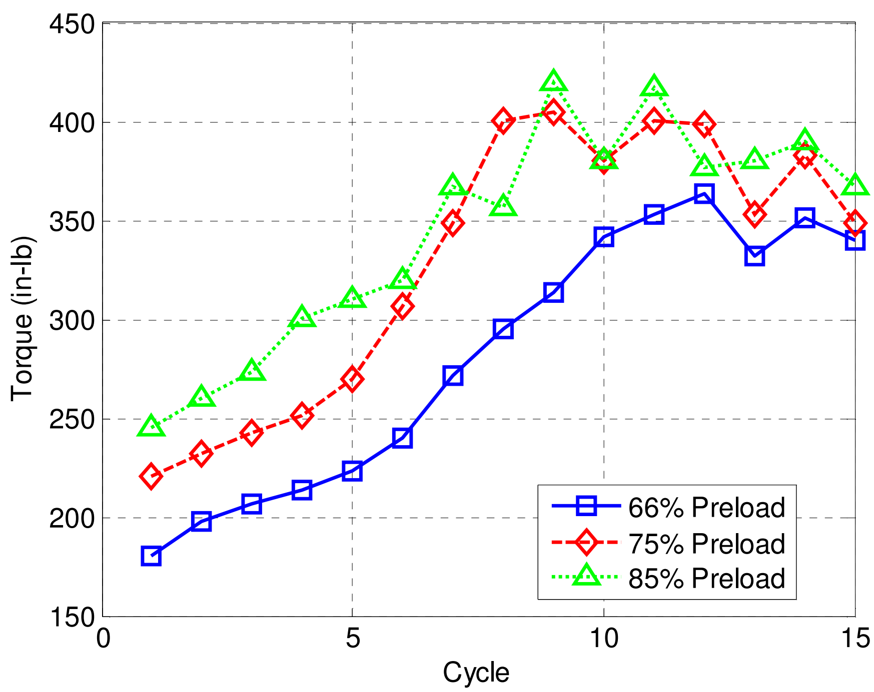

Figure D-141: MS21044D4 Tightening Torque; Preload Average

Appendix D (Continued)

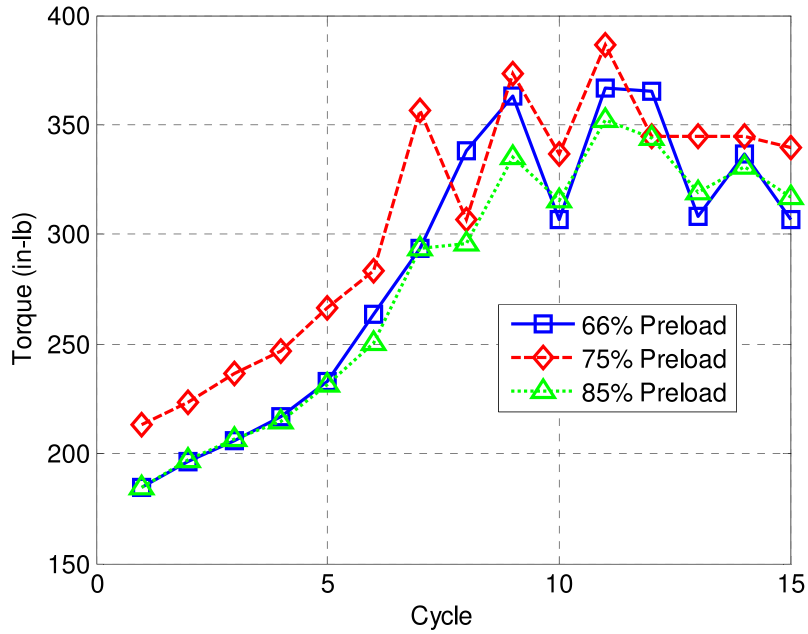

Figure D-142: MS21044D4 Breakloose Torque; Preload Average

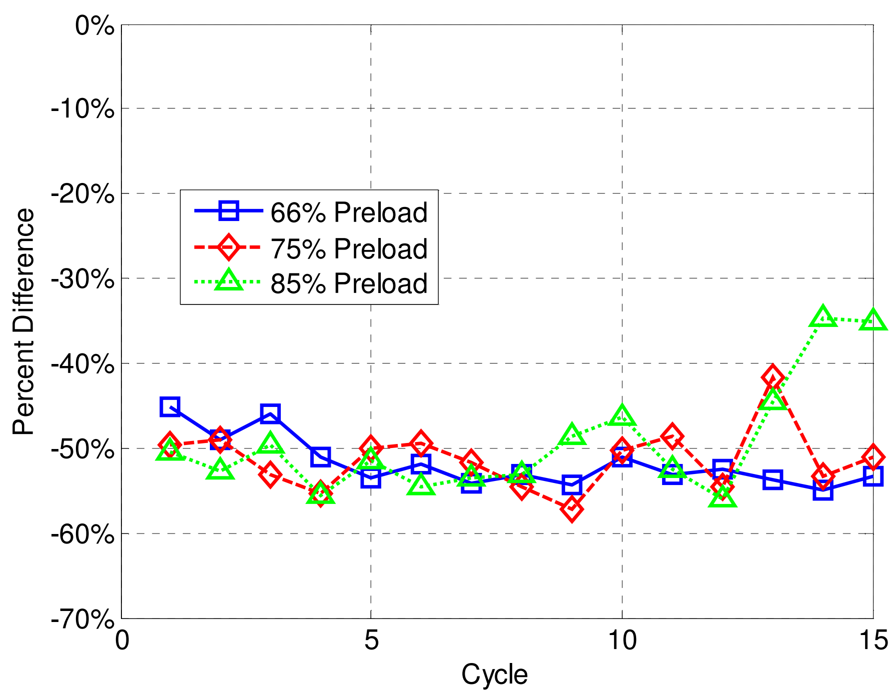

Figure D-143: MS21044D4 Percent Difference; Preload Average

Appendix D (Continued)

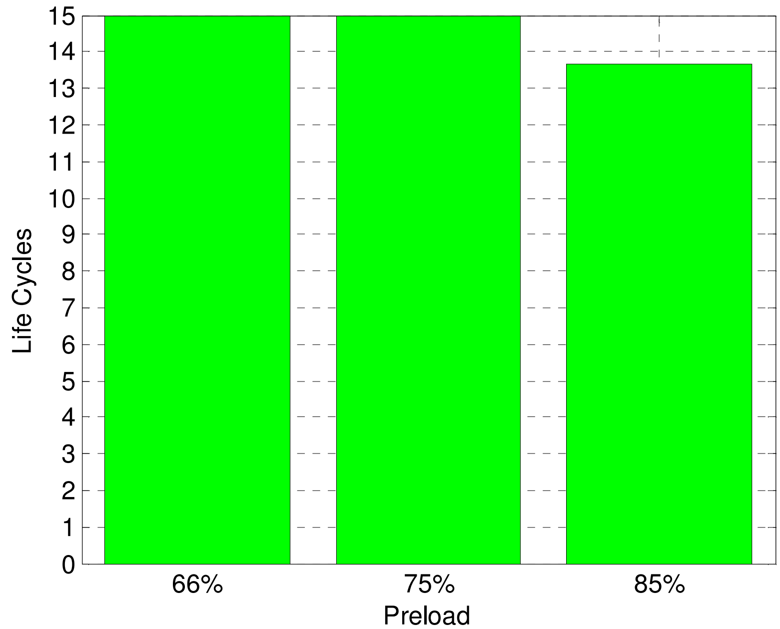

Figure D-144: MS21044D4 Life; Preload Average

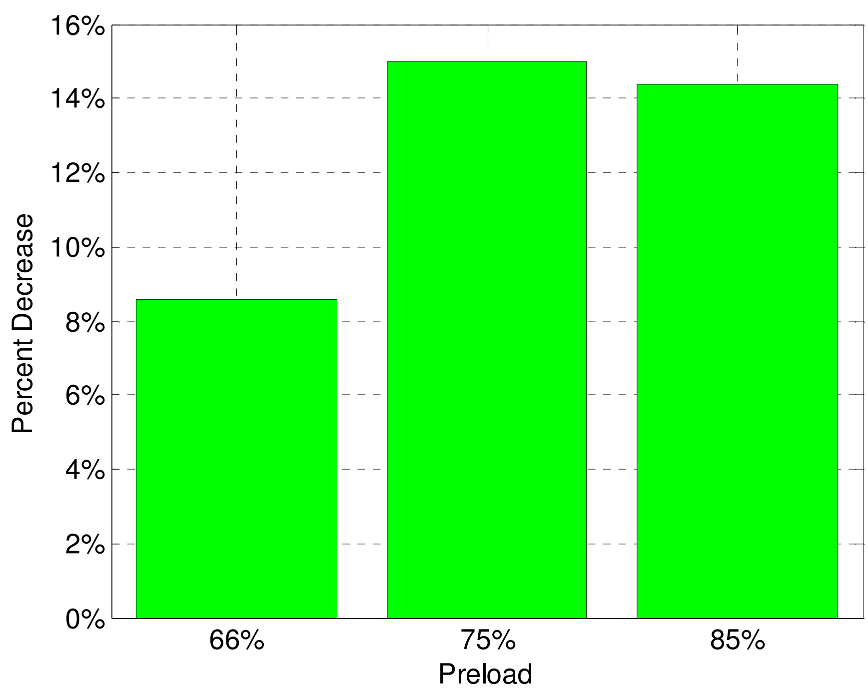

Figure D-145: MS21044D4 Percent Decrease of Assembly Prevailing Torque from Cycle 1 to 2; Preload Average

Appendix D (Continued)

D.6 MS21044D4 Lubricated with Braycote

D.6.1 Unseated – Braycote

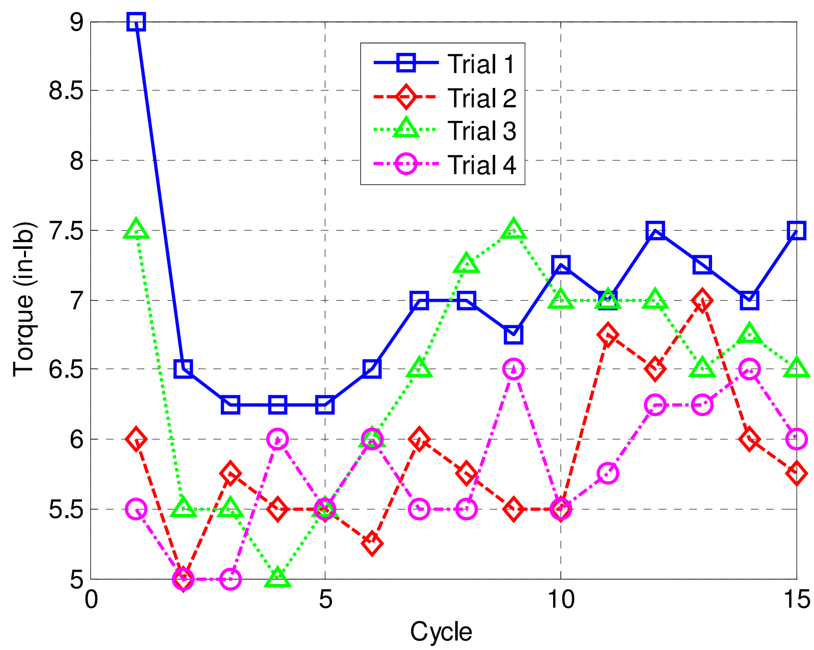

Figure D-146: MS21044D4 Braycote Assembly Prevailing Torque; Unseated

Appendix D (Continued)

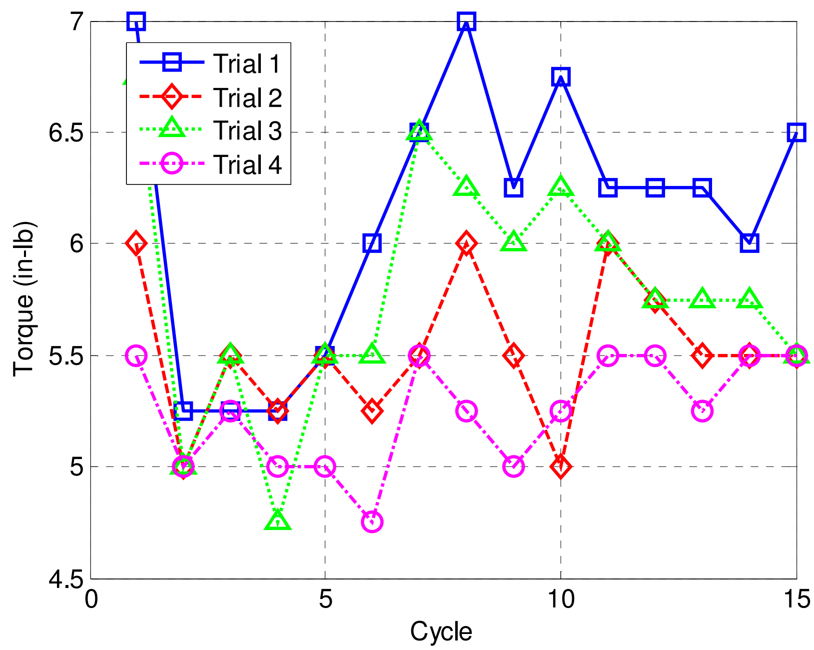

Figure D-147: MS21044D4 Braycote Removal Prevailing Torque; Unseated

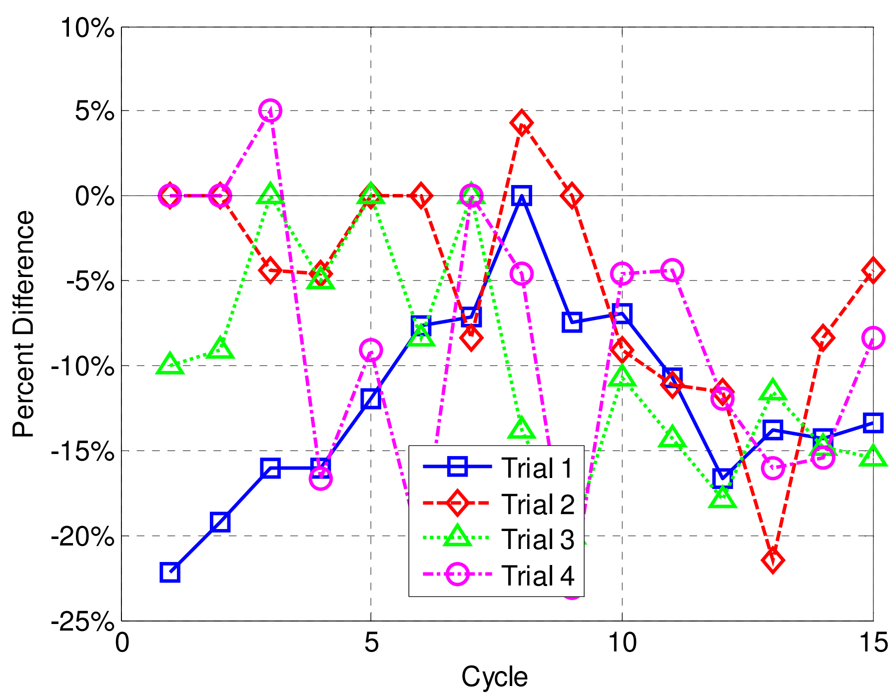

Figure D-148: MS21044D4 Braycote Percent Difference; Unseated

Appendix D (Continued)

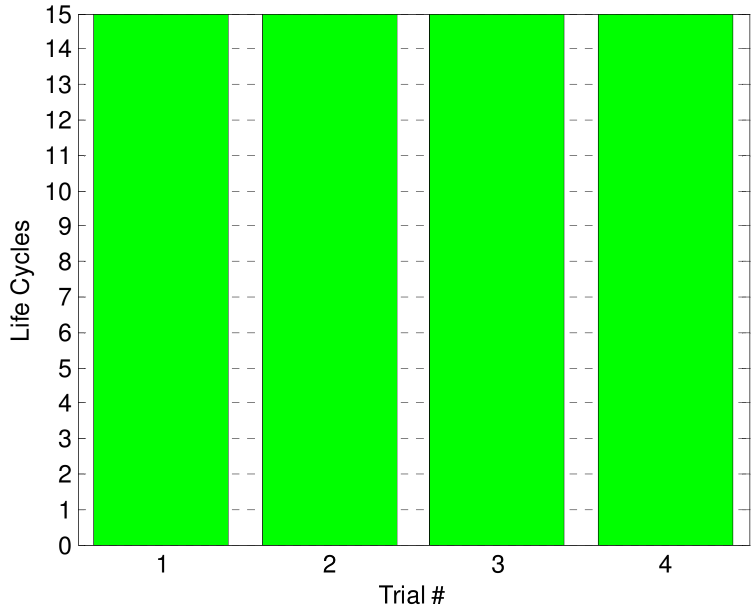

Figure D-149: MS21044D4 Braycote Life; Unseated

D.6.2 66% Y Preload – Braycote

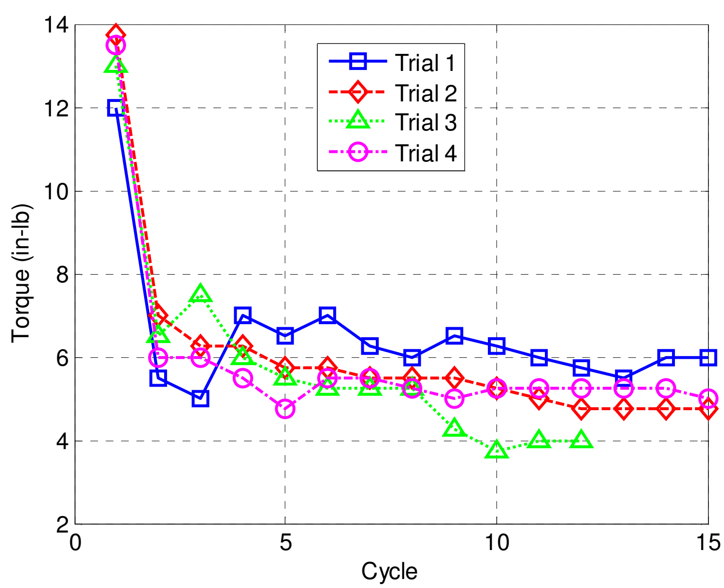

Figure D-150: MS21044D4 Braycote Assembly Prevailing Torque; 66% Y Preload

Appendix D (Continued)

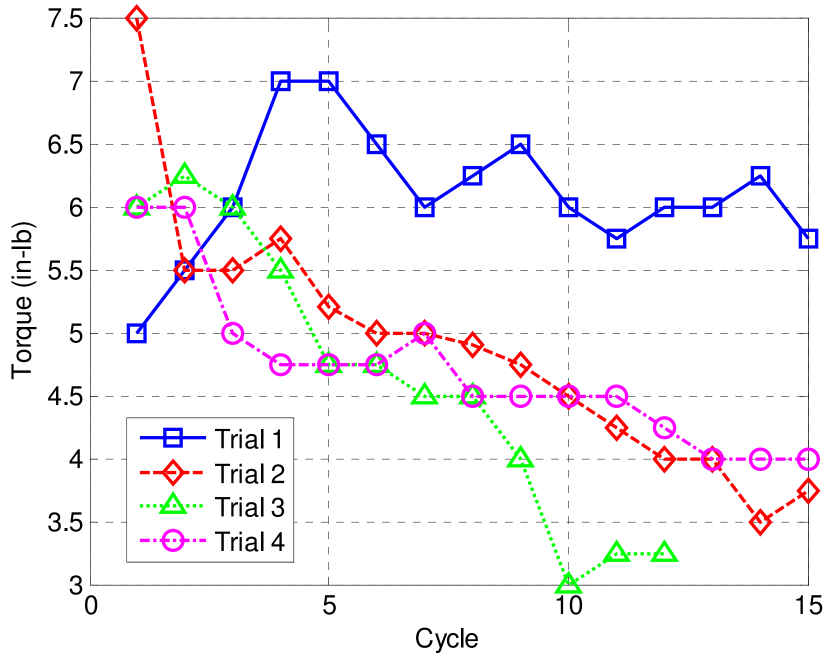

Figure D-151: MS21044D4 Braycote Removal Prevailing Torque; 66% Y Preload

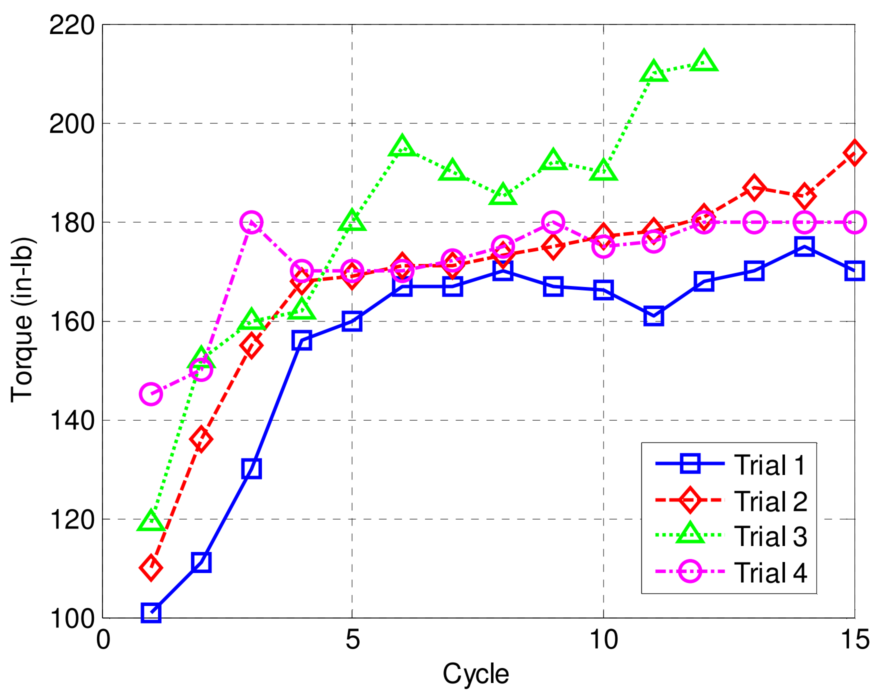

Figure D-152: MS21044D4 Braycote Tightening Torque; 66% Y Preload

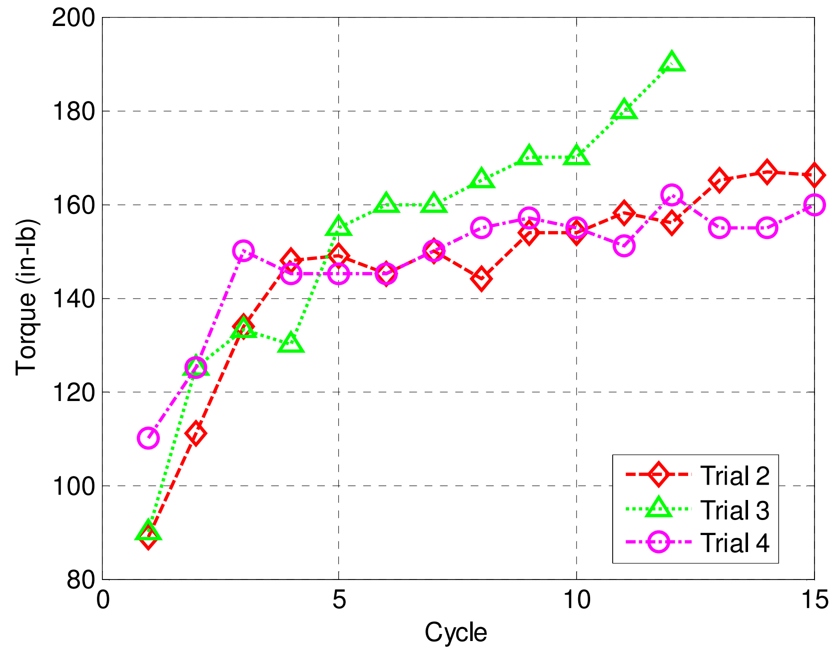

Figure D-153: MS21044D4 Braycote Breakloose Torque; 66% Y Preload

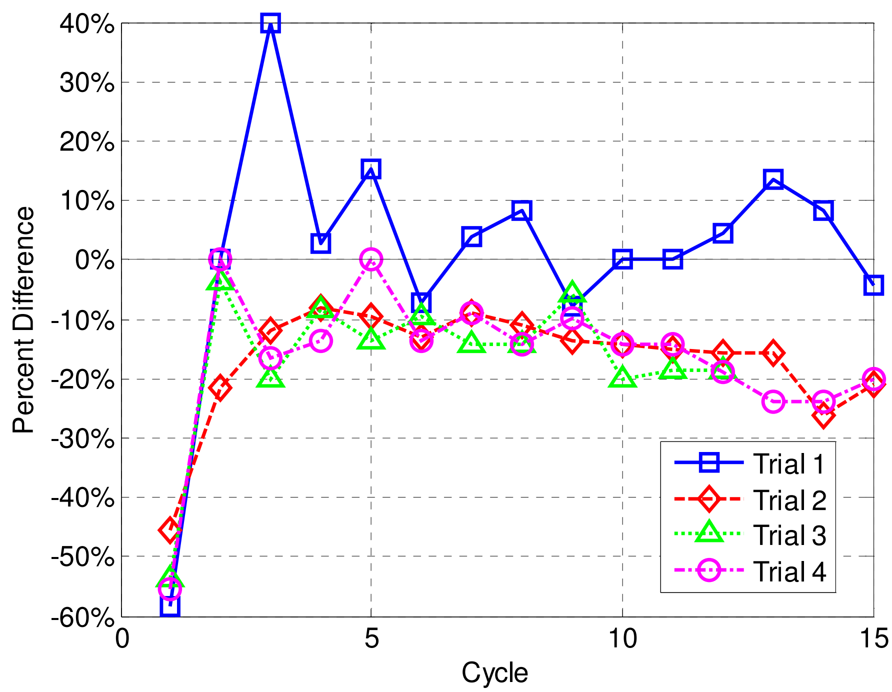

Figure D-154: MS21044D4 Braycote Percent Difference; 66% Y Preload

Appendix D (Continued)

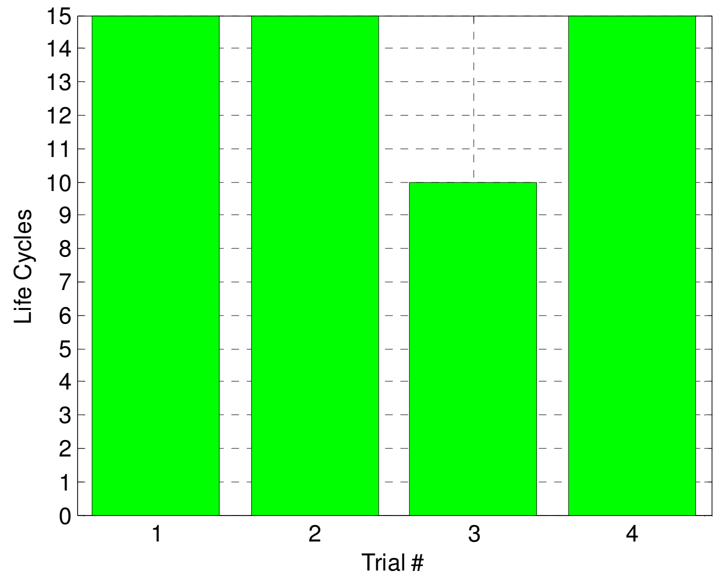

Figure D-155: MS21044D4 Braycote Life; 66% Y Preload

D.6.3 75% Y Preload – Braycote

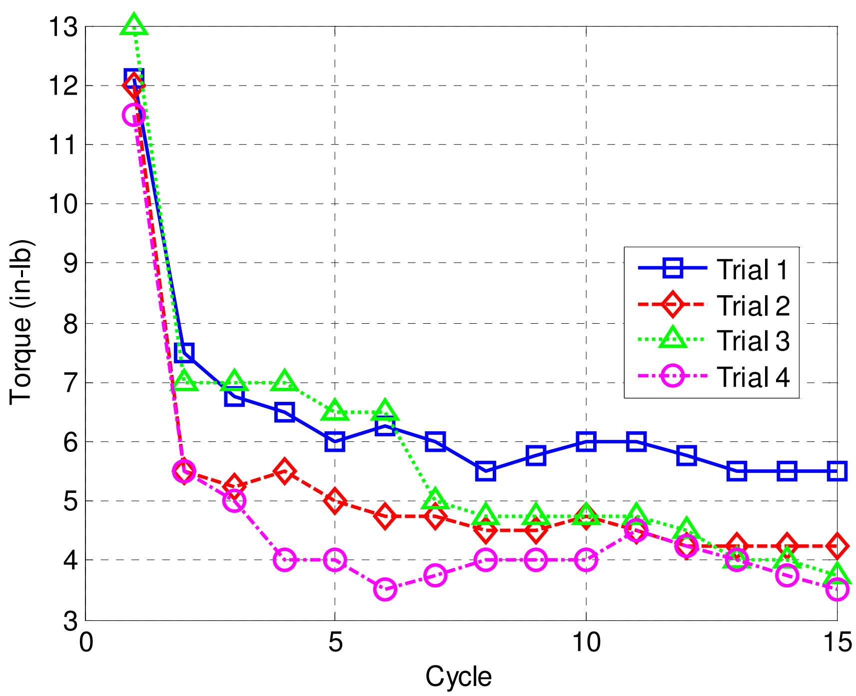

Figure D-156: MS21044D4 Braycote Assembly Prevailing Torque; 75% Y Preload

Appendix D (Continued)

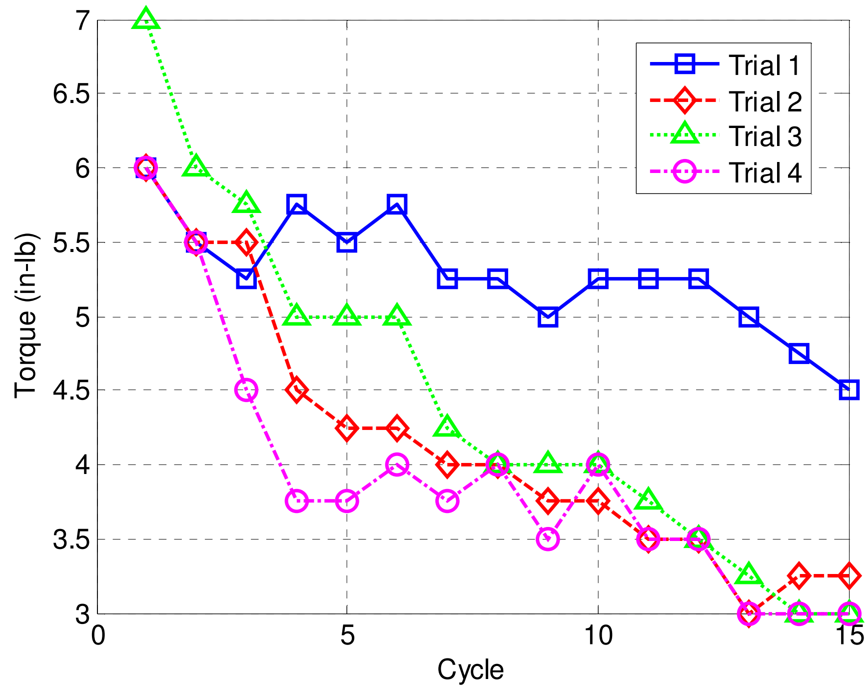

Figure D-157: MS21044D4 Braycote Removal Prevailing Torque; 75% Y Preload

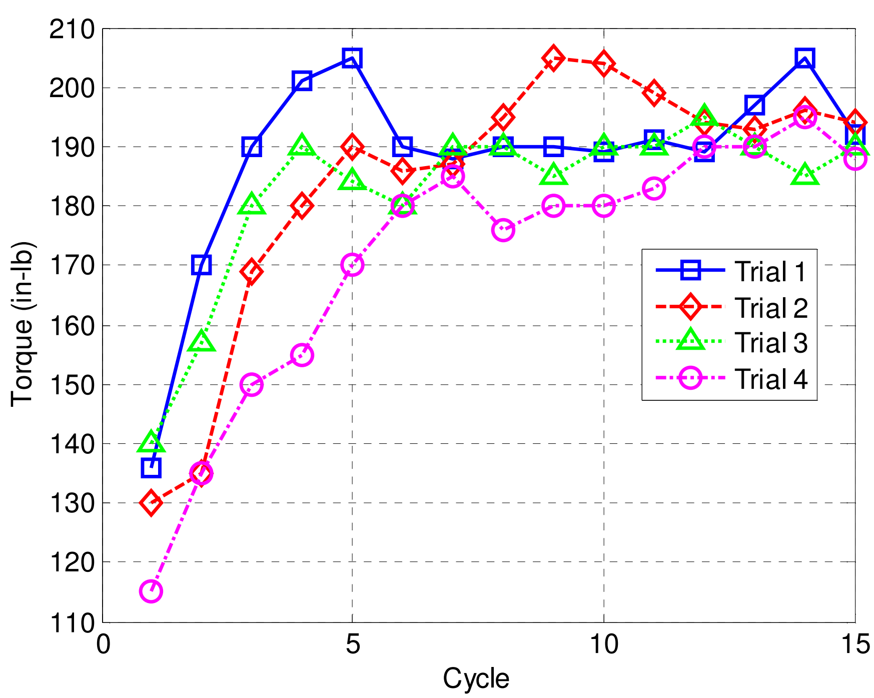

Figure D-158: MS21044D4 Braycote Tightening Torque; 75% Y Preload

Appendix D (Continued)

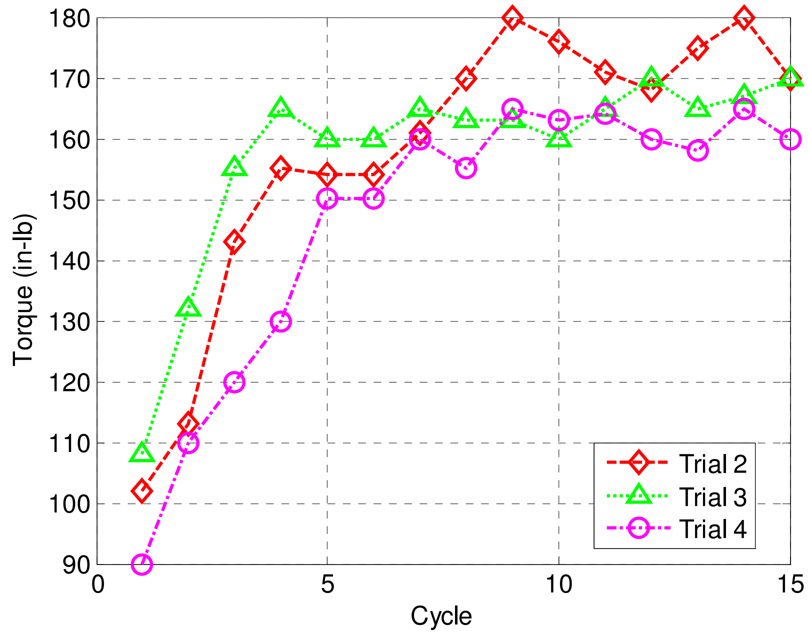

Figure D-159: MS21044D4 Braycote Breakloose Torque; 75% Y Preload

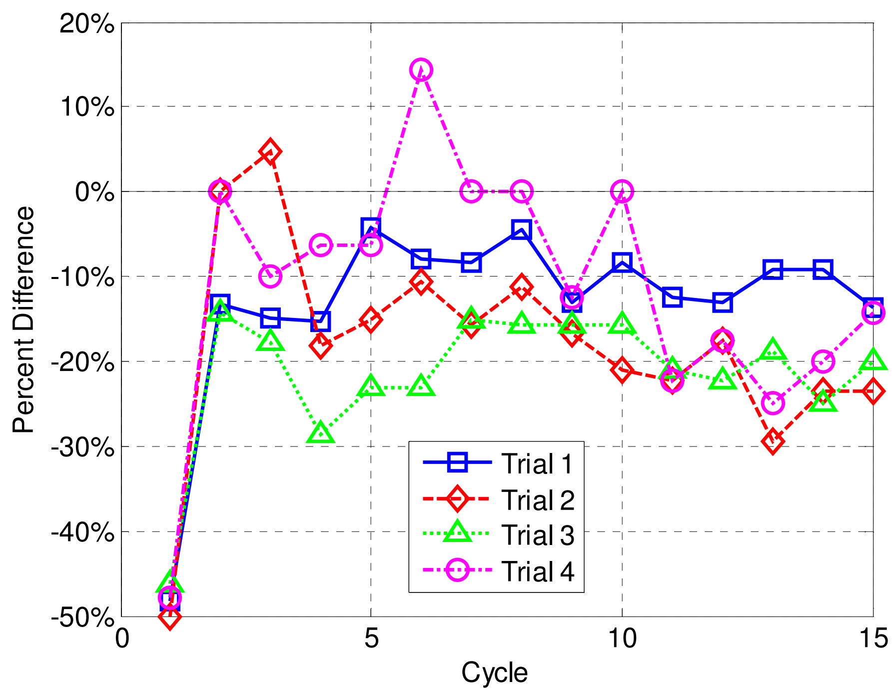

Figure D-160: MS21044D4 Braycote Percent Difference; 75% Y Preload

Appendix D (Continued)

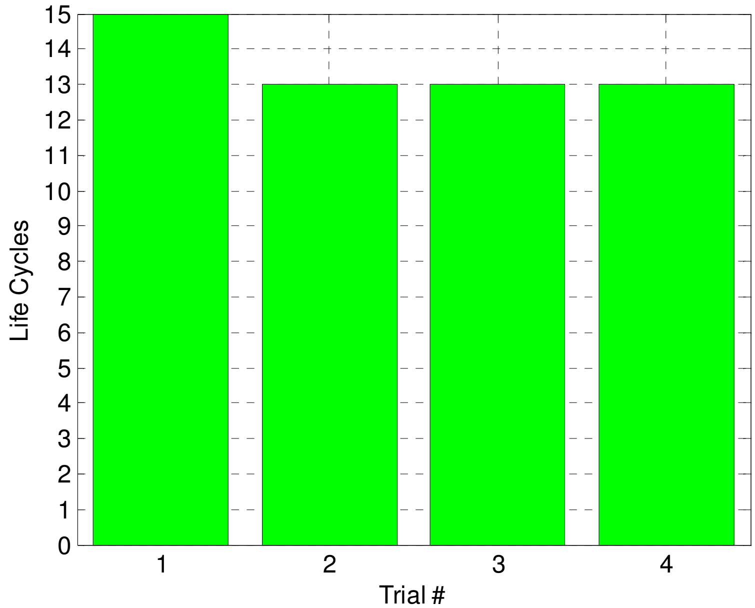

Figure D-161: MS21044D4 Braycote Life; 75% Y Preload

D.6.4 85% Y Preload – Braycote

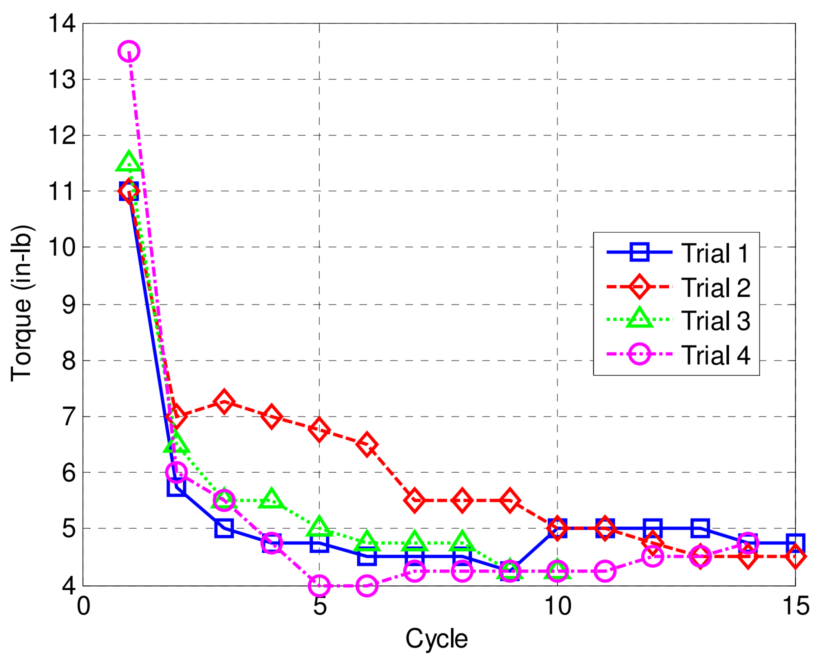

Figure D-162: MS21044D4 Braycote Assembly Prevailing Torque; 85% Y Preload

Appendix D (Continued)

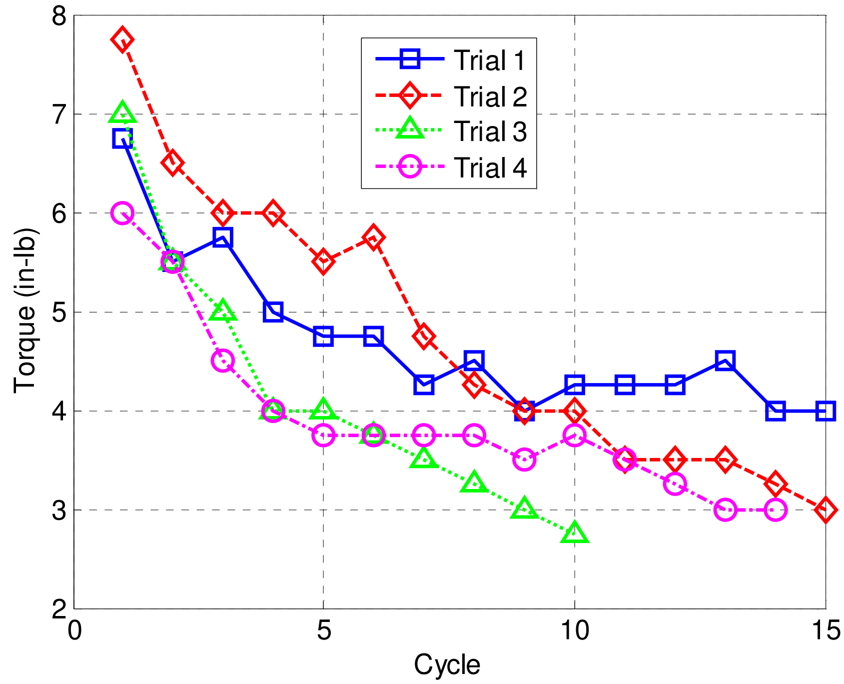

Figure D-163: MS21044D4 Braycote Removal Prevailing Torque; 85% Y Preload

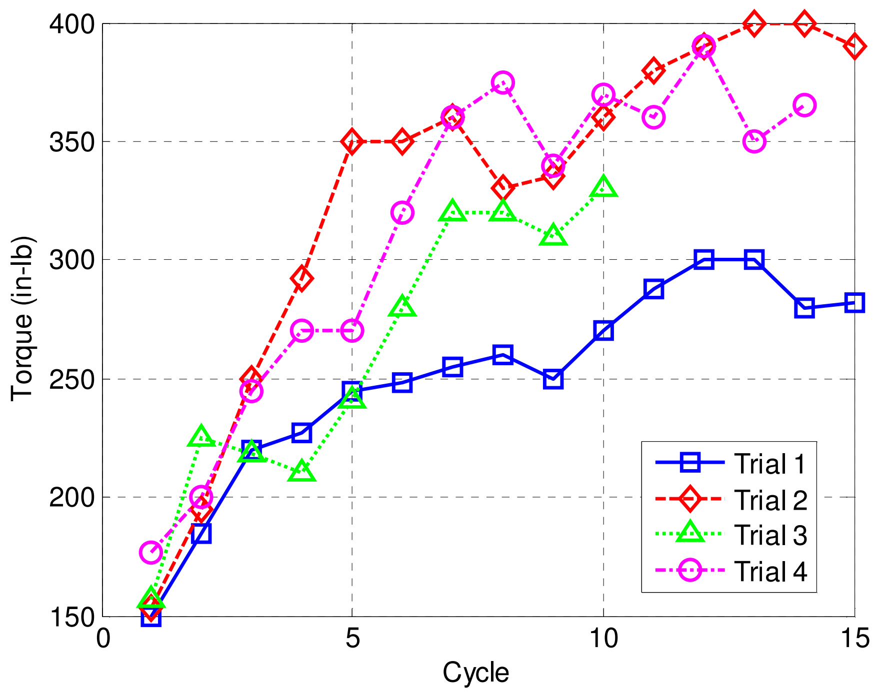

Figure D-164: MS21044D4 Braycote Tightening Torque; 85% Y Preload

Appendix D (Continued)

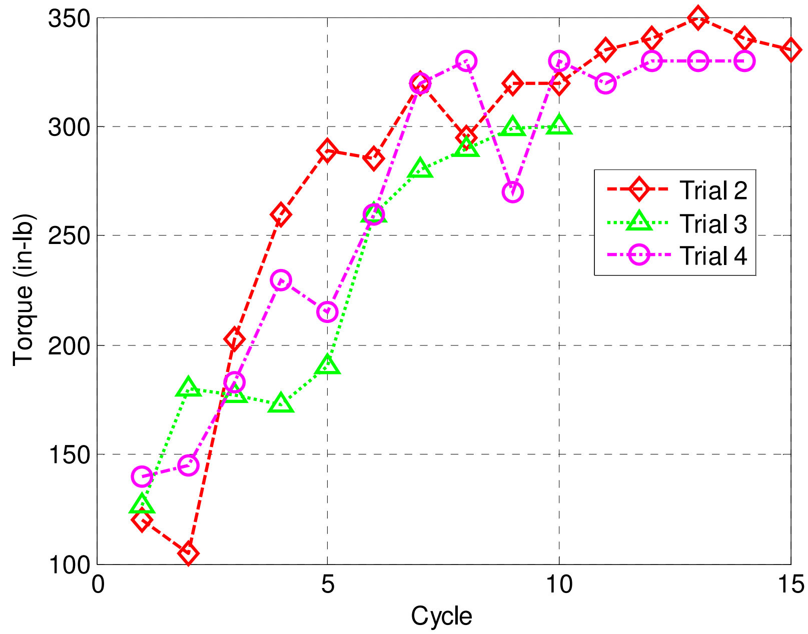

Figure D-165: MS21044D4 Braycote Breakloose Torque; 85% Y Preload

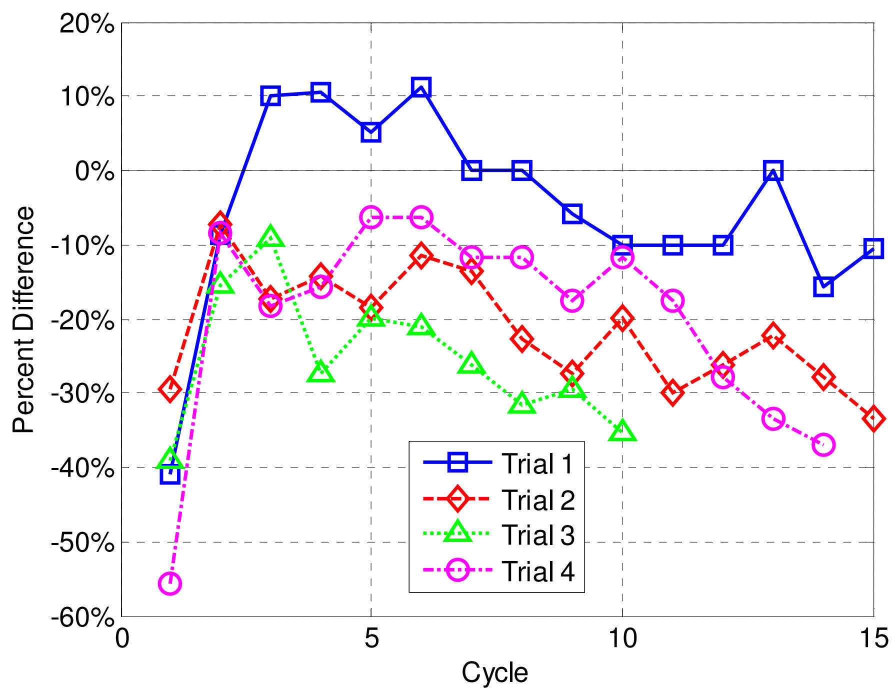

Figure D-166: MS21044D4 Braycote Percent Difference; 85% Y Preload

Appendix D (Continued)

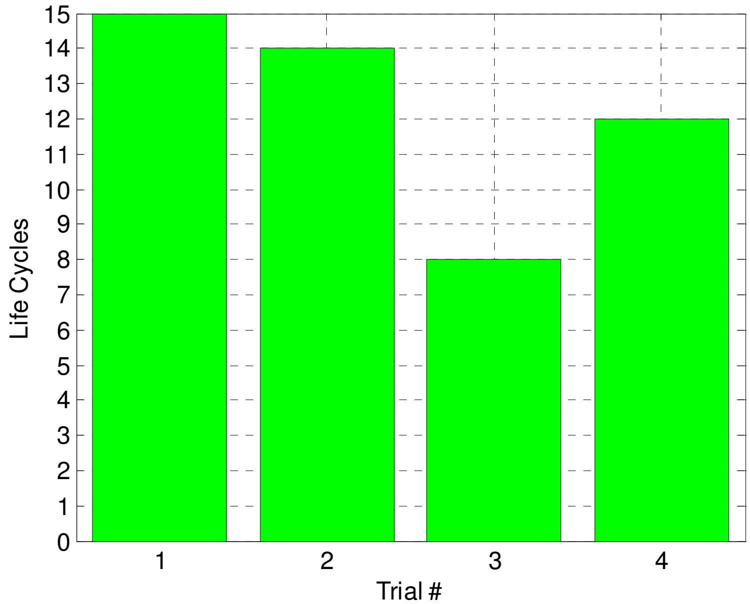

Figure D-167: MS21044D4 Braycote Life; 85% Y Preload

D.6.5 Preload Averages – Braycote

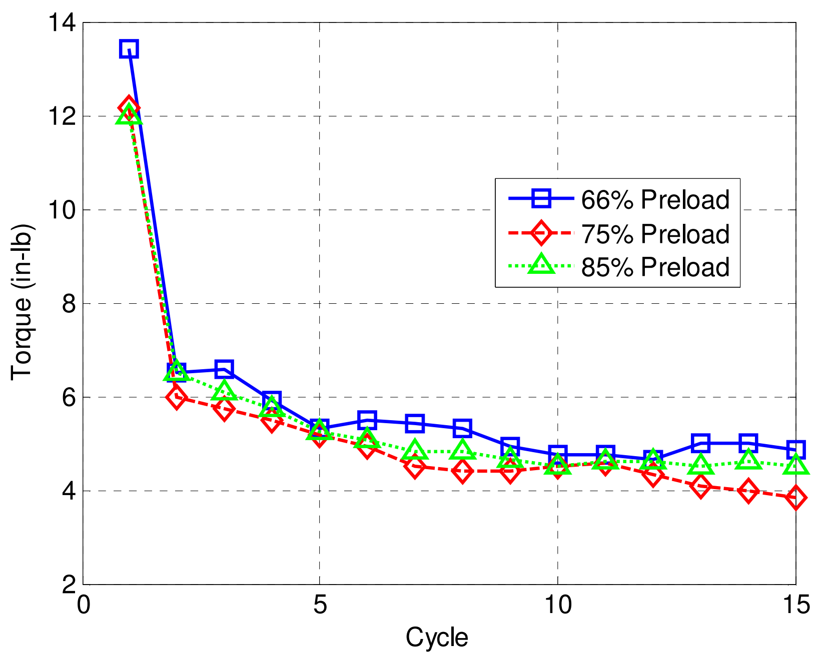

Figure D-168: MS21044D4 Braycote Assembly Prevailing Torque; Preload Average

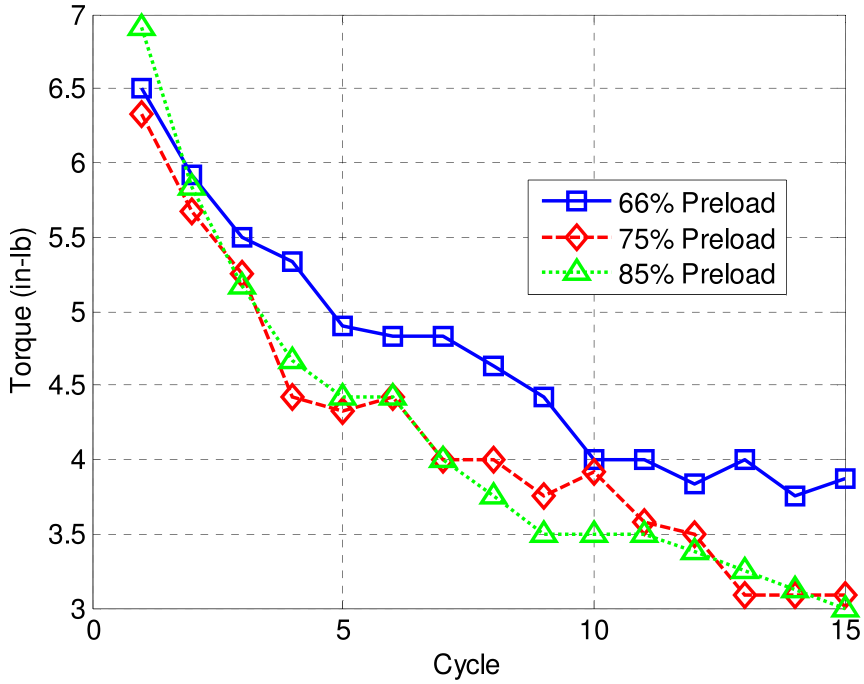

Figure D-169: MS21044D4 Braycote Removal Prevailing Torque; Preload Average

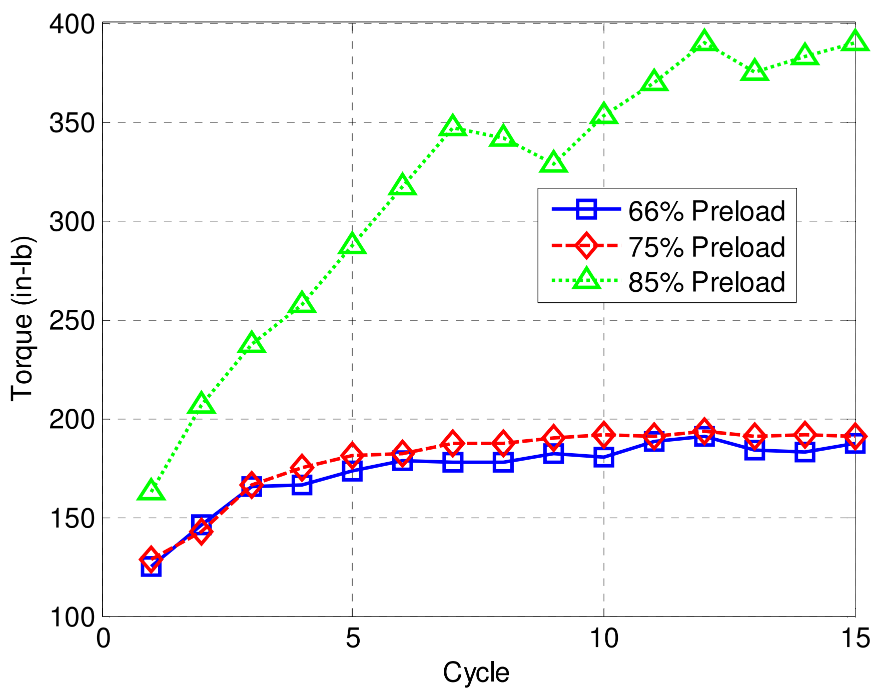

Figure D-170: MS21044D4 Braycote Tightening Torque; Preload Average

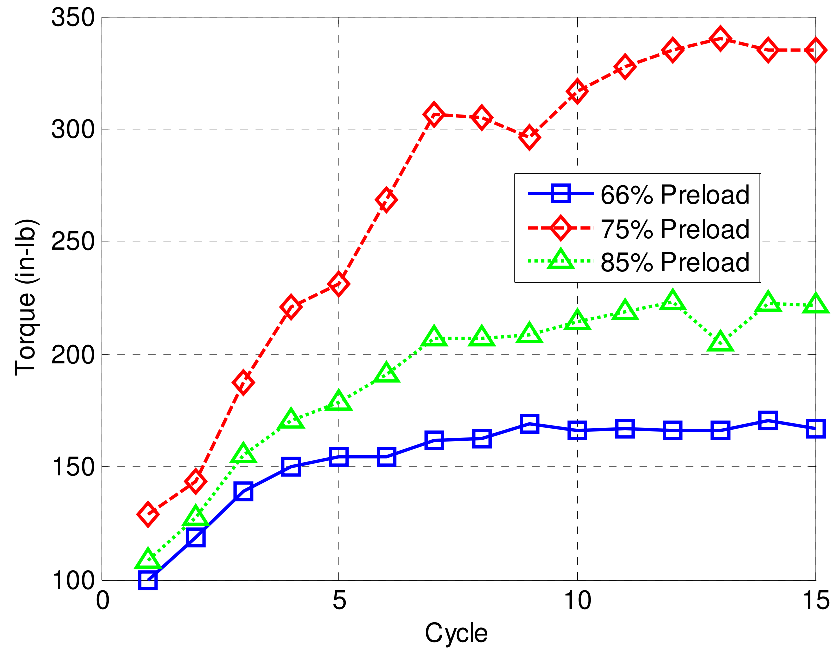

Figure D-171: MS21044D4 Braycote Breakloose Torque; Preload Average

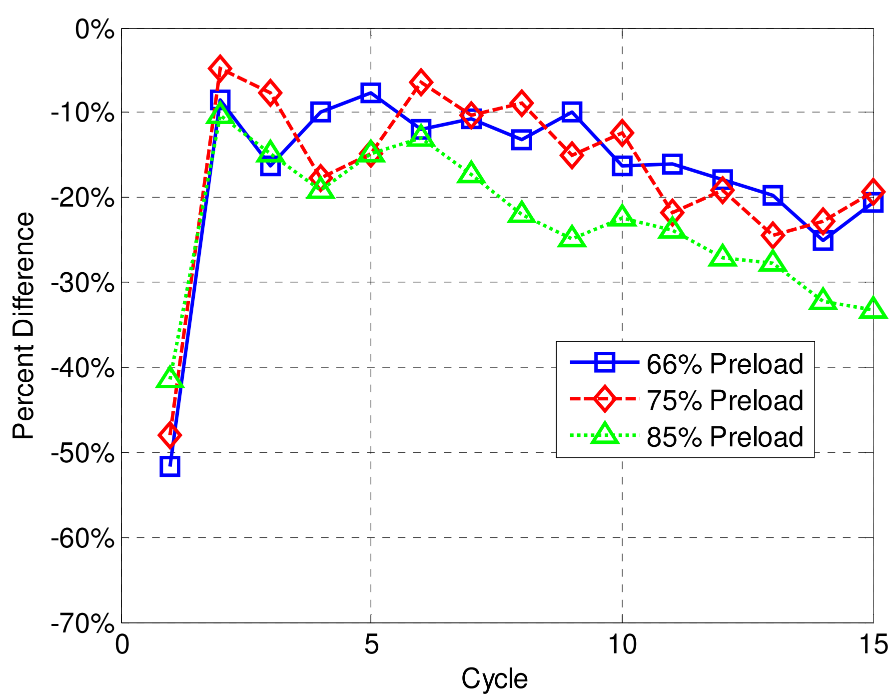

Figure D-172: MS21044D4 Braycote Percent Difference; Preload Average

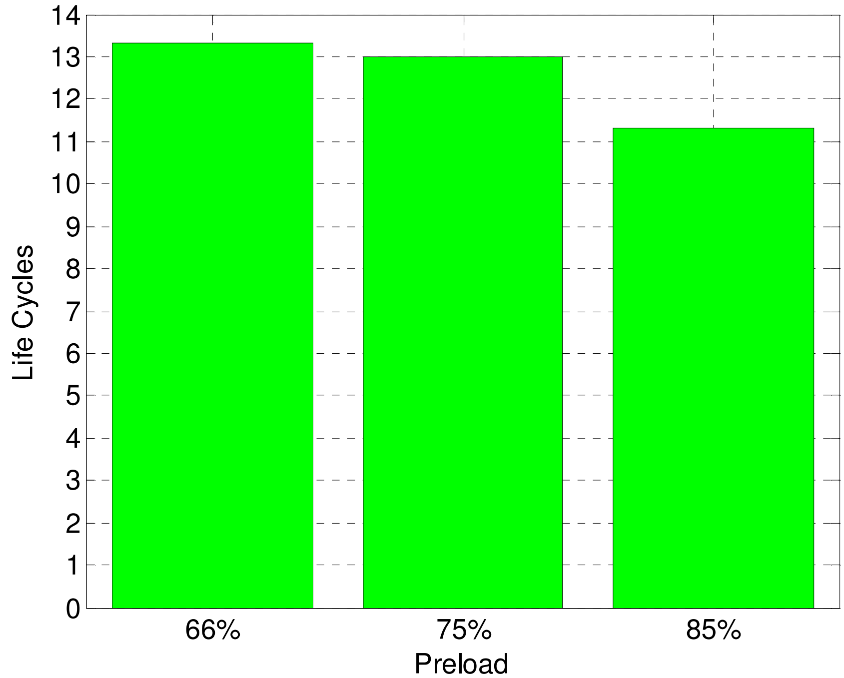

Figure D-173: MS21044D4 Braycote Life; Preload Average

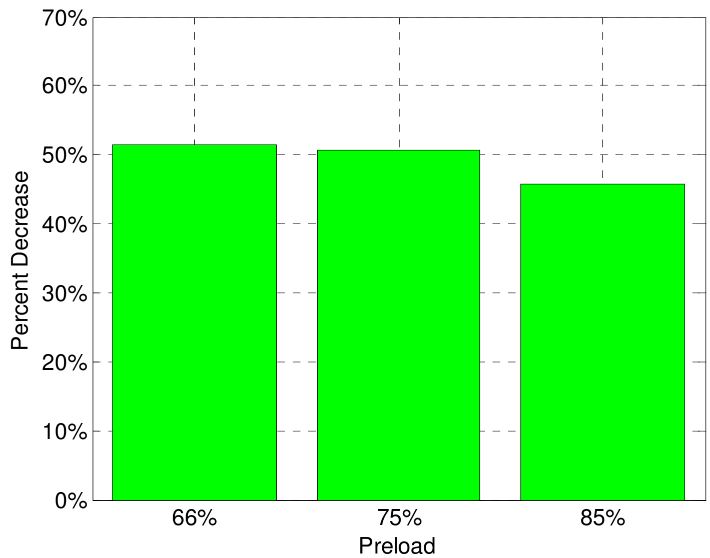

Figure D-174: MS21044D4 Braycote Percent Decrease of Assembly Prevailing Torque from Cycle 1 to 2; Preload Average

D.7 MS21044D4 Lubrication Comparison

D.7.1 Unseated

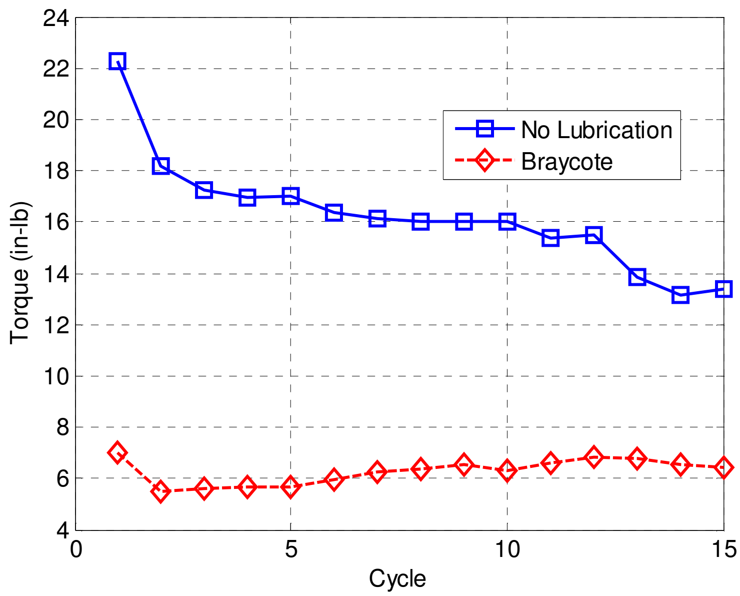

Figure D-175: MS21044D4 Lubrication Comparison Assembly Prevailing Torque; Unseated

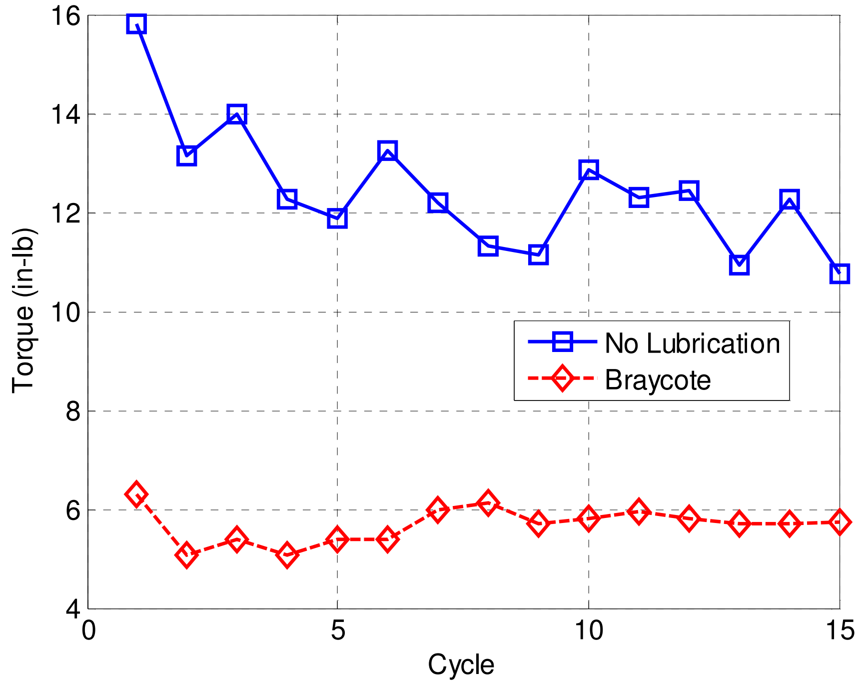

Figure D-176: MS21044D4 Lubrication Comparison Removal Prevailing Torque; Unseated

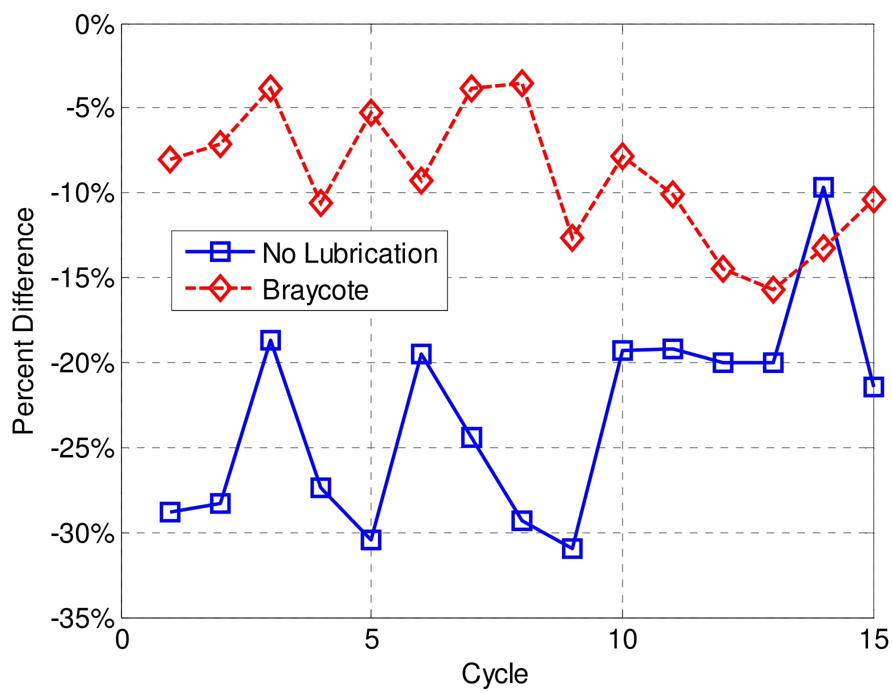

Figure D-177: MS21044D4 Lubrication Comparison Percent Difference; Unseated

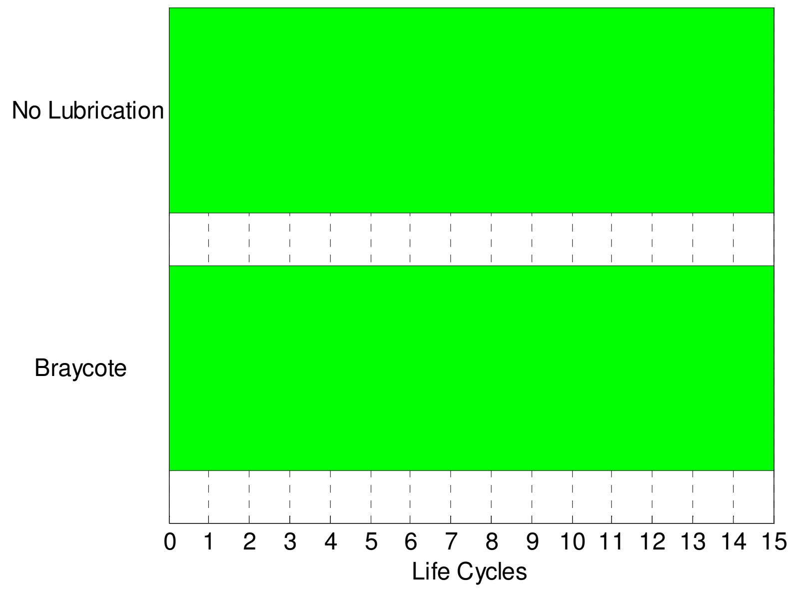

Figure D-178: MS21044D4 Lubrication Comparison Life; Unseated

D.7.2 66% Y Preload

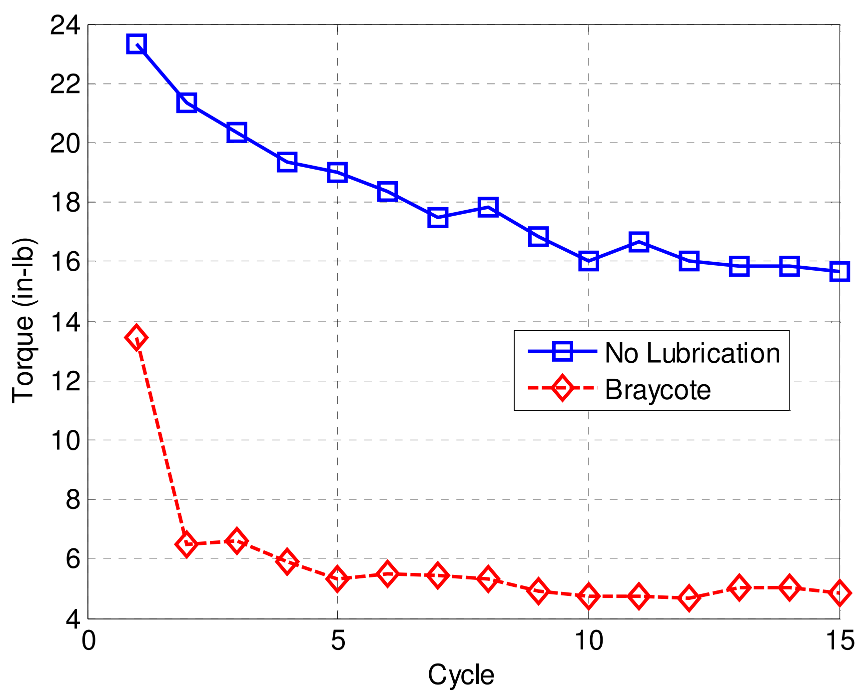

Figure D-179: MS21044D4 Lubrication Comparison Assembly Prevailing Torque; 66% Y Preload

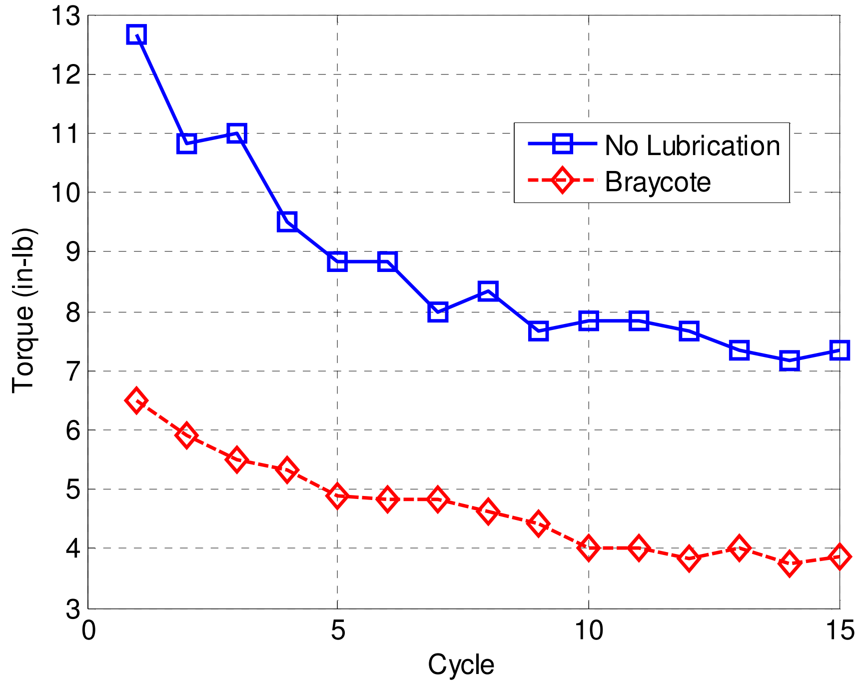

Figure D-180: MS21044D4 Lubrication Comparison Removal Prevailing Torque; 66% Y Preload

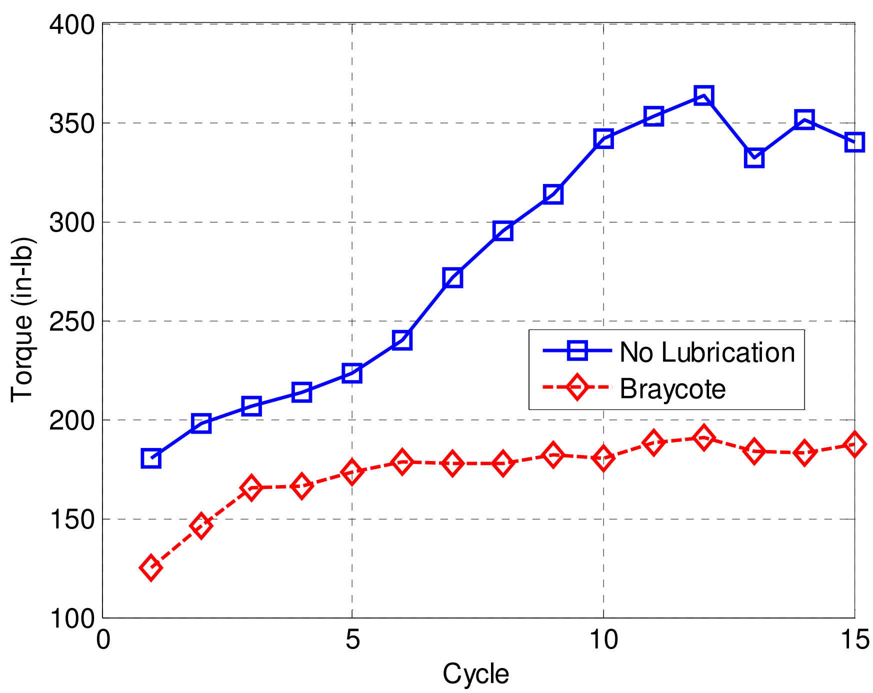

Figure D-181: MS21044D4 Lubrication Comparison Tightening Torque; 66% Y Preload

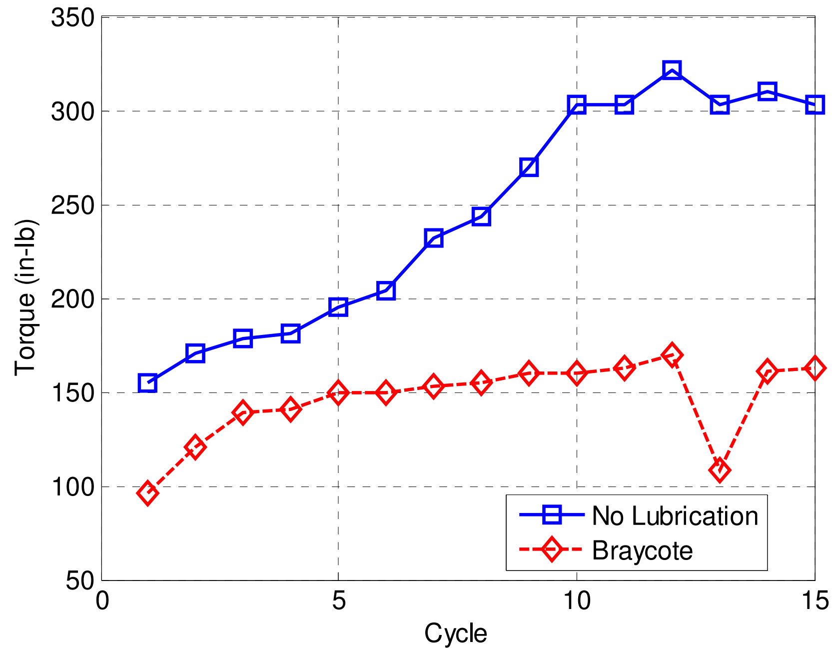

Figure D-182: MS21044D4 Lubrication Comparison Breakloose Torque; 66% Y Preload

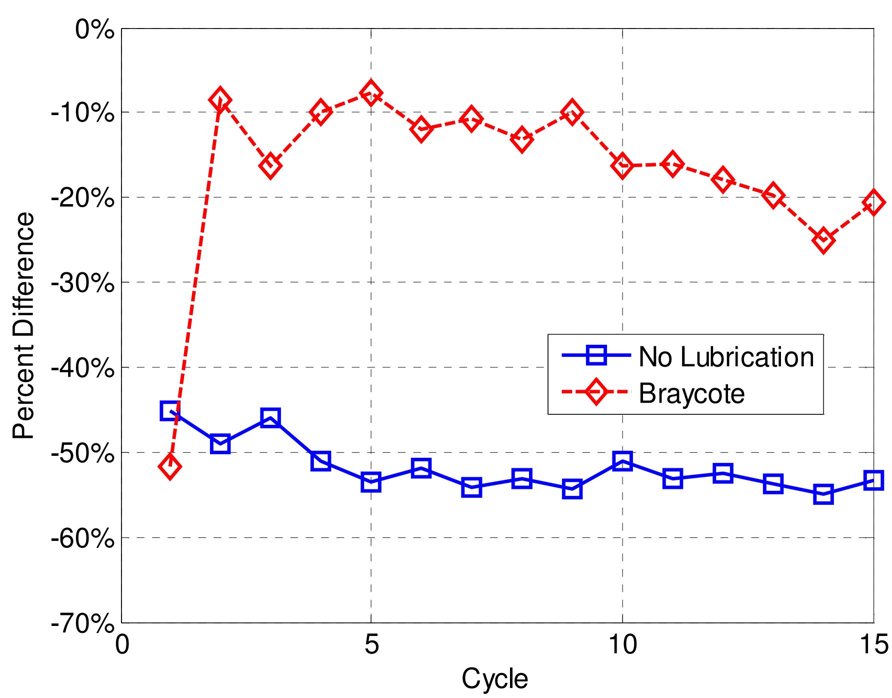

Figure D-183: MS21044D4 Lubrication Comparison Percent Difference; 66% Y Preload

Appendix D (Continued)

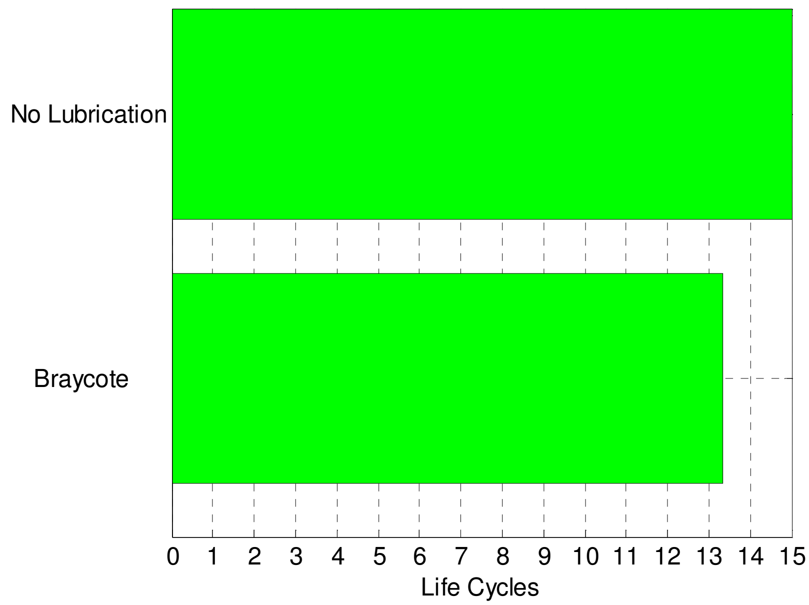

Figure D-184: MS21044D4 Lubrication Comparison Life; 66% Y Preload

D.7.3 75% Y Preload

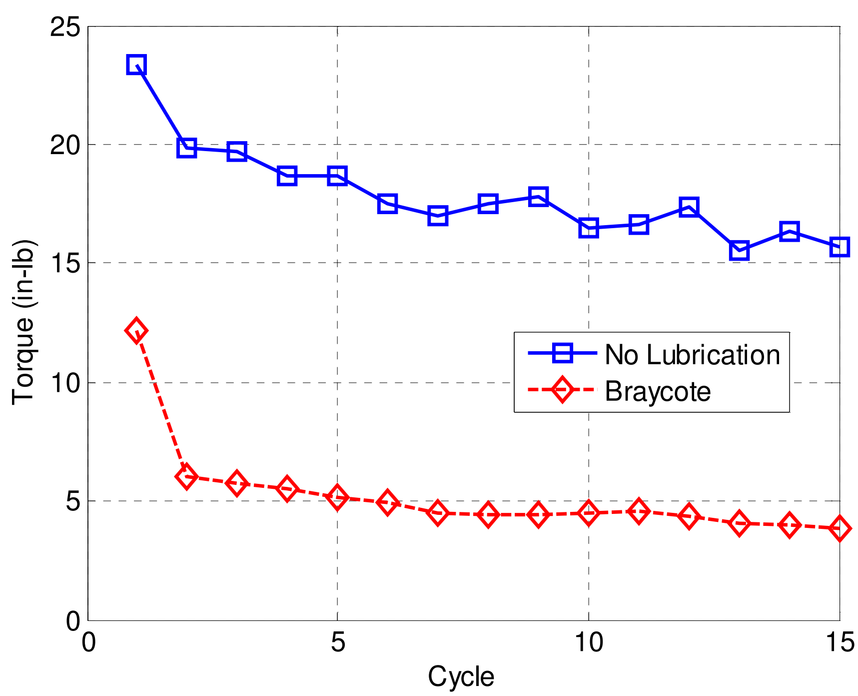

Figure D-185: MS21044D4 Lubrication Comparison Assembly Prevailing Torque; 75% Y Preload

Appendix D (Continued)

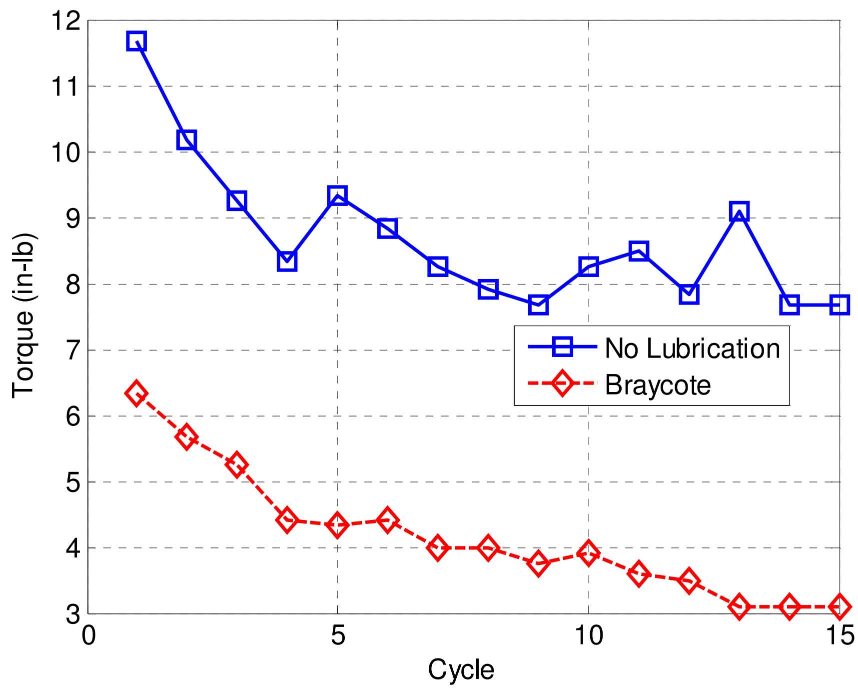

Figure D-186: MS21044D4 Lubrication Comparison Removal Prevailing Torque; 75% Y Preload

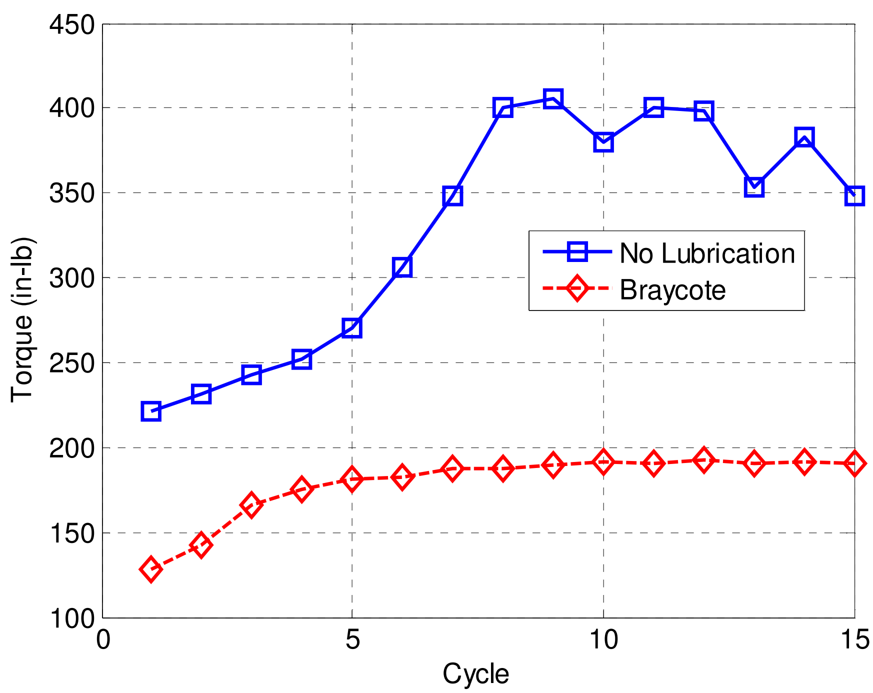

Figure D-187: MS21044D4 Lubrication Comparison Tightening Torque; 75% Y Preload

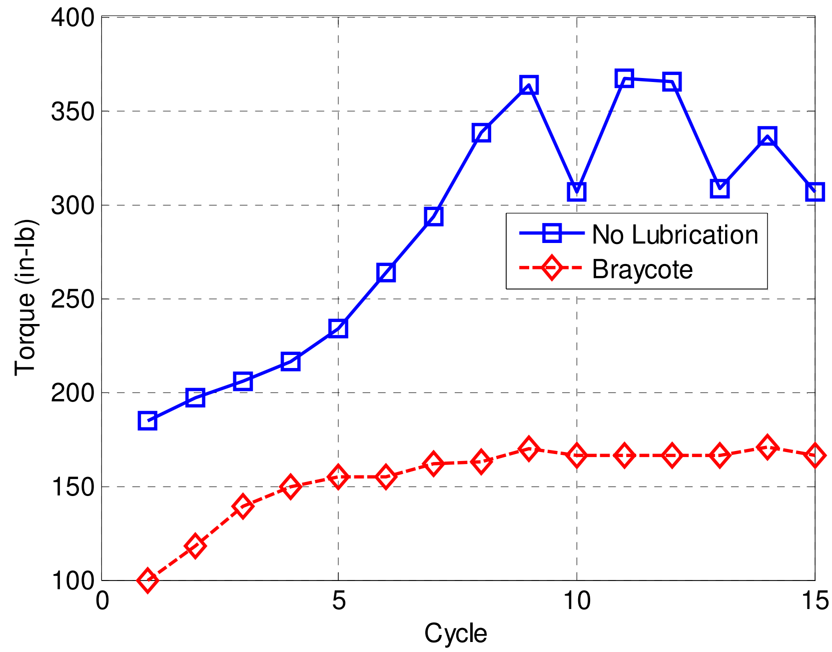

Figure D-188: MS21044D4 Lubrication Comparison Breakloose Torque; 75% Y Preload

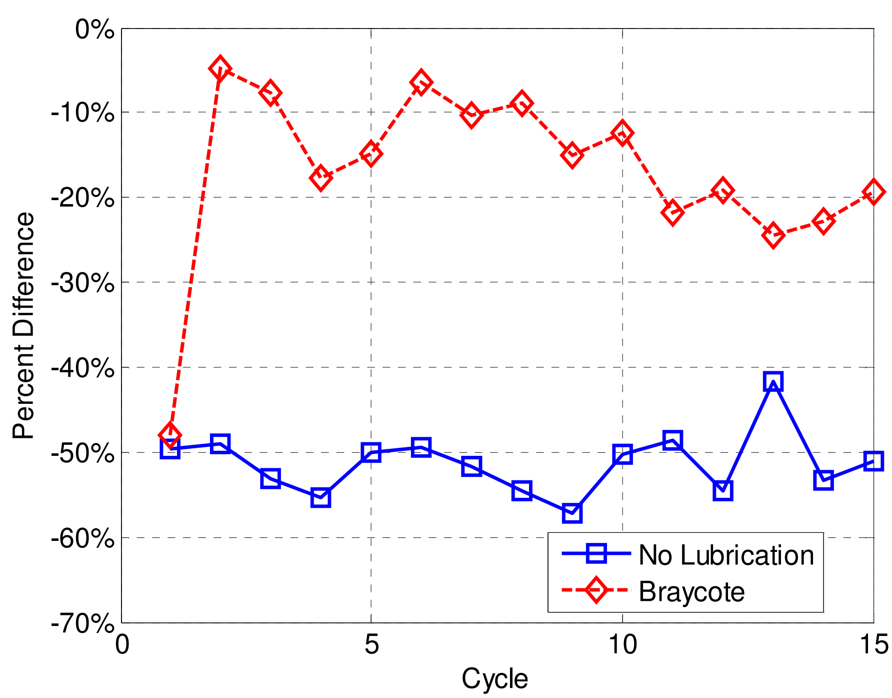

Figure D-189: MS21044D4 Lubrication Comparison Percent Difference; 75% Y Preload

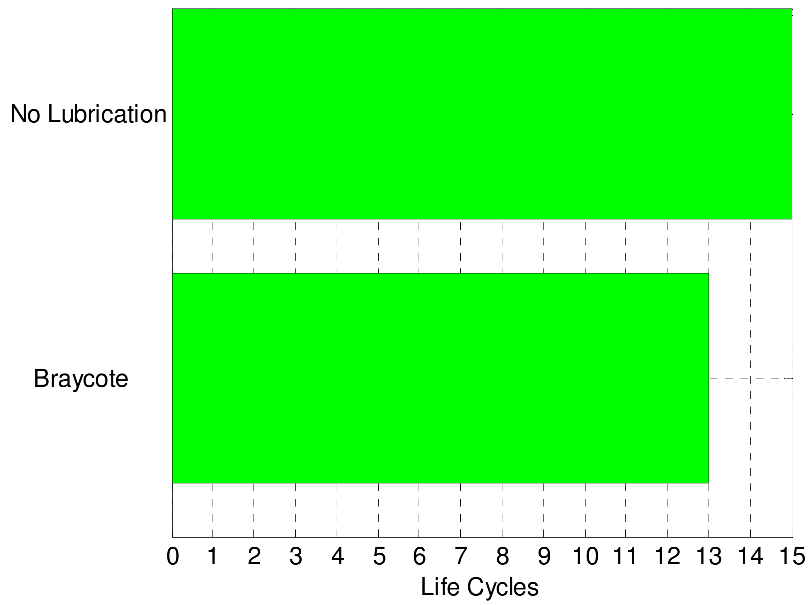

Figure D-190: MS21044D4 Lubrication Comparison Life; 75% Y Preload

D.7.4 85% Y Preload

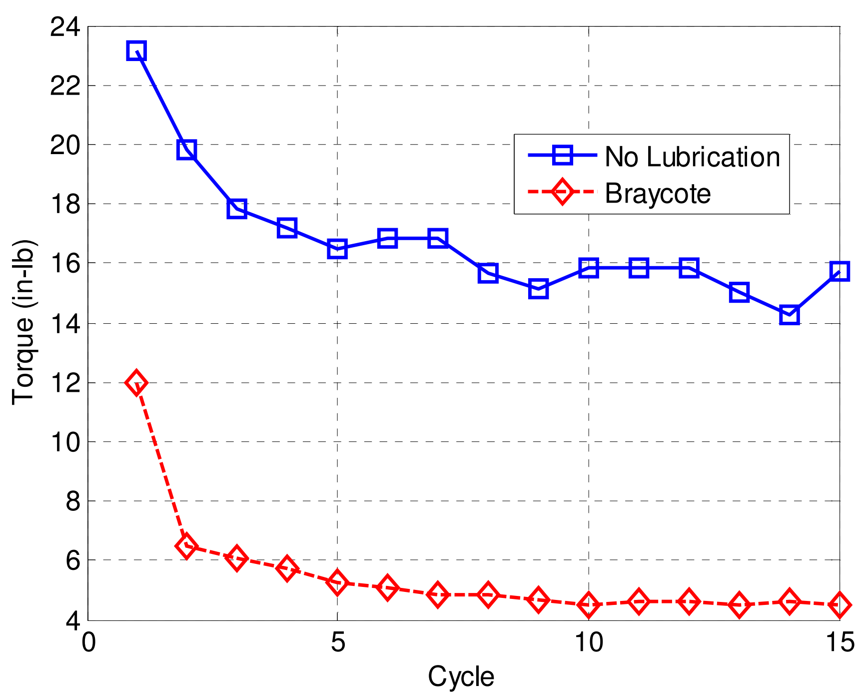

Figure D-191: MS21044D4 Lubrication Comparison Assembly Prevailing Torque; 85% Y Preload

Appendix D (Continued)

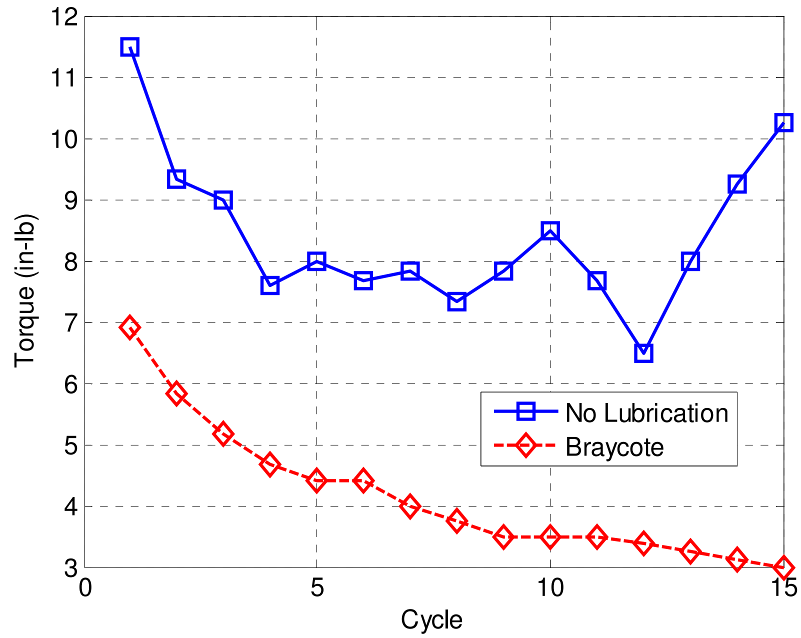

Figure D-192: MS21044D4 Lubrication Comparison Removal Prevailing Torque; 85% Y Preload

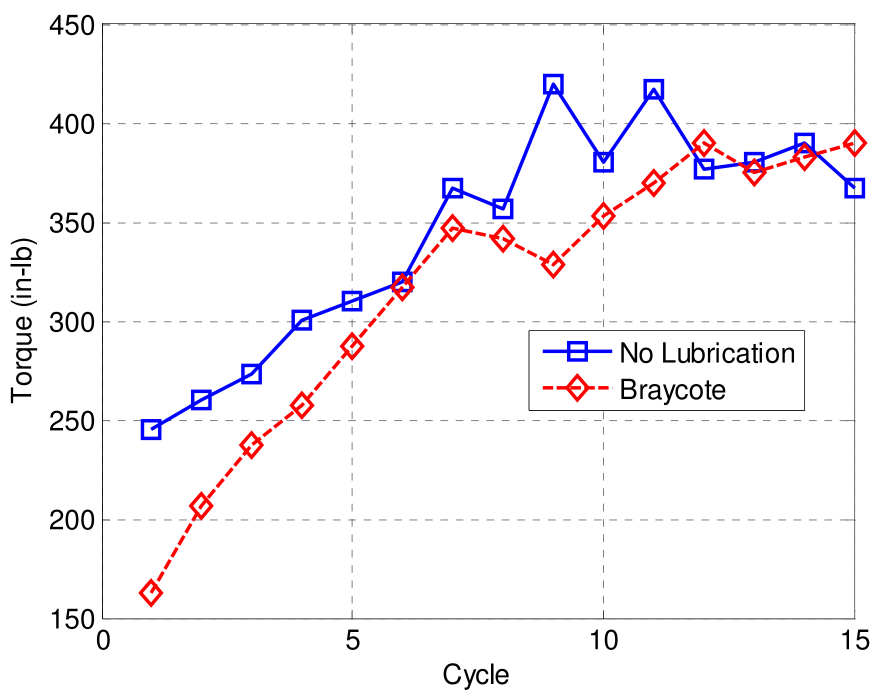

Figure D-193: MS21044D4 Lubrication Comparison Tightening Torque; 85% Y Preload

Appendix D (Continued)

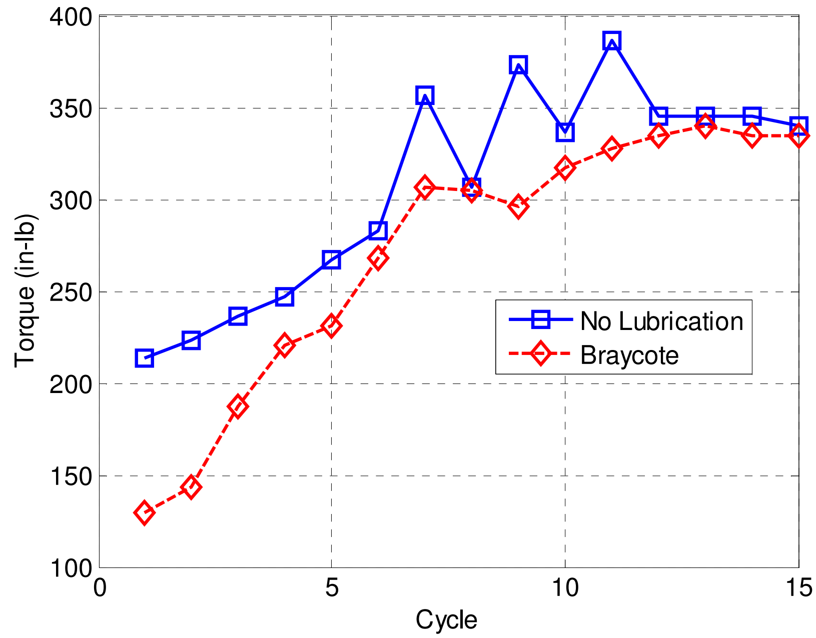

Figure D-194: MS21044D4 Lubrication Comparison Breakloose Torque; 85% Y Preload

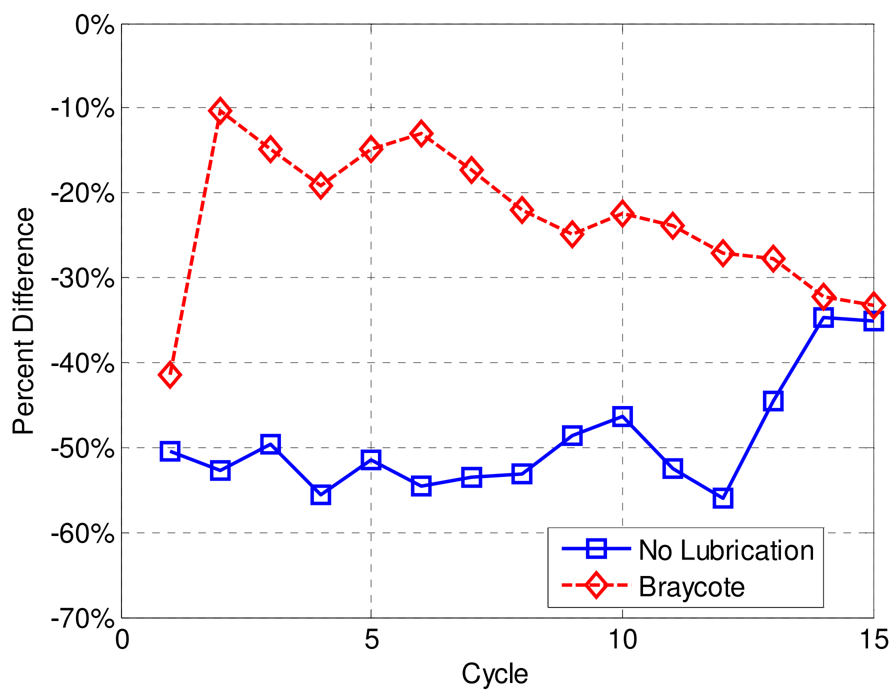

Figure D-195: MS21044D4 Lubrication Comparison Percent Difference; 85% Y Preload

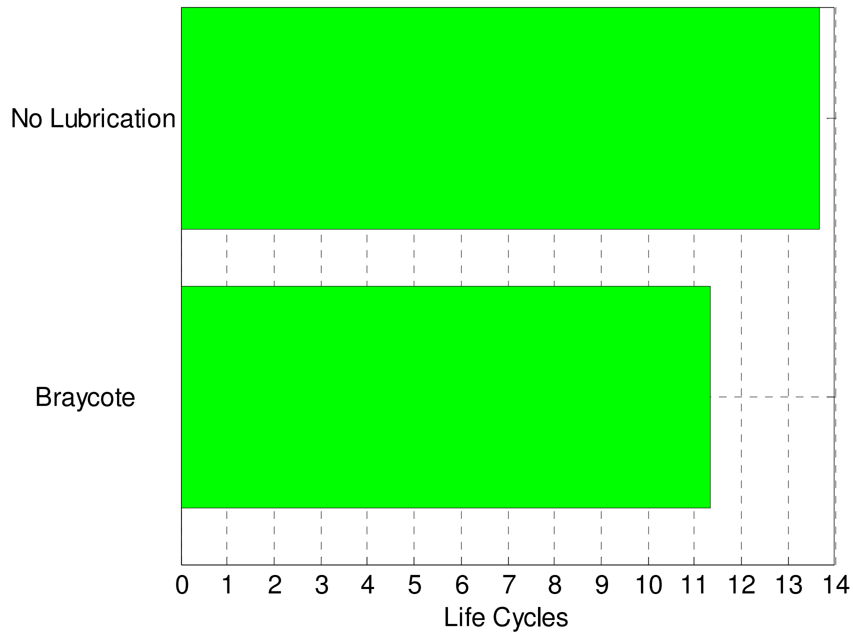

Figure D-196: MS21044D4 Lubrication Comparison Life; 85% Y Preload

D.7.5 Averaged Preload Comparison

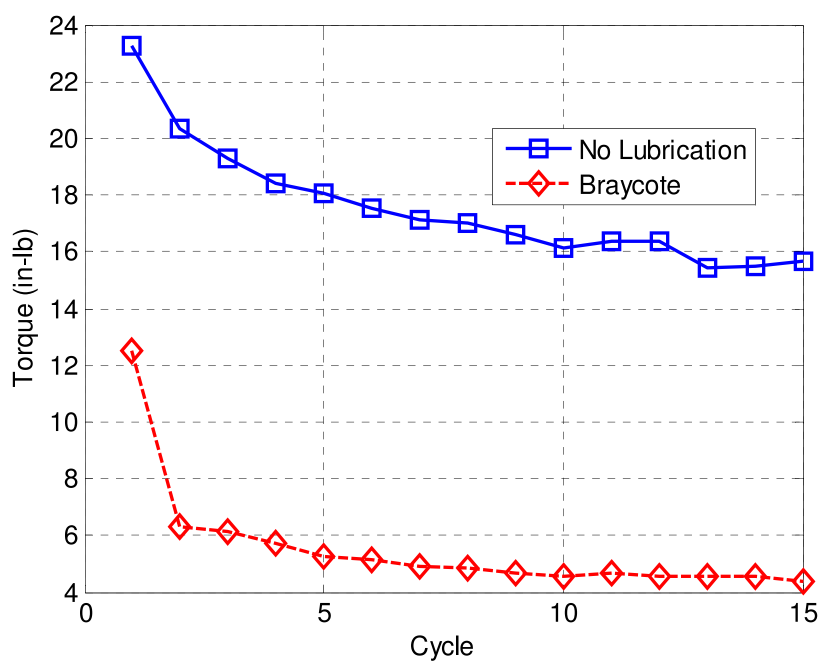

Figure D-197: MS21044D4 Lubrication Comparison Assembly Prevailing Torque; Preload Average

Appendix D (Continued)

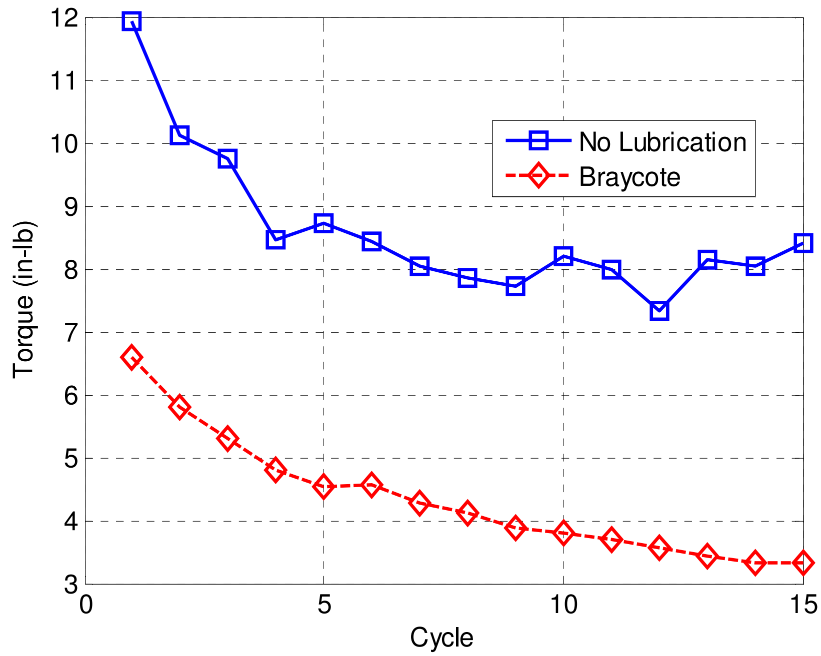

Figure D-198: MS21044D4 Lubrication Comparison Removal Prevailing Torque; Preload Average

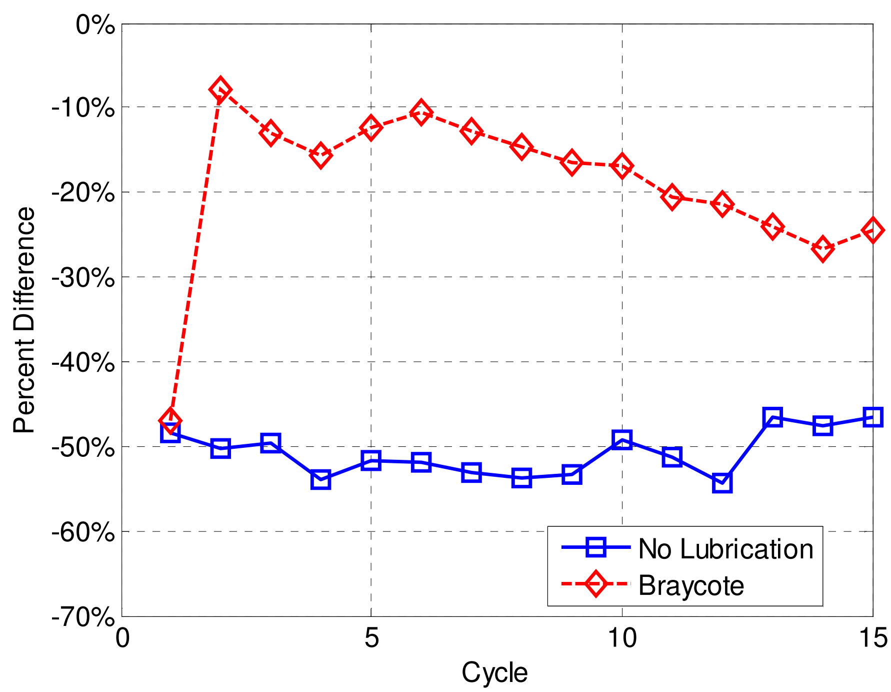

Figure D-199: MS21044D4 Lubrication Comparison Percent Difference; Preload Average

Appendix D (Continued)

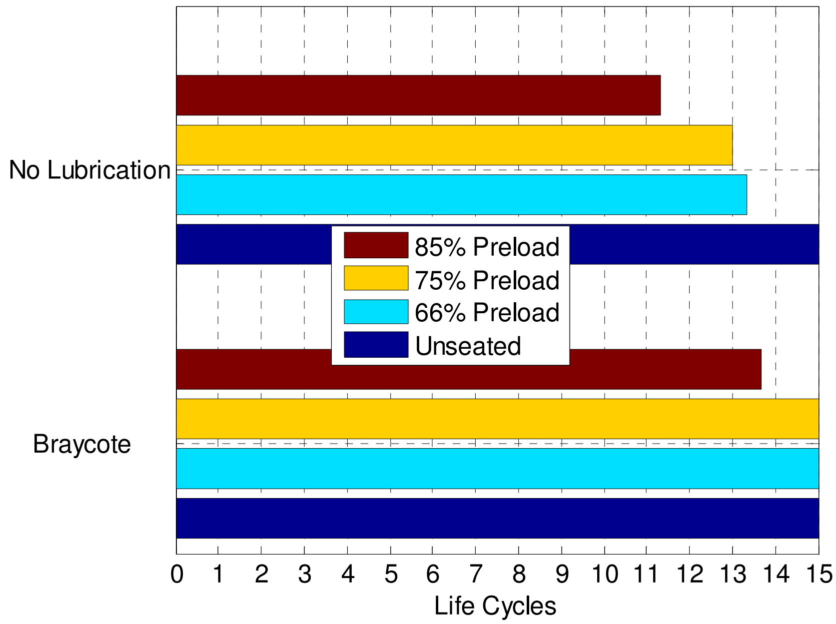

Figure D-200: MS21044D4 Lubrication Comparison Life

D.8 NAS1021N4

D.8.1 Unseated

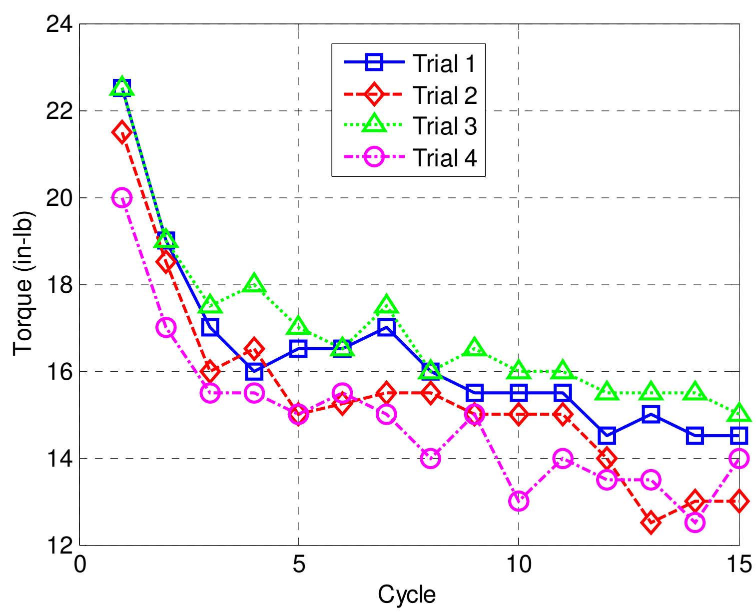

Figure D-201: NAS1021N4 Assembly Prevailing Torque; Unseated

Appendix D (Continued)

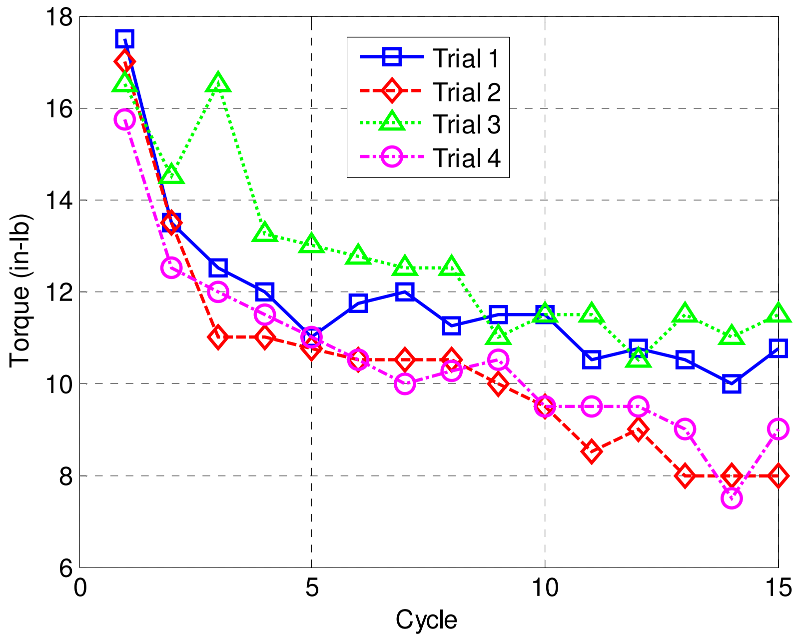

Figure D-202: NAS1021N4 Removal Prevailing Torque; Unseated

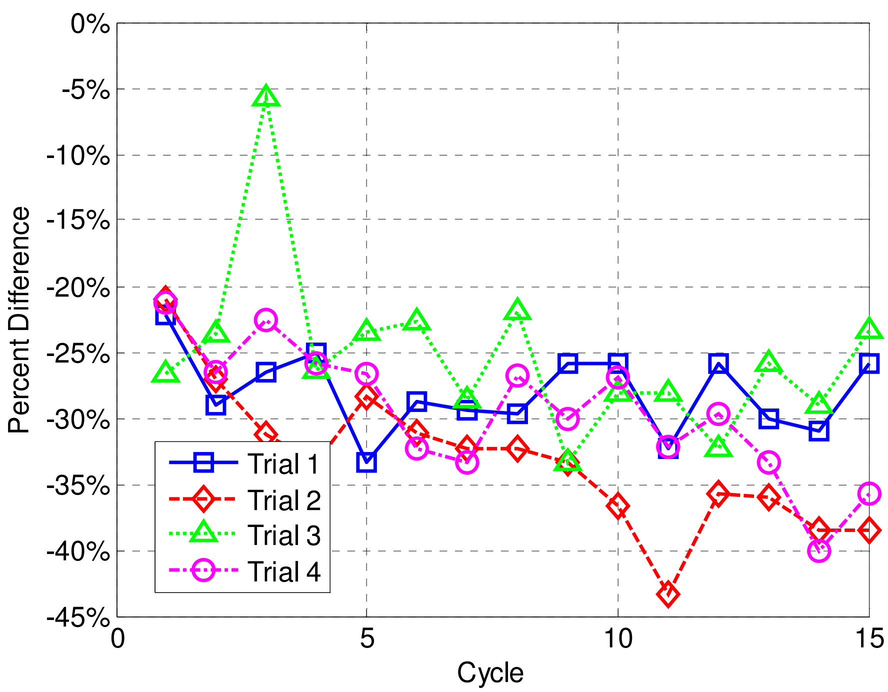

Figure D-203: NAS1021N4 Percent Difference; Unseated

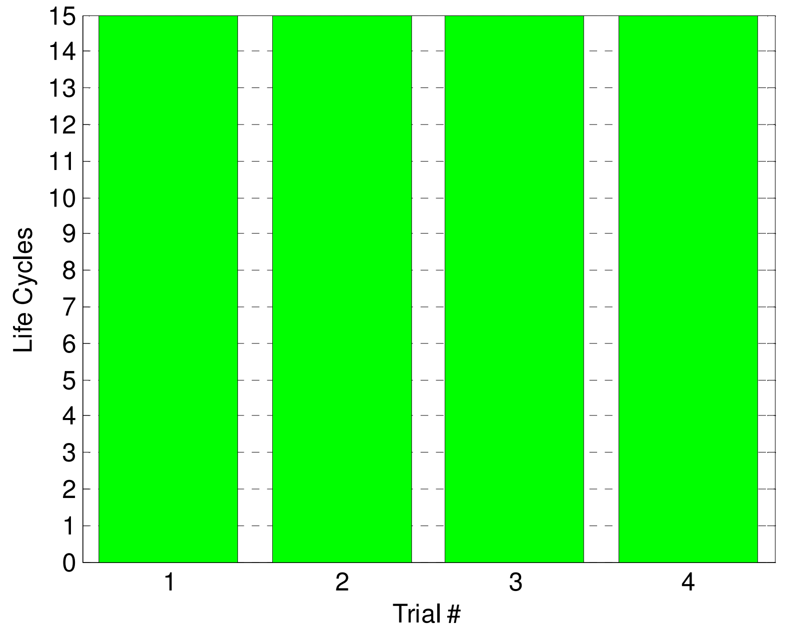

Figure D-204: NAS2021N4 Life; Unseated

D.8.2 66% Y Preload

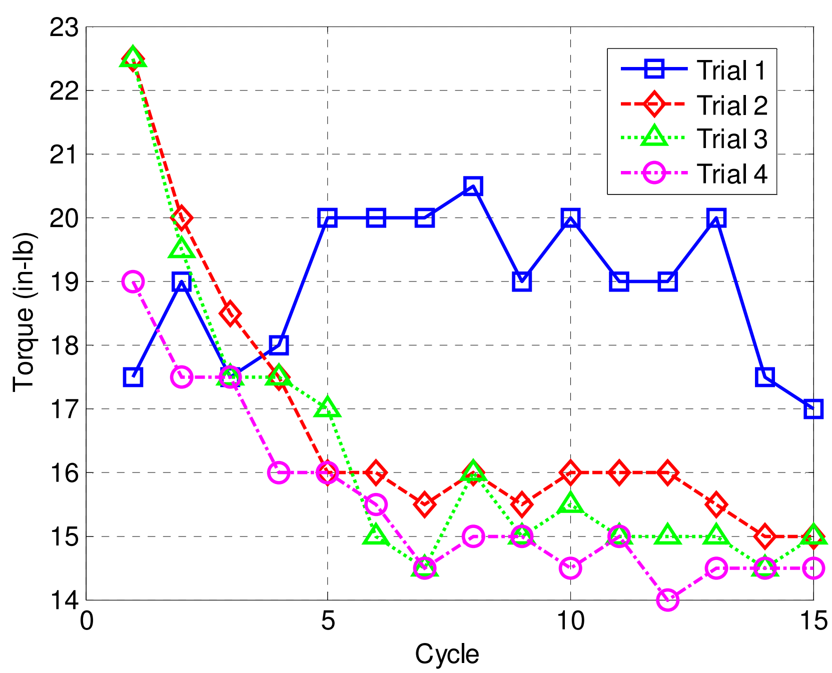

Figure D-205: NAS1021N4 Assembly Prevailing Torque; 66% Y Preload

Appendix D (Continued)

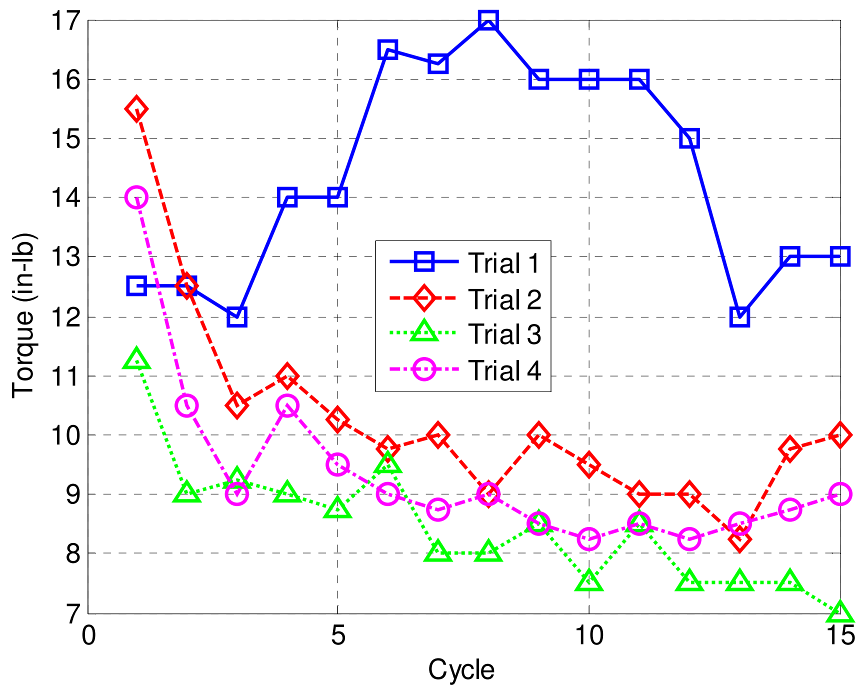

Figure D-206: NAS1021N4 Removal Prevailing Torque; 66% Y Preload

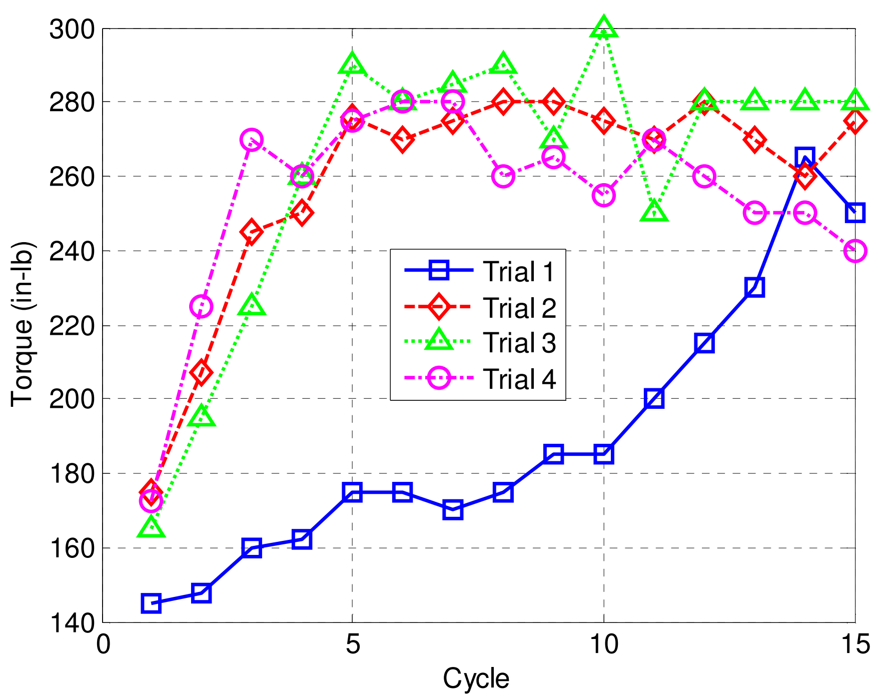

Figure D-207: NAS1021N4 Tightening Torque; 66% Y Preload

Appendix D (Continued)

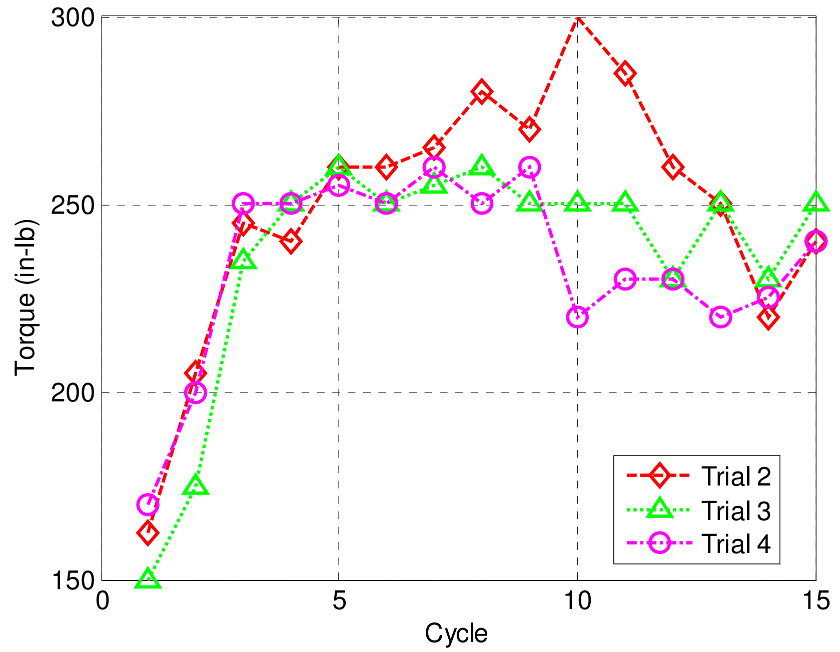

Figure D-208: NAS1021N4 Breakloose Torque; 66% Y Preload

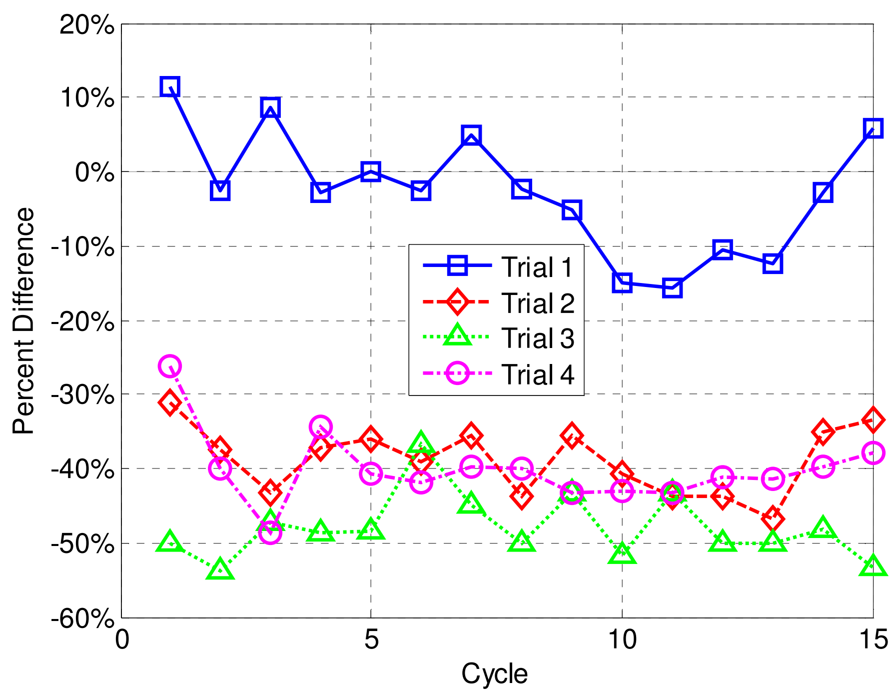

Figure D-209: NAS1021N4 Percent Difference; 66% Y Preload

Appendix D (Continued)

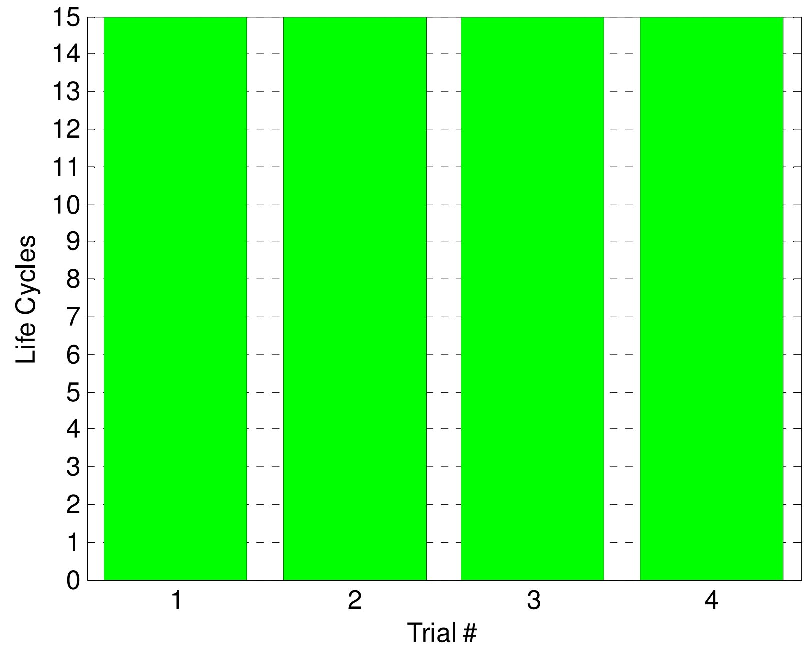

Figure D-210: NAS1021N4 Life; 66% Y Preload

D.8.3 75% Y Preload

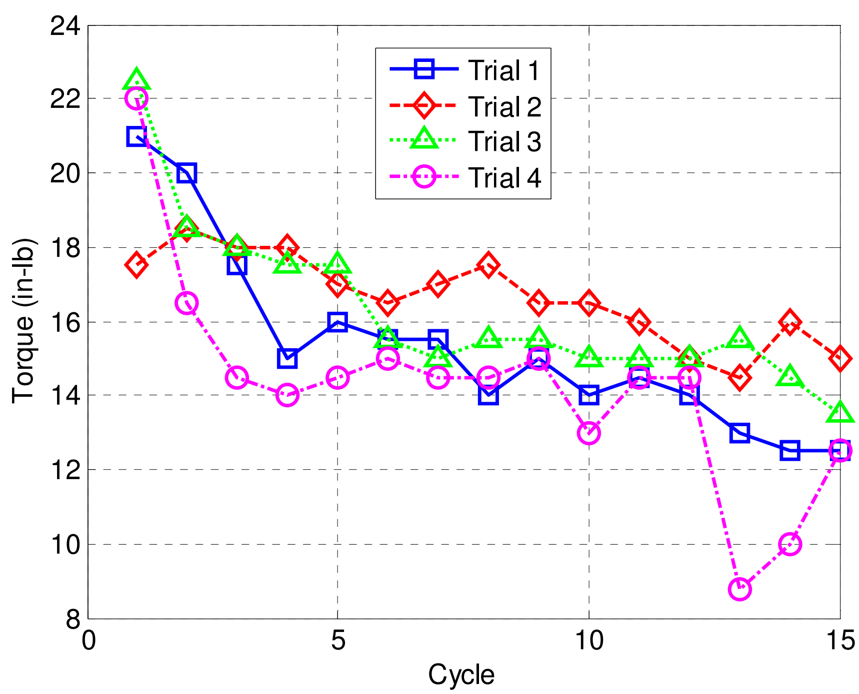

Figure D-211: NAS1021N4 Assembly Prevailing Torque; 75% Y Preload

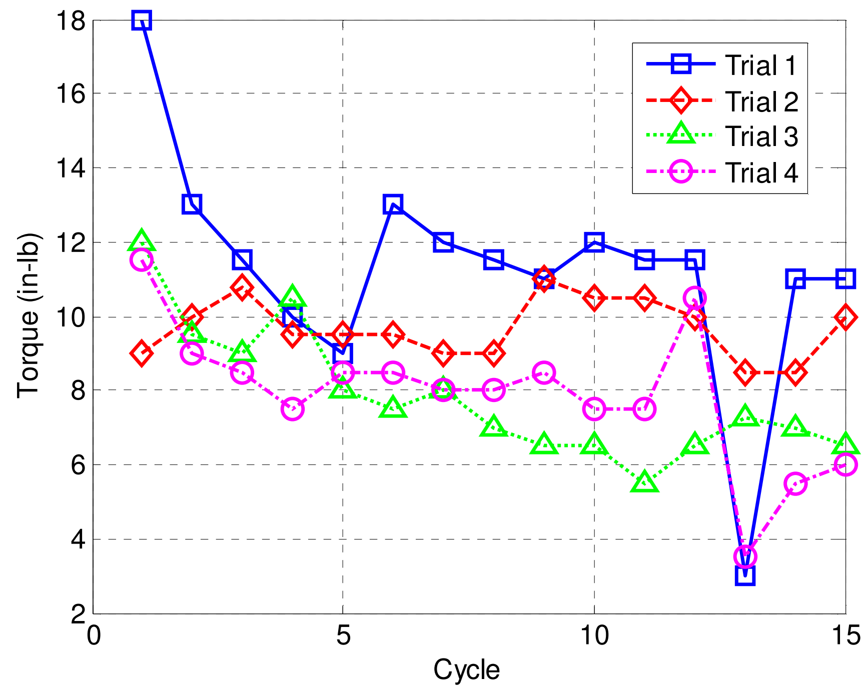

Figure D-212: NAS1021N4 Removal Prevailing Torque; 75% Y Preload

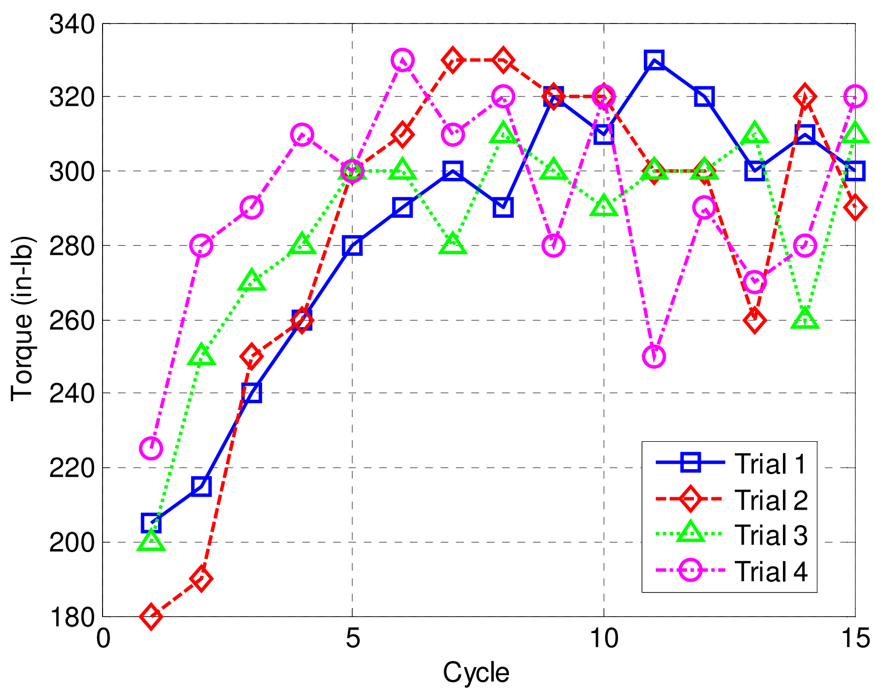

Figure D-213: NAS1021N4 Tightening Torque; 75% Y Preload

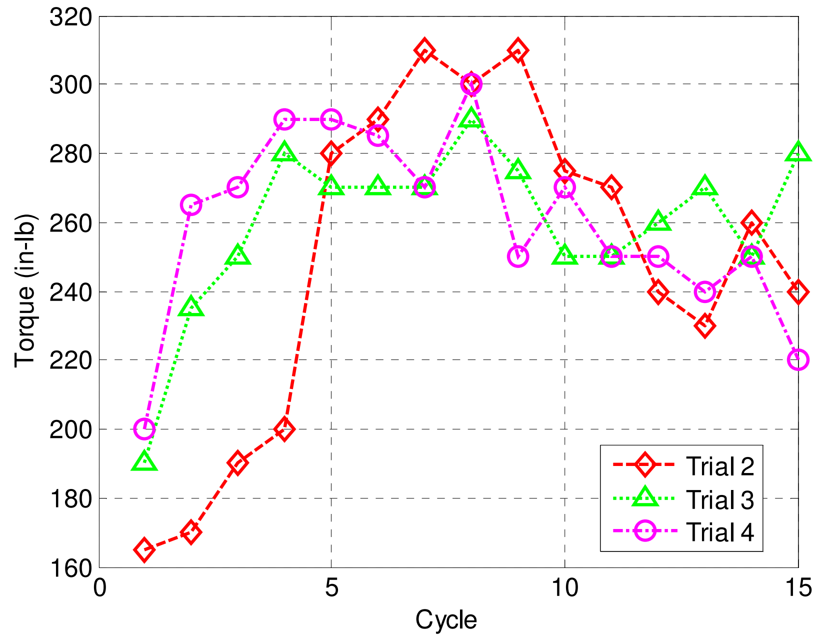

Figure D-214: NAS1021N4 Breakloose Torque; 75% Y Preload

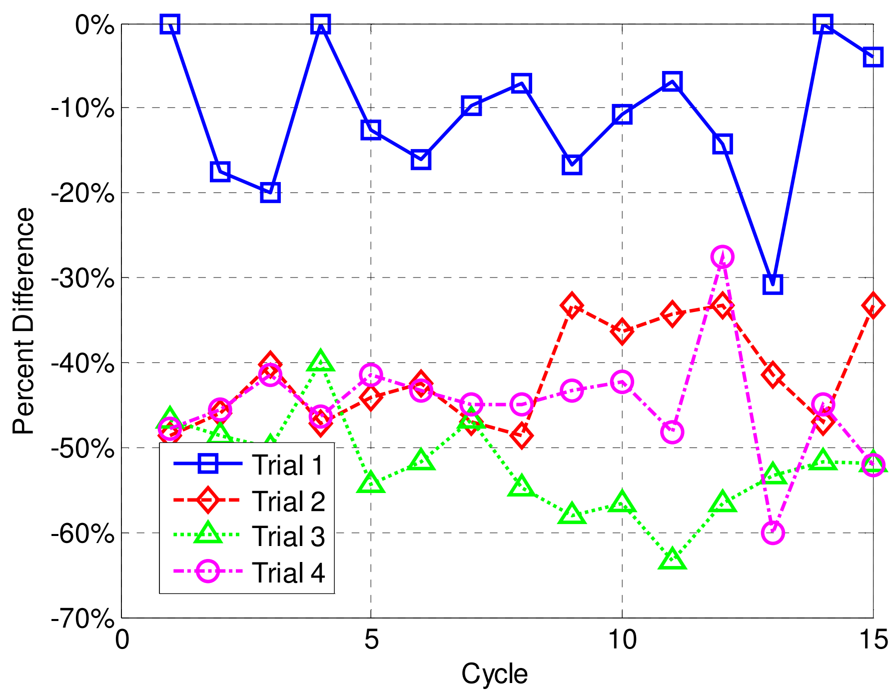

Figure D-215: NAS1021N4 Percent Difference; 75% Y Preload

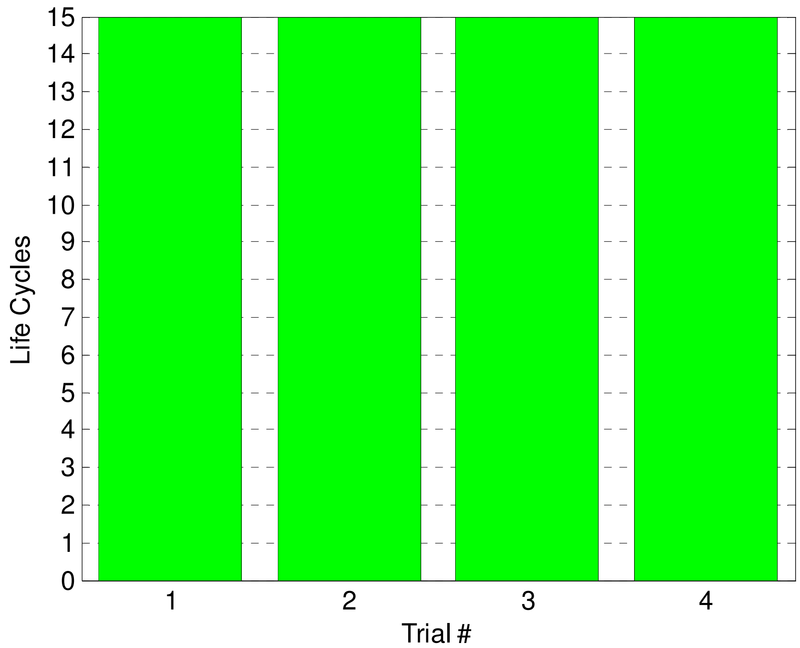

Figure D-216: NAS1021N4 Life; 75% Y Preload

D.8.4 85% Y Preload

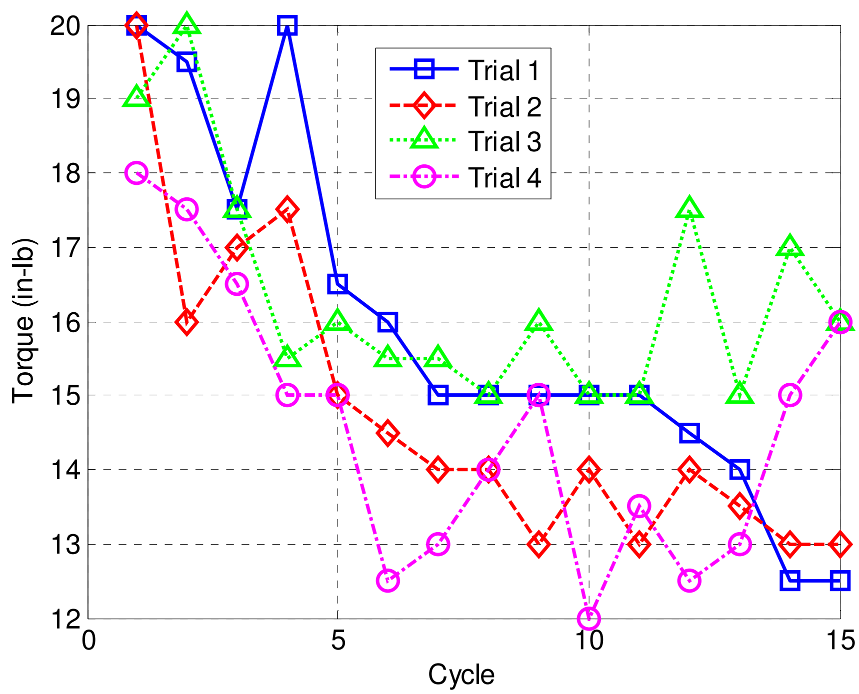

Figure D-217: NAS1021N4 Assembly Prevailing Torque; 85% Y Preload

Appendix D (Continued)

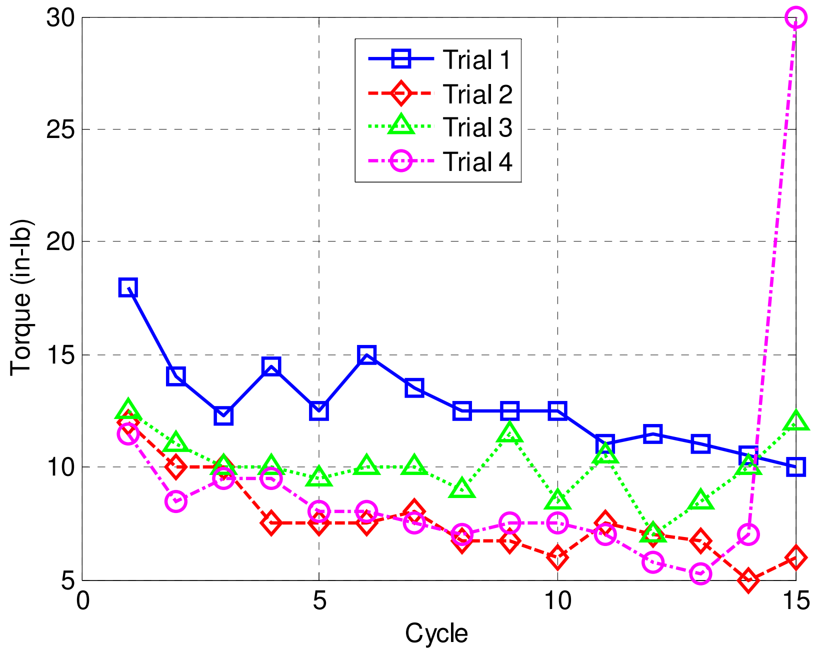

Figure D-218: NAS1021N4 Removal Prevailing Torque; 85% Y Preload

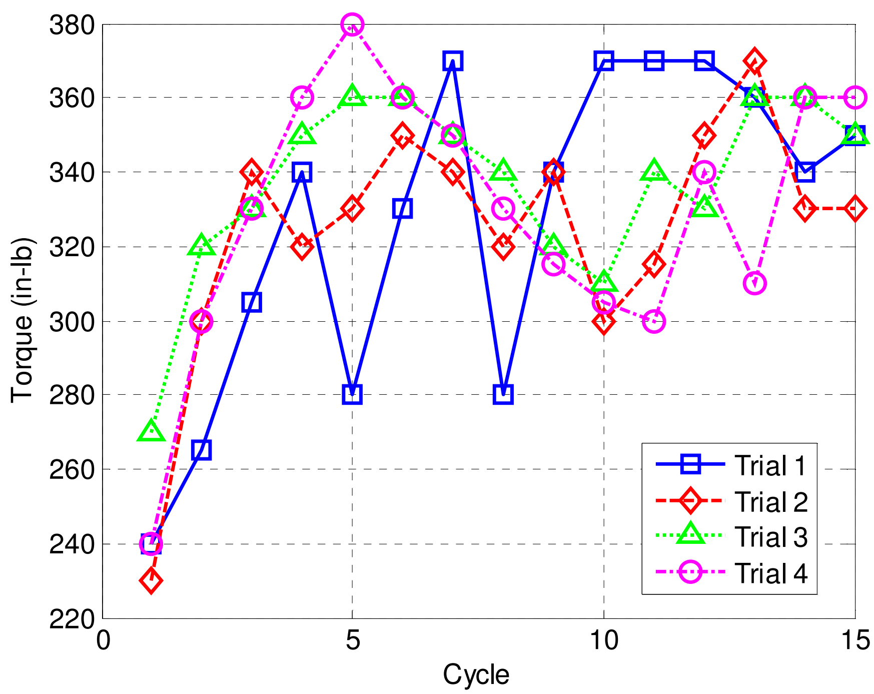

Figure D-219: NAS1021N4 Tightening Torque; 85% Y Preload

Appendix D (Continued)

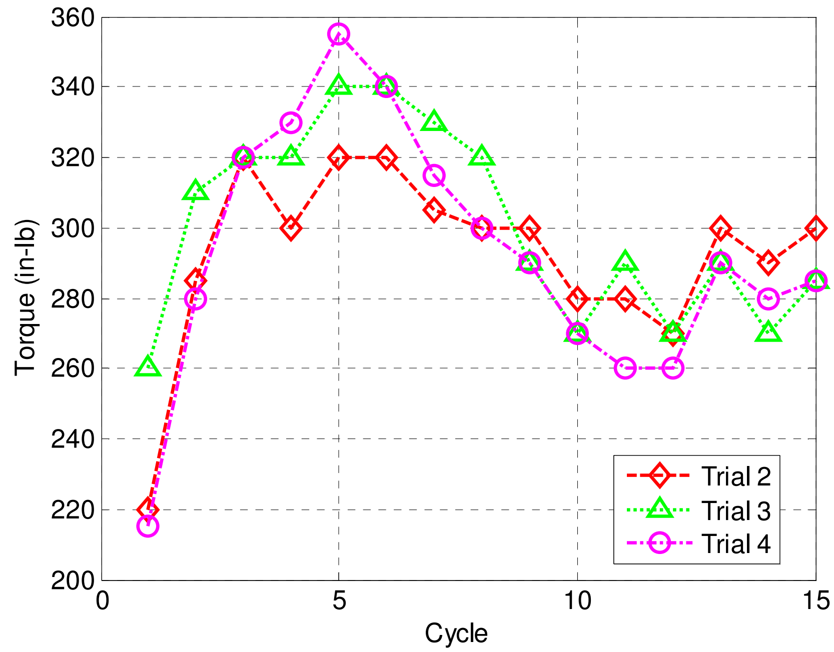

Figure D-220: NAS1021N4 Breakloose Torque; 85% Y Preload

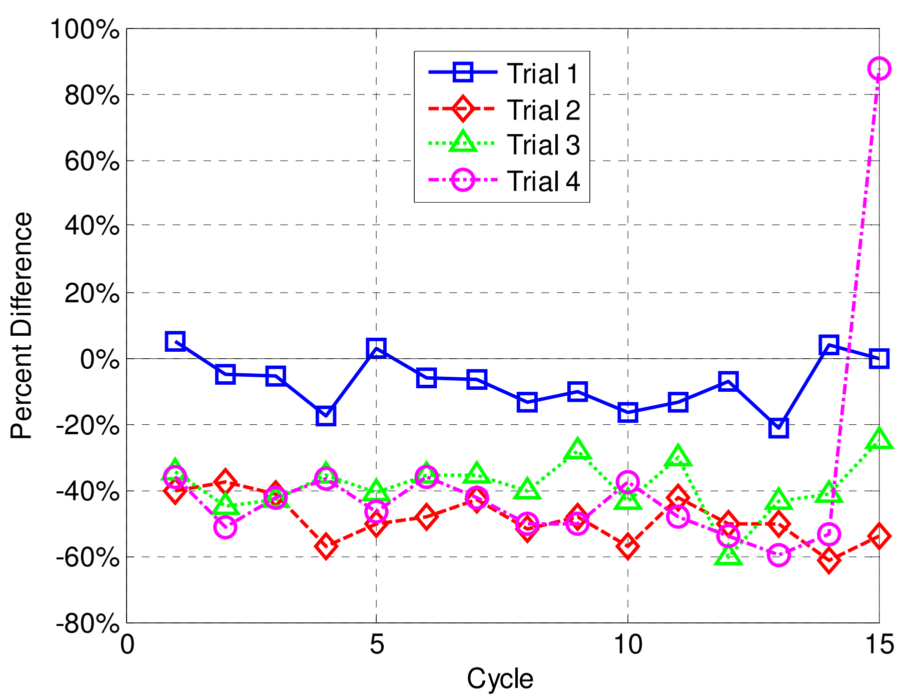

Figure D-221: NAS1021N4 Percent Difference; 85% Y Preload

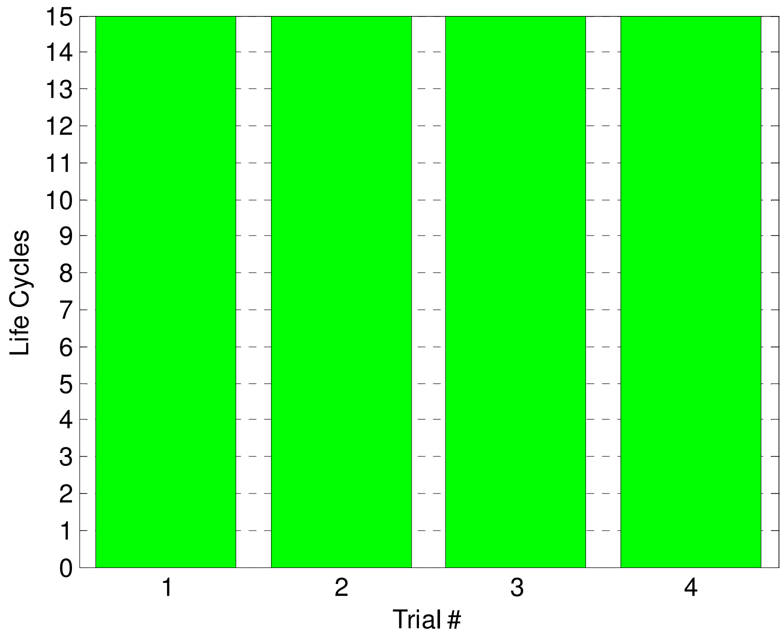

Figure D-222: NAS1021N4 Life; 85% Y Preload

D.8.5 Preload Averages

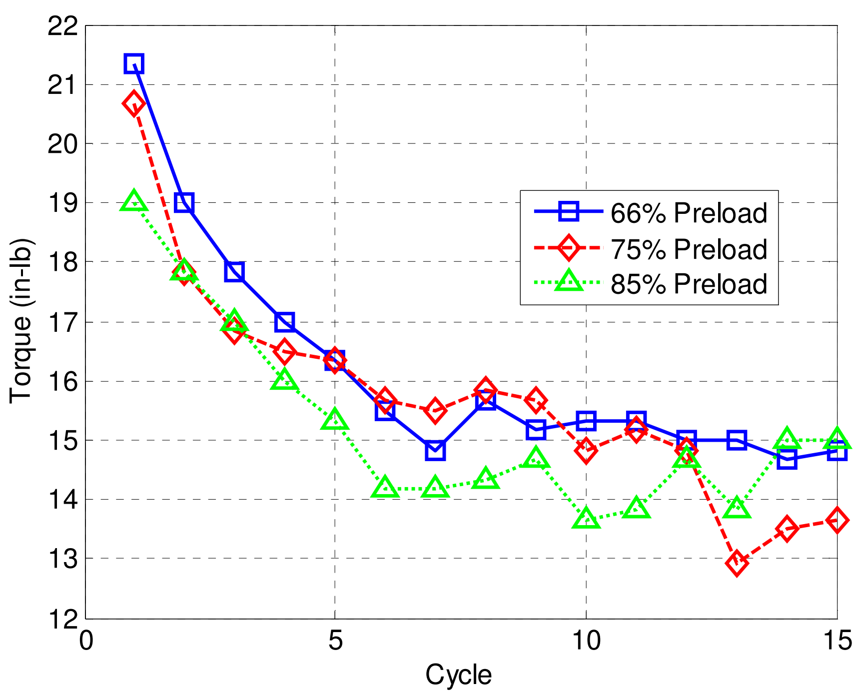

Figure D-223: NAS1021N4 Assembly Prevailing Torque; Preload Average

Appendix D (Continued)

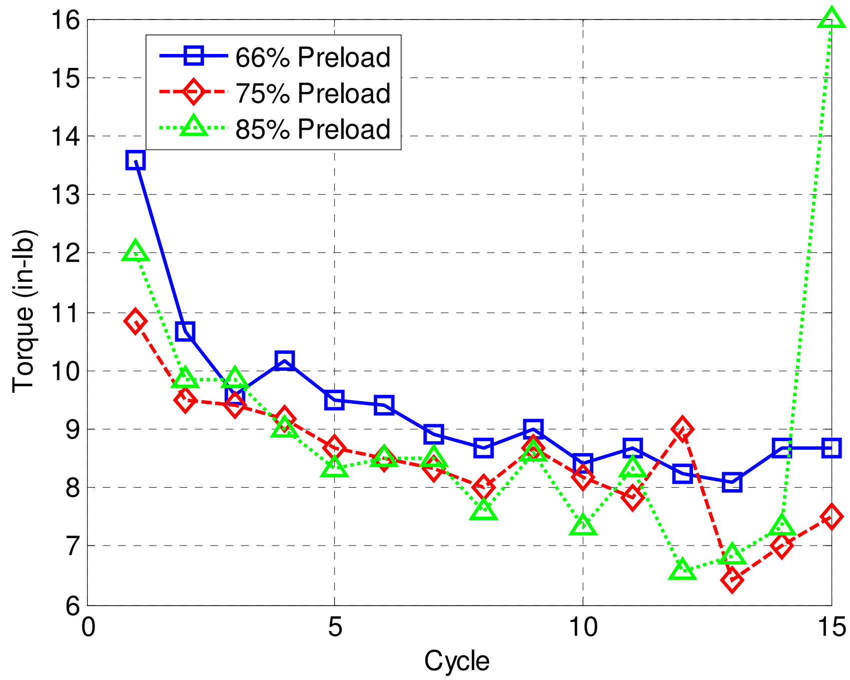

Figure D-224: NAS1021N4 Removal Prevailing Torque; Preload Average

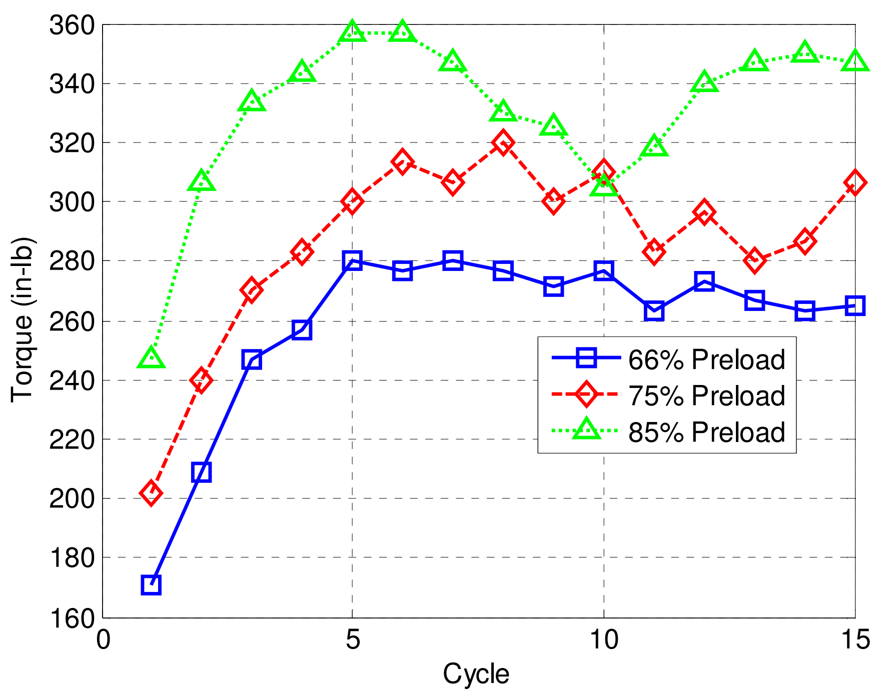

Figure D-225: NAS1021N4 Tightening Torque; Preload Average

Appendix D (Continued)

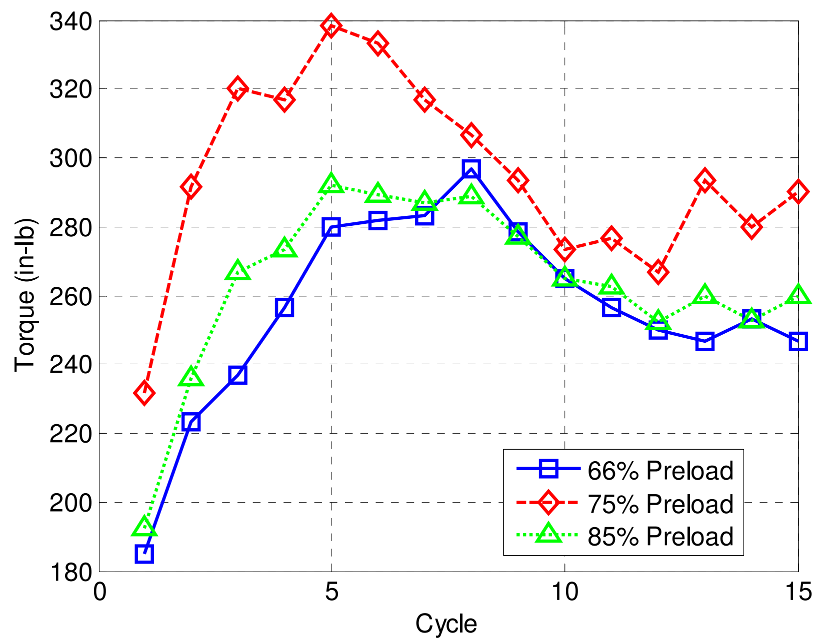

Figure D-226: NAS1021N4 Breakloose Torque; Preload Average

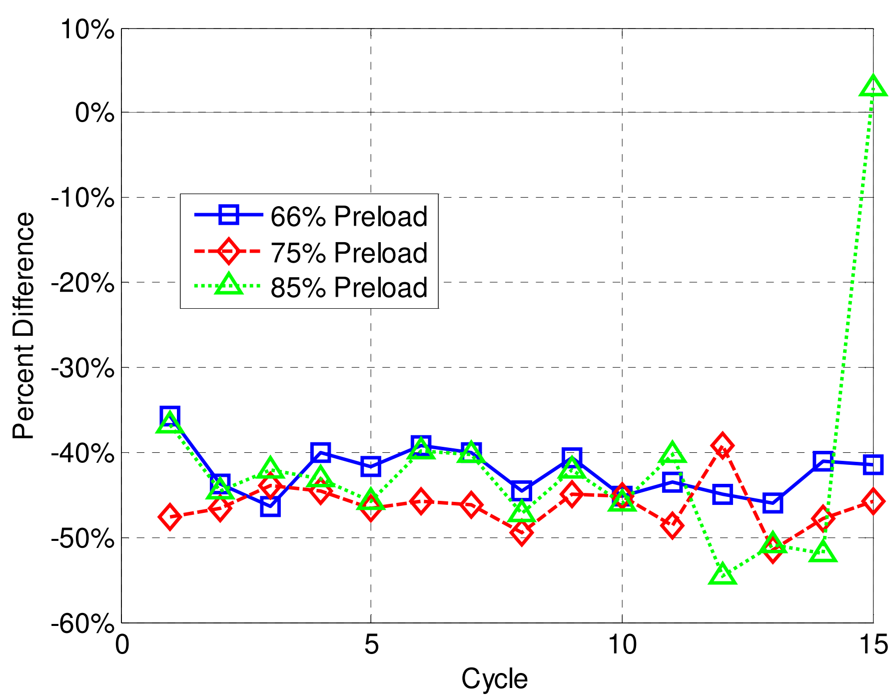

Figure D-227: NAS1021N4 Percent Difference; Preload Average

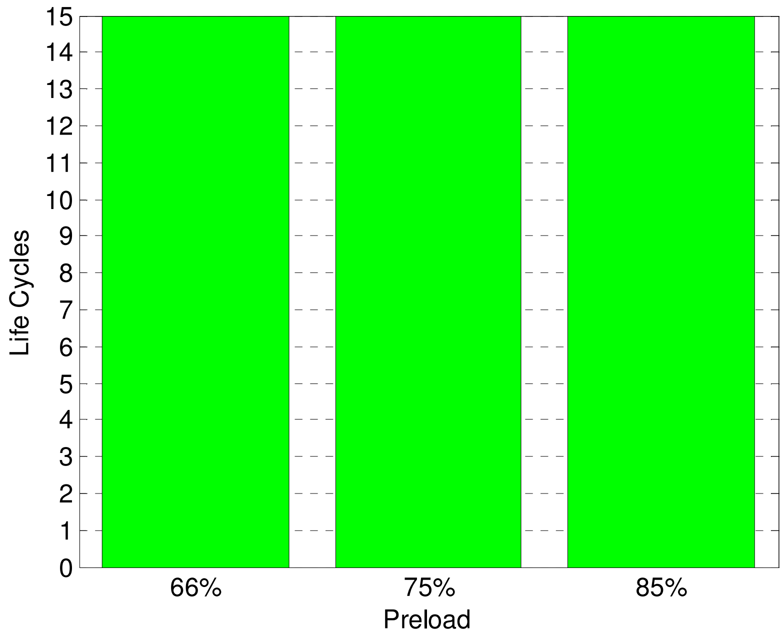

Figure D-228: NAS1021N4 Life; Preload Average

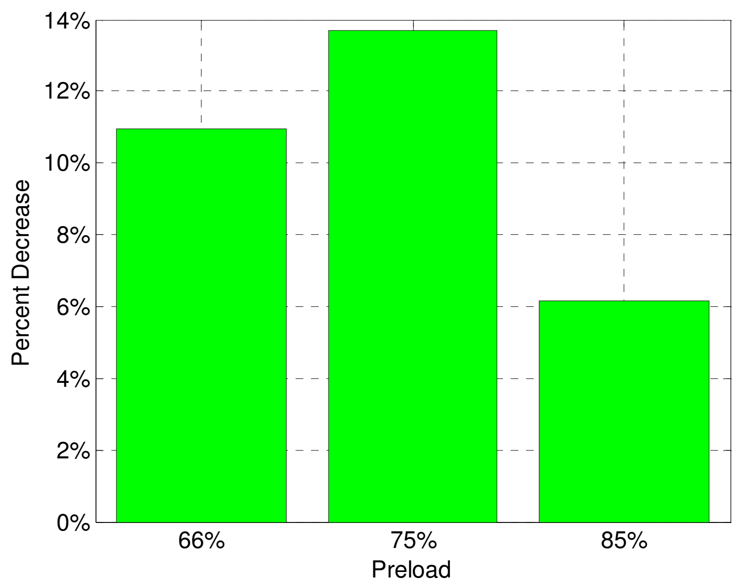

Figure D-229: NAS1021N4 Percent Decrease of Assembly Prevailing Torque from Cycle 1 to 2; Preload Average

Appendix D (Continued)

D.9 NAS1021N4 Lubricated with Braycote

D.9.1 Unseated – Braycote

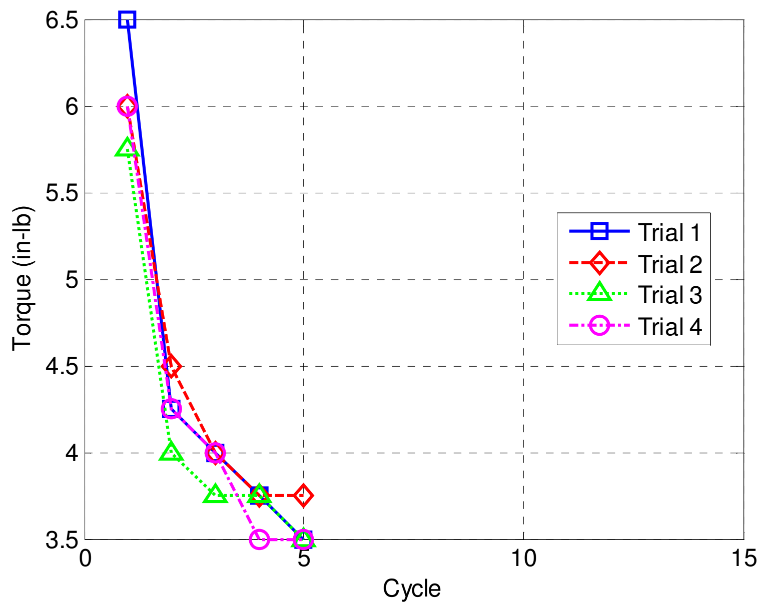

Figure D-230: NAS1021N4 Braycote Assembly Prevailing Torque; Unseated

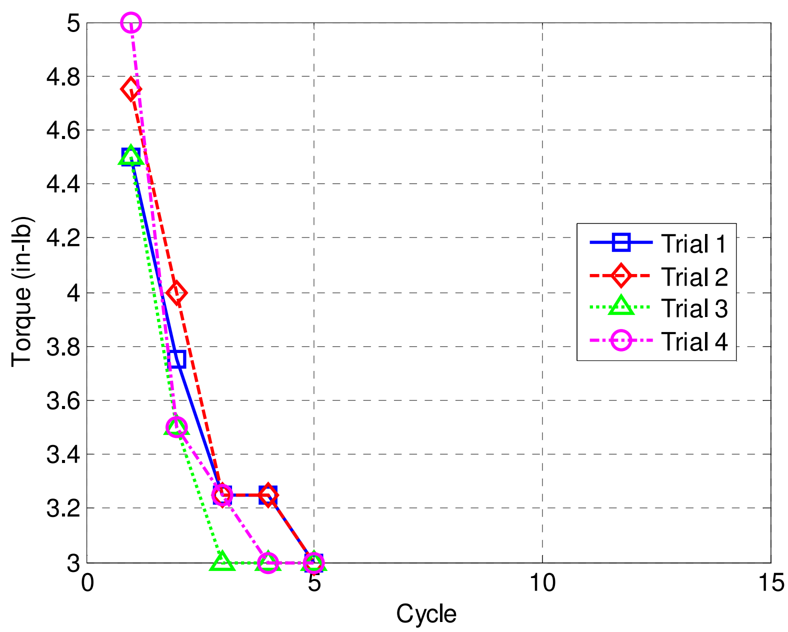

Figure D-231: NAS1021N4 Braycote Removal Prevailing Torque; Unseated

Appendix D (Continued)

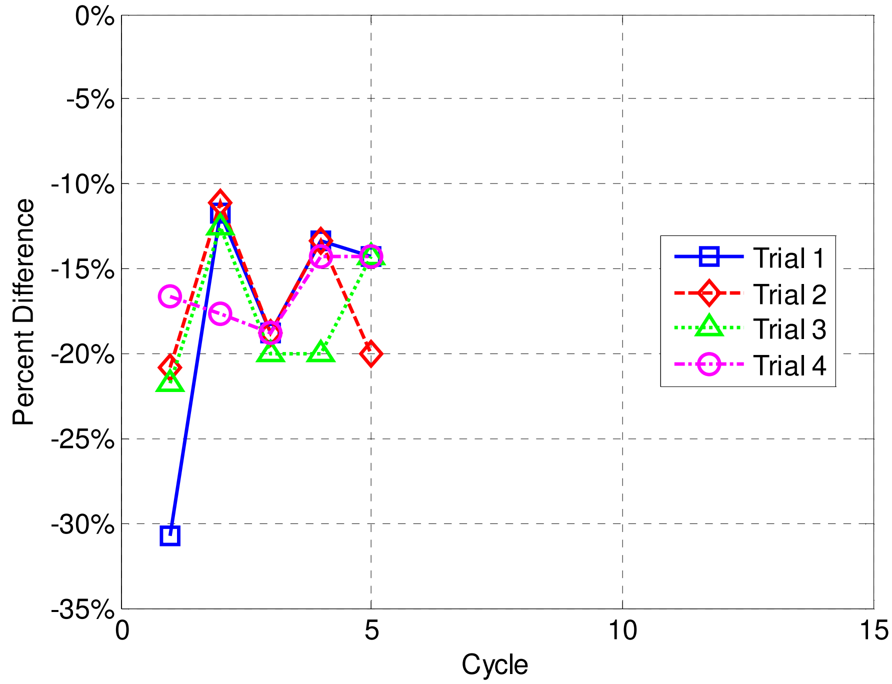

Figure D-232: NAS1021N4 Braycote Percent Difference; Unseated

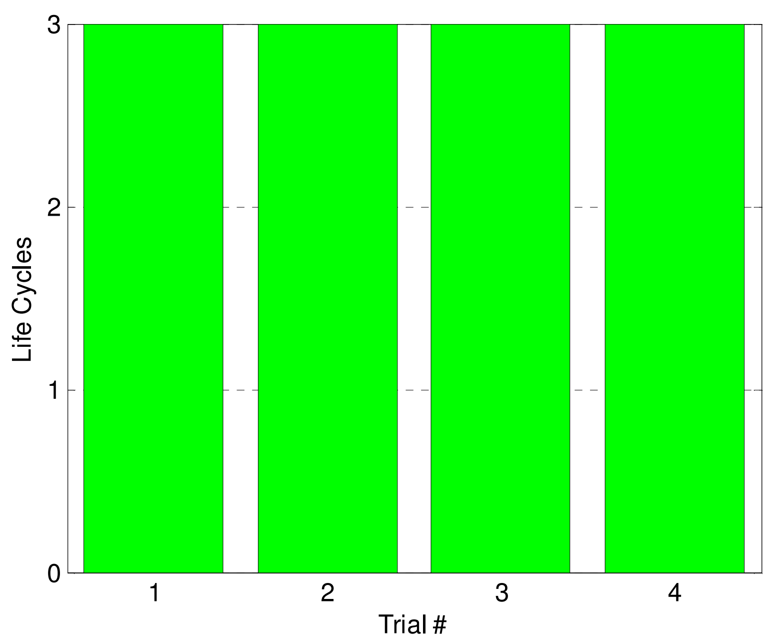

Figure D-233: NAS1021N4 Braycote Life; Unseated

Appendix D (Continued)

D.9.2 66% Y Preload – Braycote

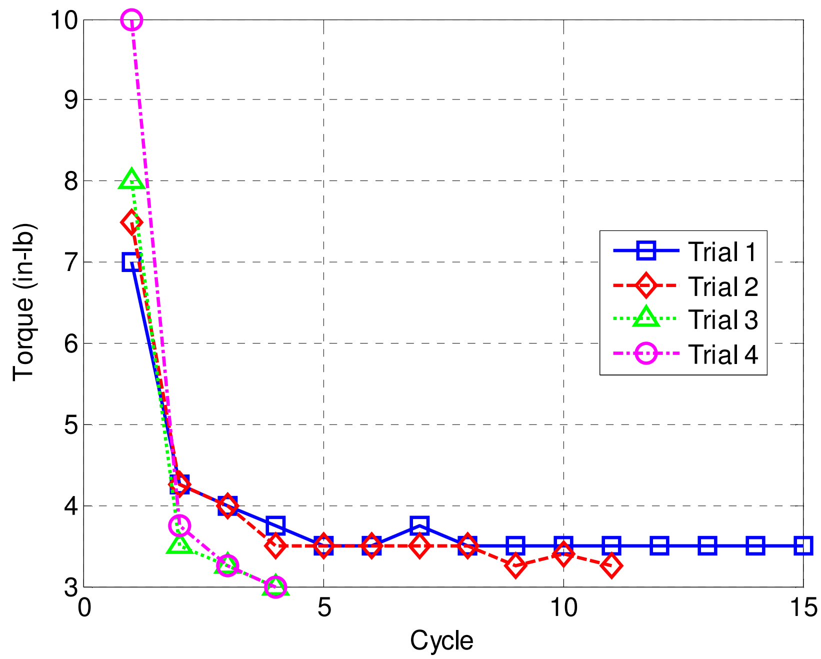

Figure D-234: NAS1021N4 Braycote Assembly Prevailing Torque; 66% Y Preload

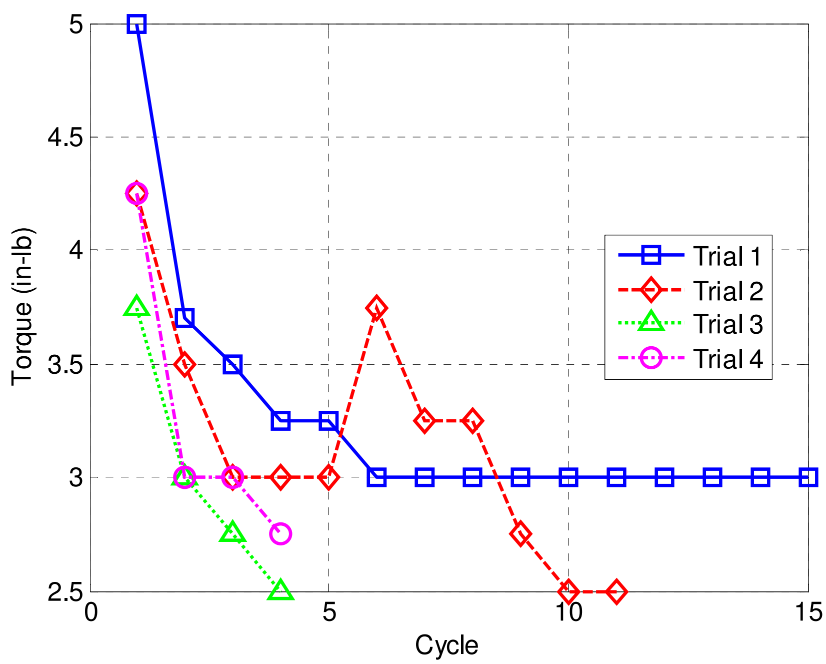

Figure D-235: NAS1021N4 Braycote Removal Prevailing Torque; 66% Y Preload

Appendix D (Continued)

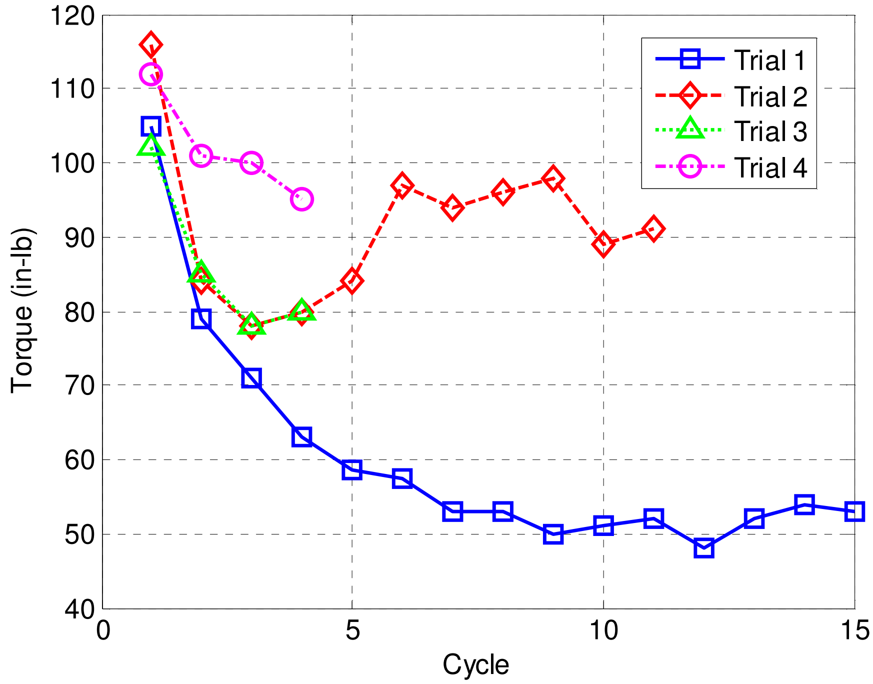

Figure D-236: NAS1021N4 Braycote Tightening Torque; 66% Y Preload

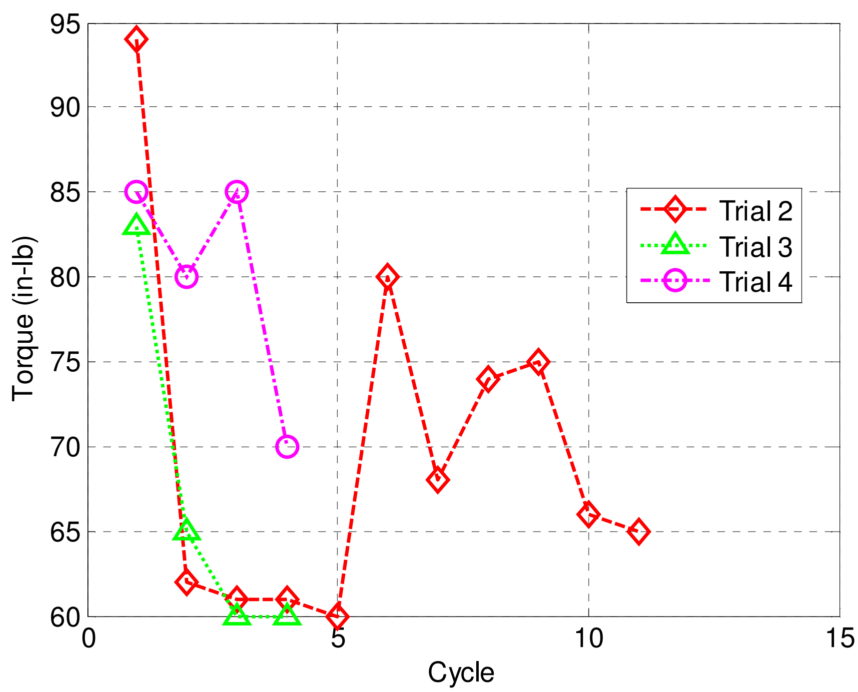

Figure D-237: NAS1021N4 Braycote Breakloose Torque; 66% Y Preload

Appendix D (Continued)

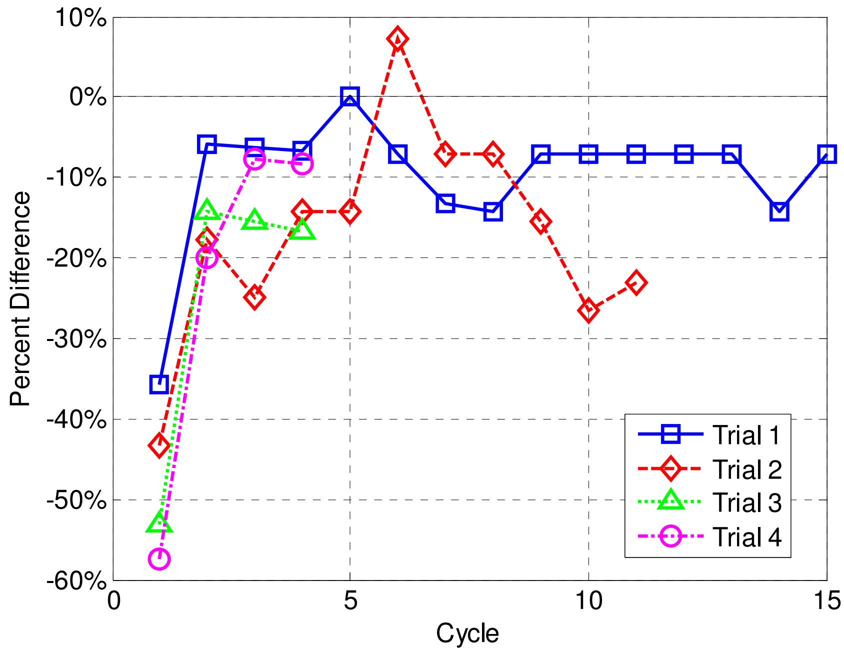

Figure D-238: NAS1021N4 Braycote Percent Difference; 66% Y Preload

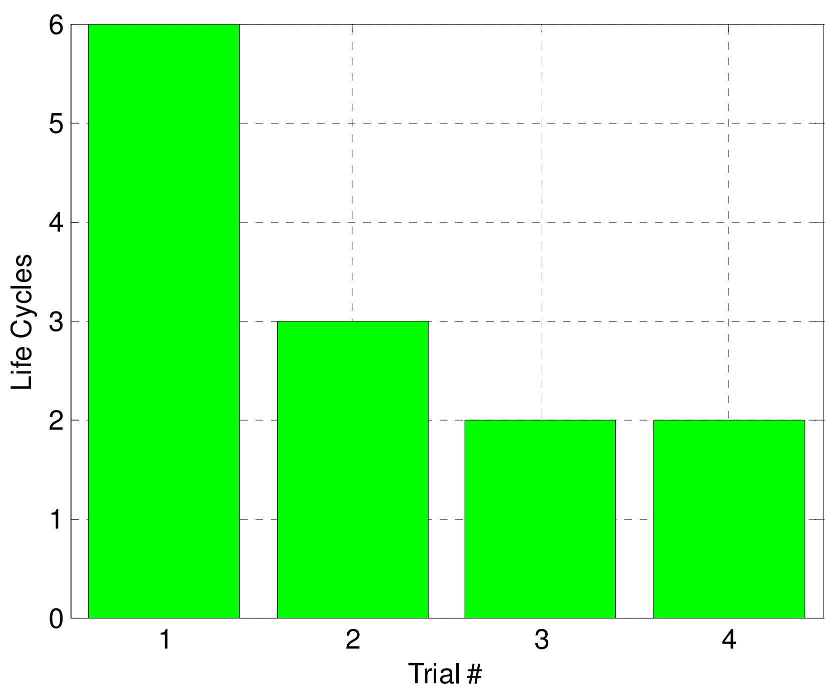

Figure D-239: NAS1021N4 Braycote Life; 66% Y Preload

D.9.3 75% Y Preload – Braycote

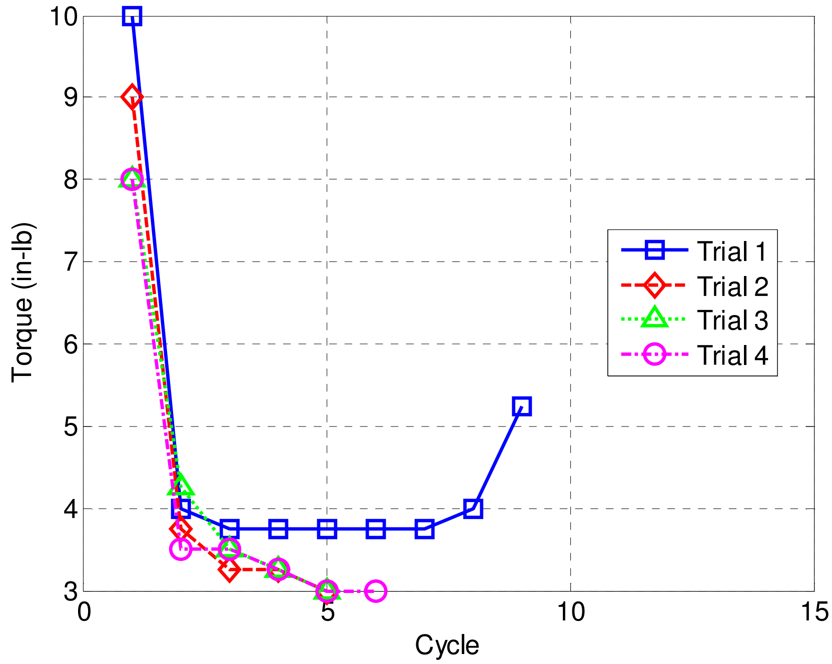

Figure D-240: NAS1021N4 Braycote Assembly Prevailing Torque; 75% Y Preload

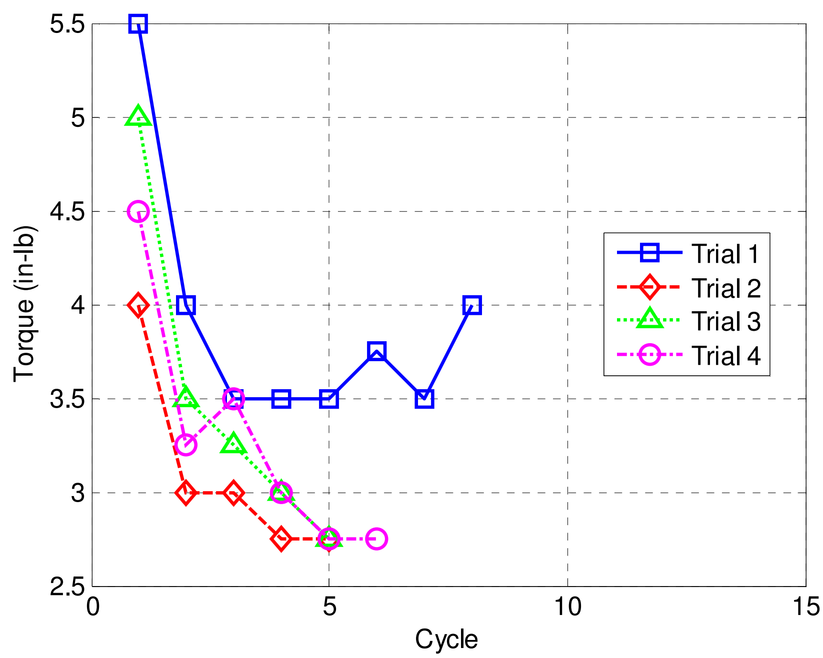

Figure D-241: NAS1021N4 Braycote Removal Prevailing Torque; 75% Y Preload

Appendix D (Continued)

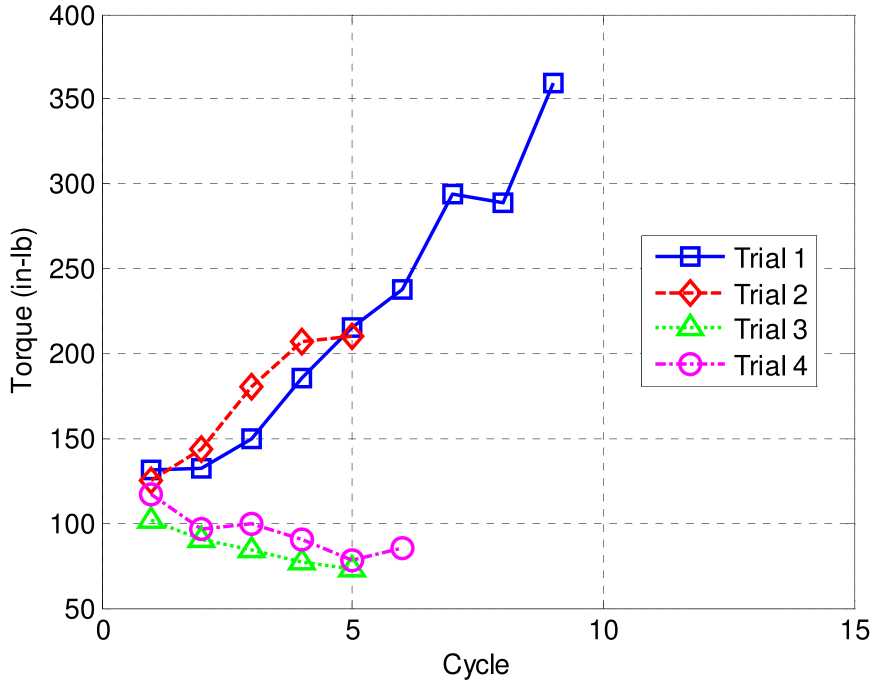

Figure D-242: NAS1021N4 Braycote Tightening Torque; 75% Y Preload

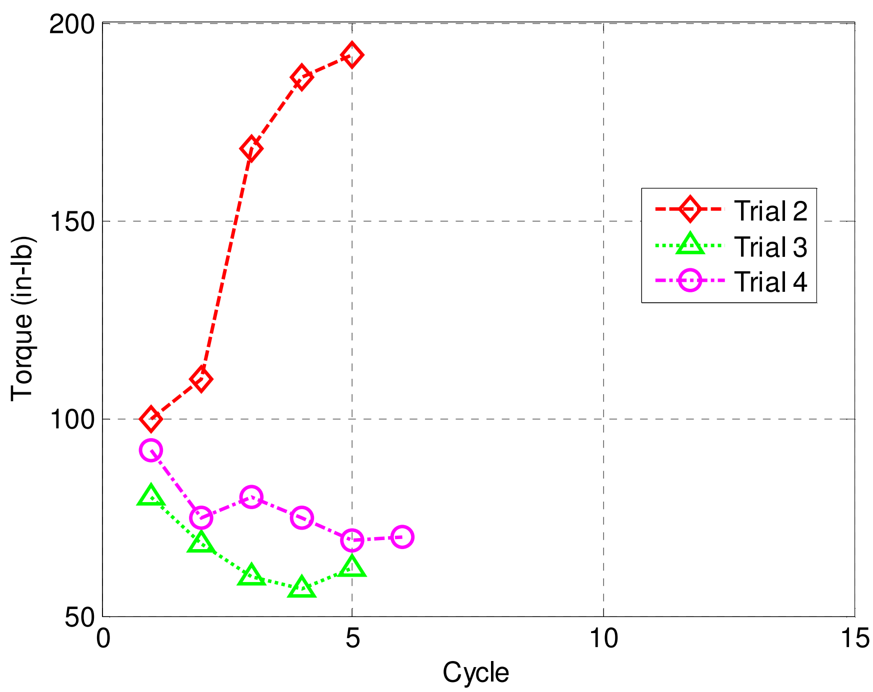

Figure D-243: NAS1021N4 Braycote Breakloose Torque; 75% Y Preload

Appendix D (Continued)

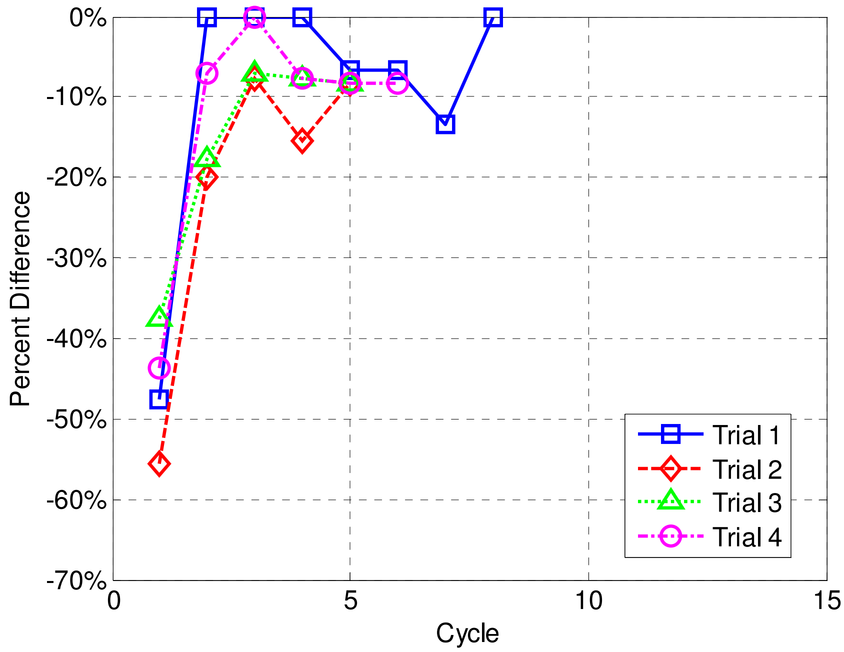

Figure D-244: NAS1021N4 Braycote Percent Difference; 75% Y Preload

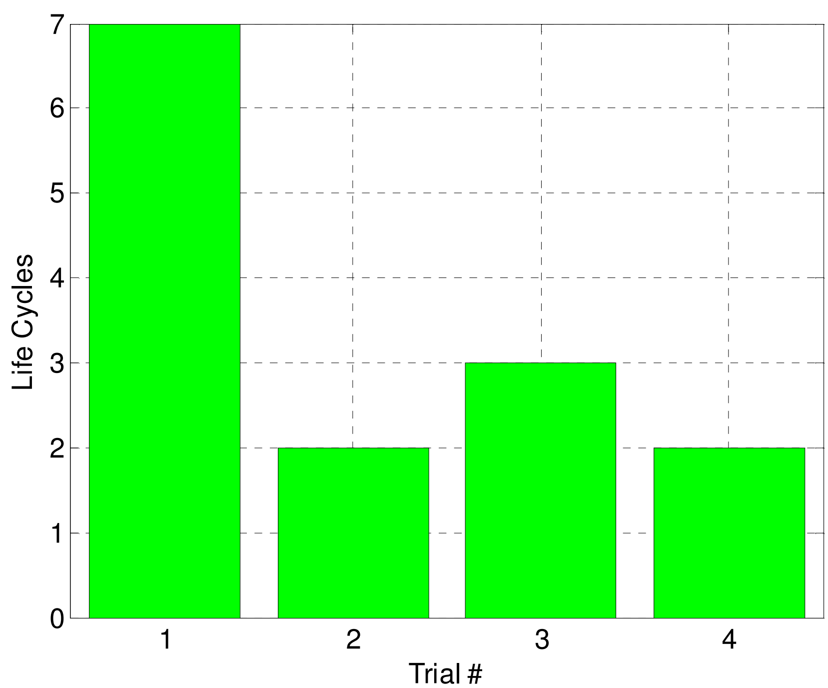

Figure D-245: NAS1021N4 Braycote Life; 75% Y Preload

Appendix D (Continued)

D.9.4 85% Y Preload – Braycote

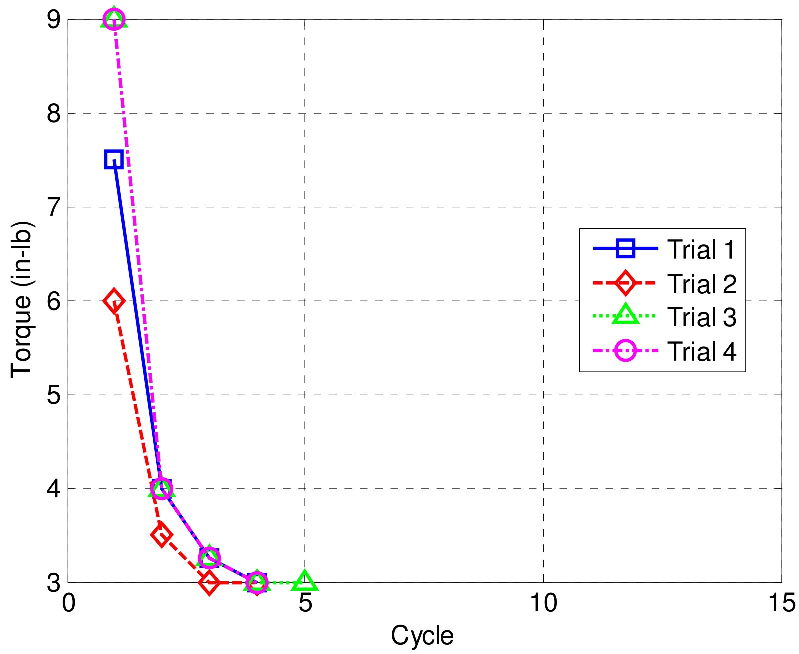

Figure D-246: NAS1021N4 Braycote Assembly Prevailing Torque; 85% Y Preload

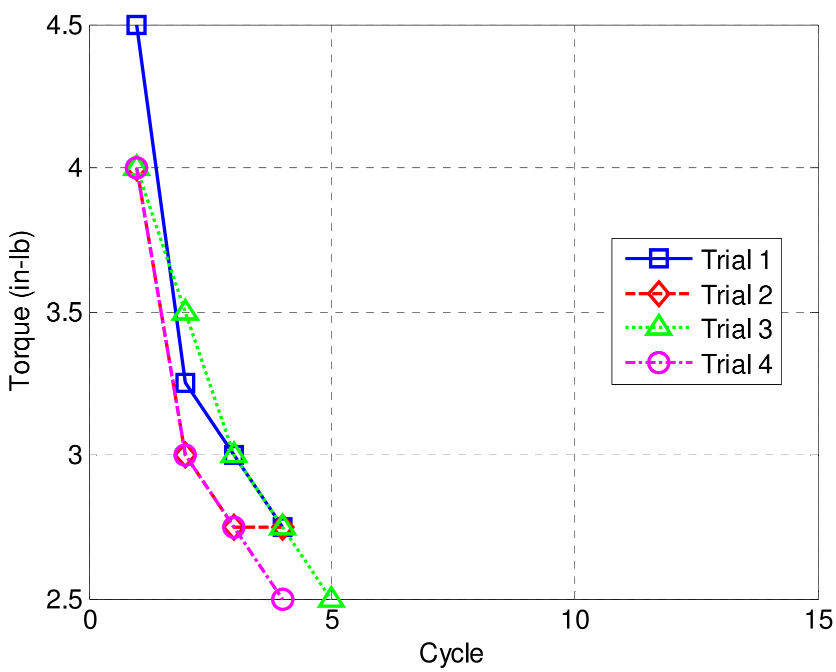

Figure D-247: NAS1021N4 Braycote Removal Prevailing Torque; 85% Y Preload

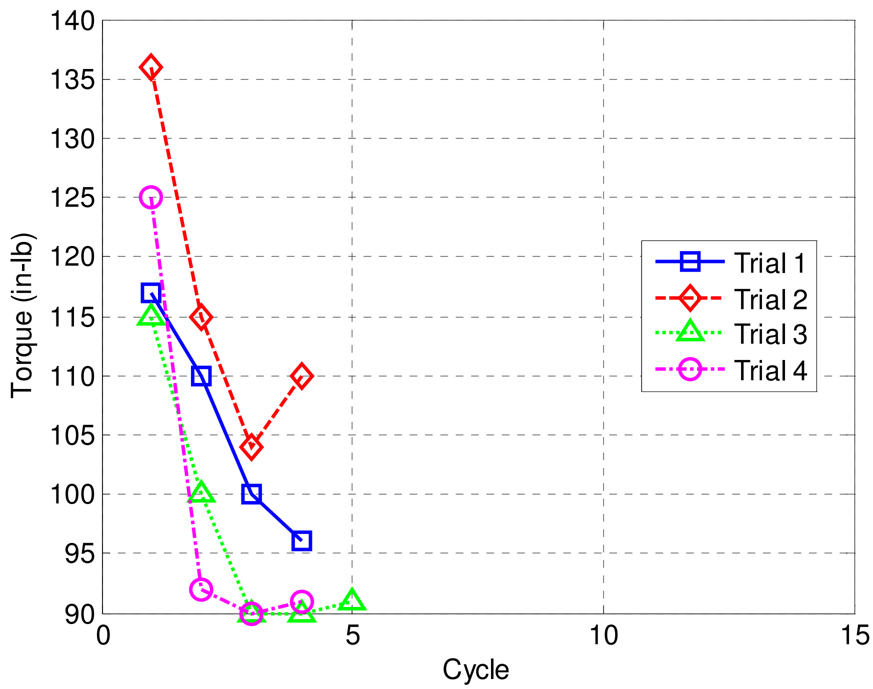

Figure D-248: NAS1021N4 Braycote Tightening Torque; 85% Y Preload

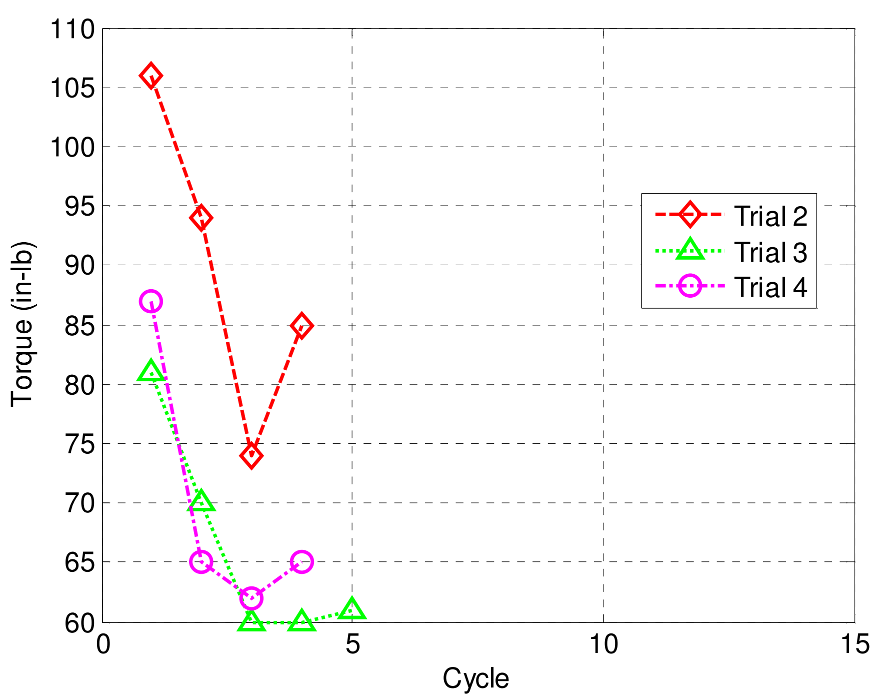

Figure D-249: NAS1021N4 Braycote Breakloose Torque; 85% Y Preload

Appendix D (Continued)

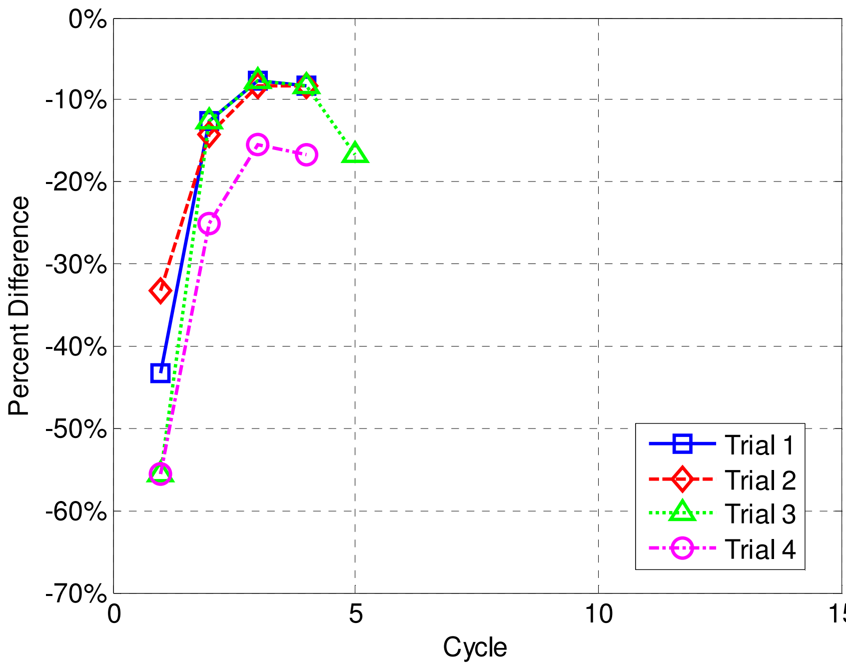

Figure D-250: NAS1021N4 Braycote Percent Difference; 85% Y Preload

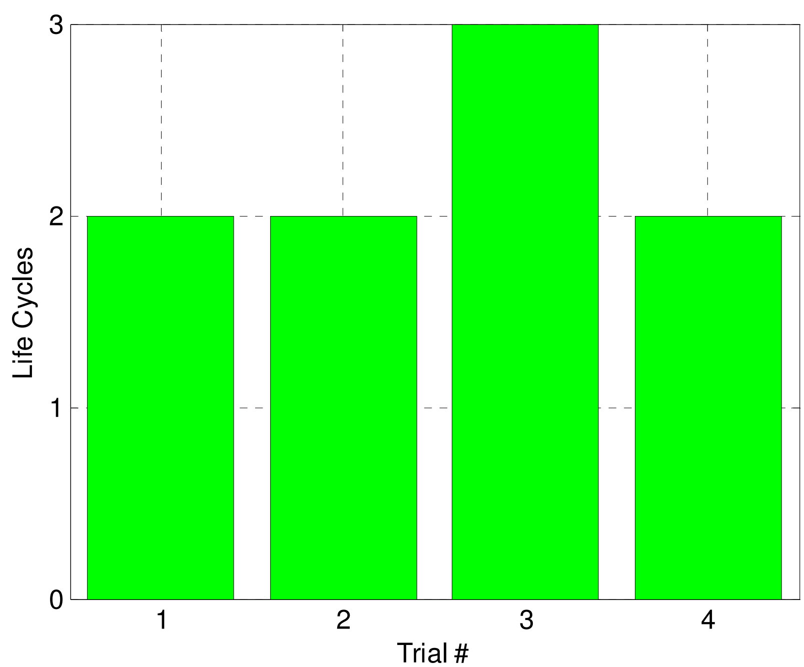

Figure D-251: NAS1021N4 Braycote Life; 85% Y Preload

Appendix D (Continued)

D.9.5 Preload Averages – Braycote

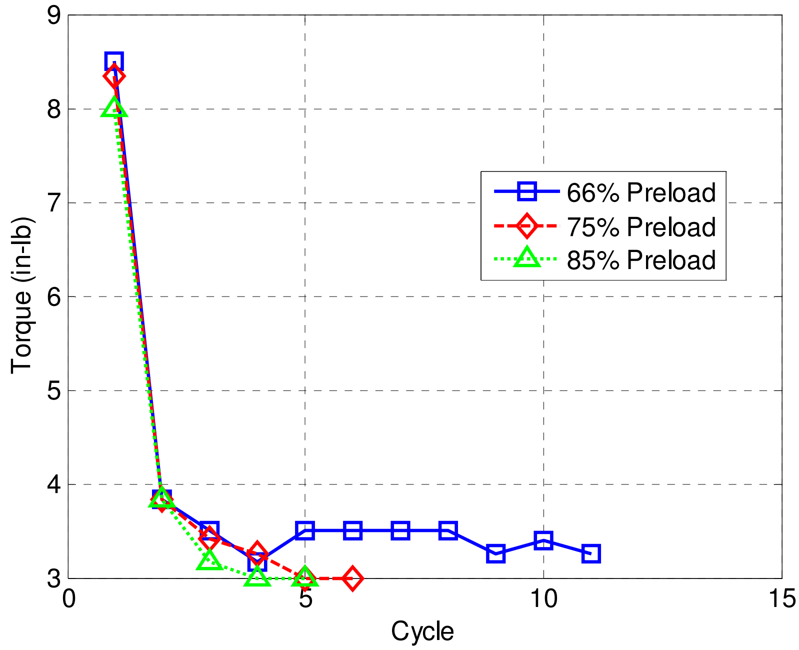

Figure D-252: NAS1021N4 Braycote Assembly Prevailing Torque; Preload Average

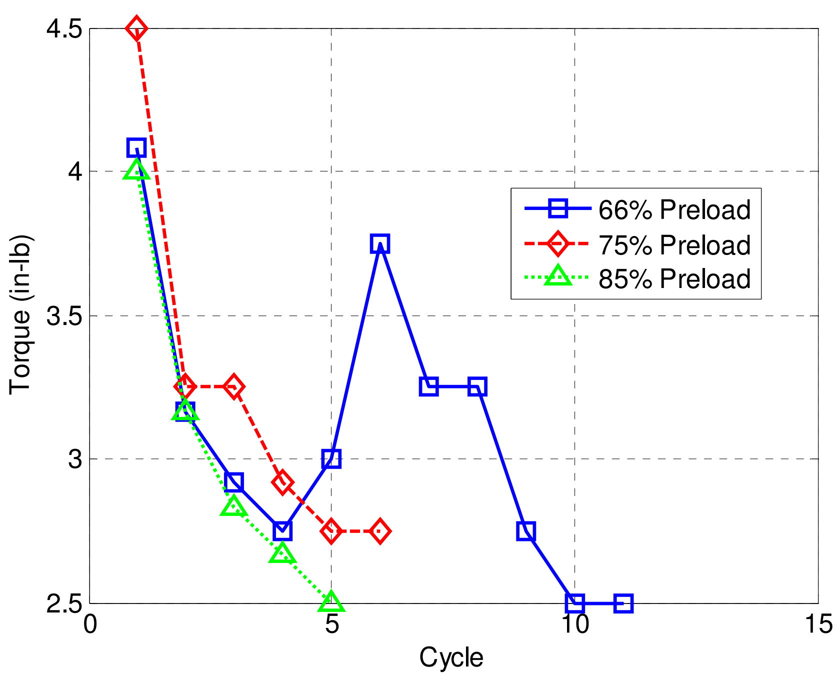

Figure D-253: NAS1021N4 Braycote Removal Prevailing Torque; Preload Average

Appendix D (Continued)

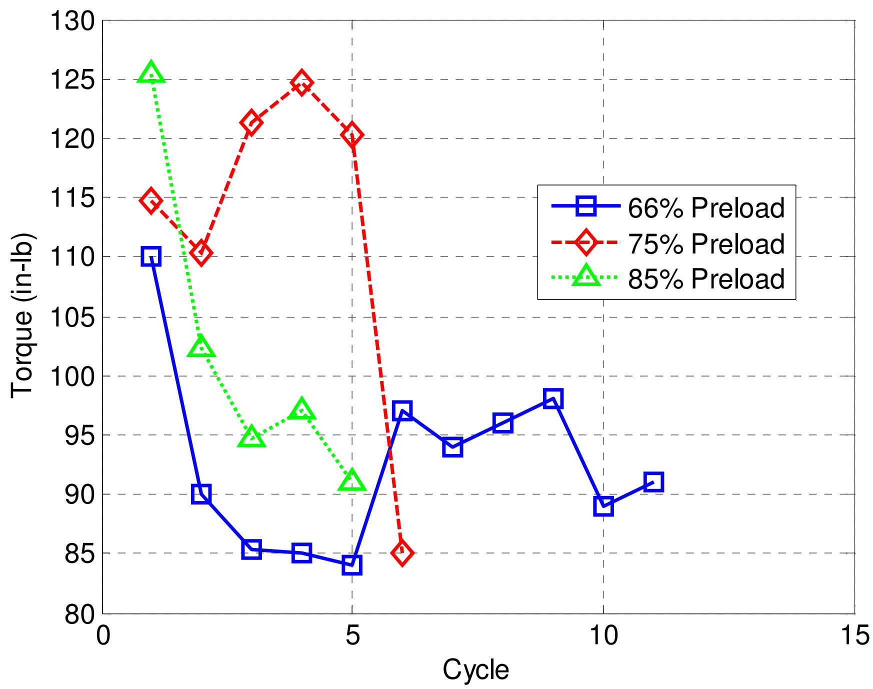

Figure D-254: NAS1021N4 Braycote Tightening Torque; Preload Average

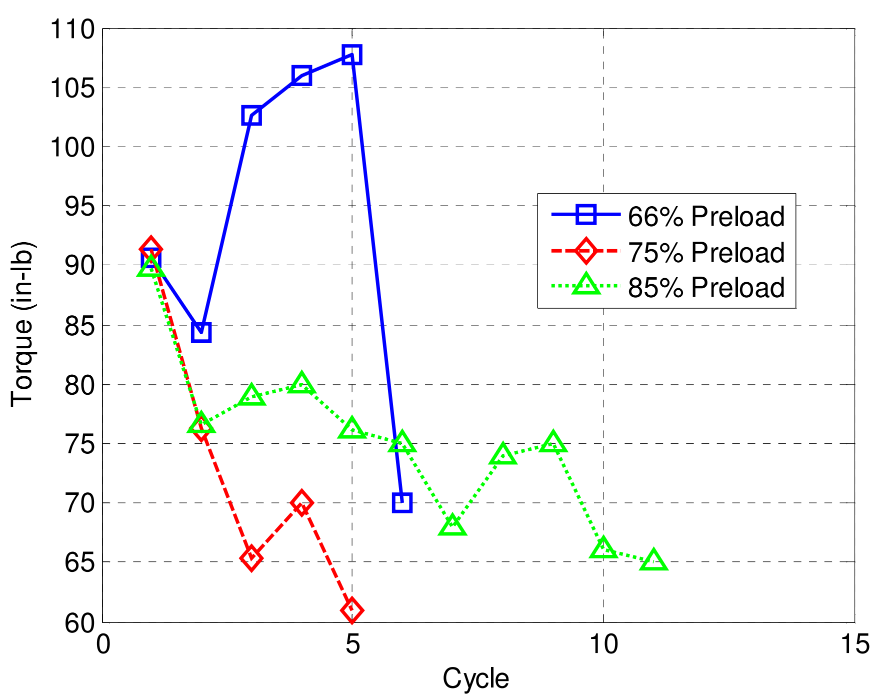

Figure D-255: NAS1021N4 Braycote Breakloose Torque; Preload Average

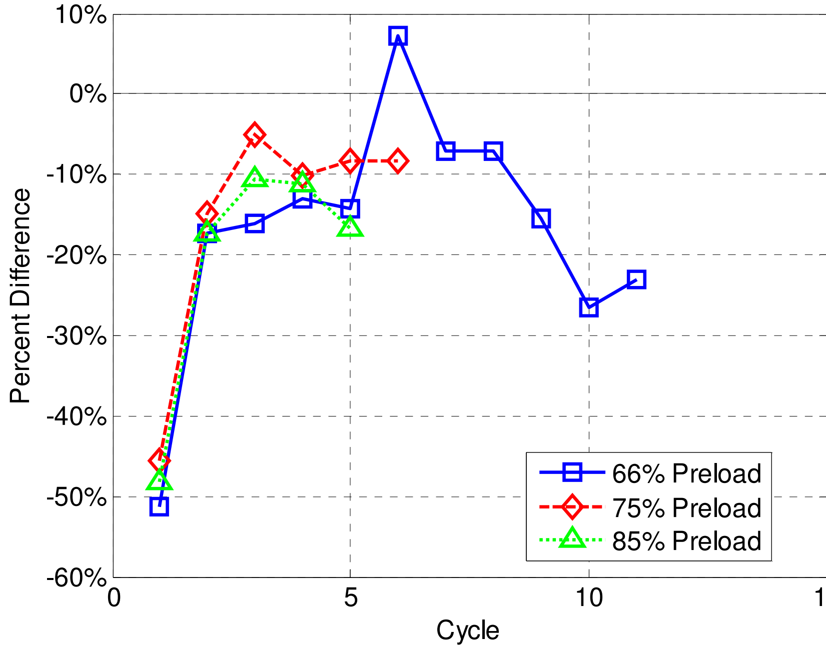

Figure D-256: NAS1021N4 Braycote Percent Difference; Preload Average

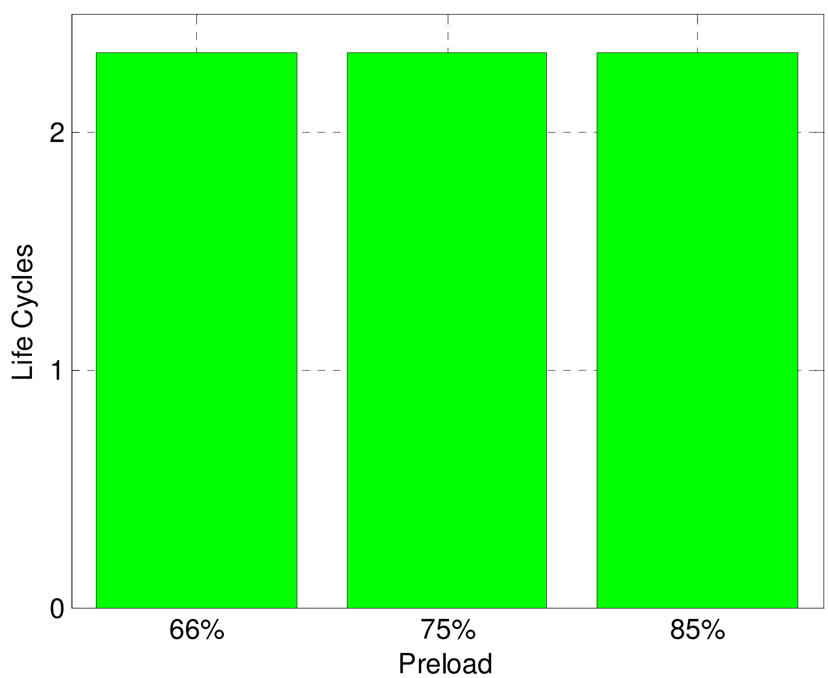

Figure D-257: NAS1021N4 Braycote Life; Preload Average

Appendix D (Continued)

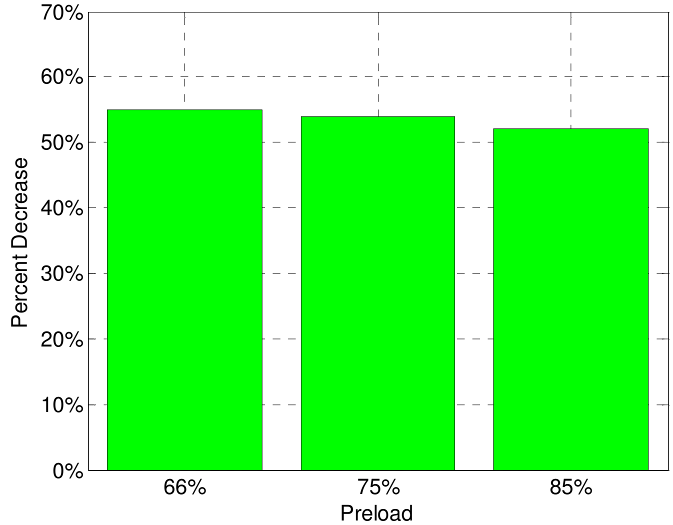

Figure D-258: NAS1021N4 Braycote Percent Decrease of Assembly Prevailing Torque from Cycle 1 to 2; Preload Average

D.10 NAS1021N4 Lubrication Comparison

D.10.1 Unseated

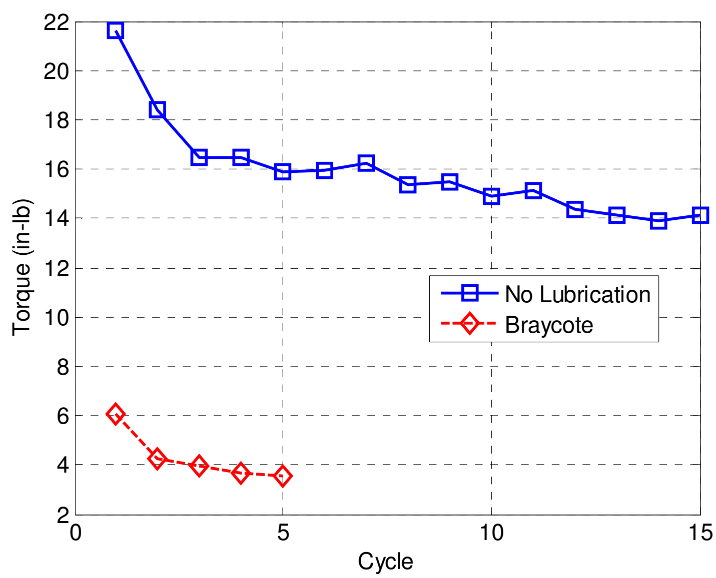

Figure D-259: NAS1021N4 Lubrication Comparison Assembly Prevailing Torque; Unseated

Appendix D (Continued)

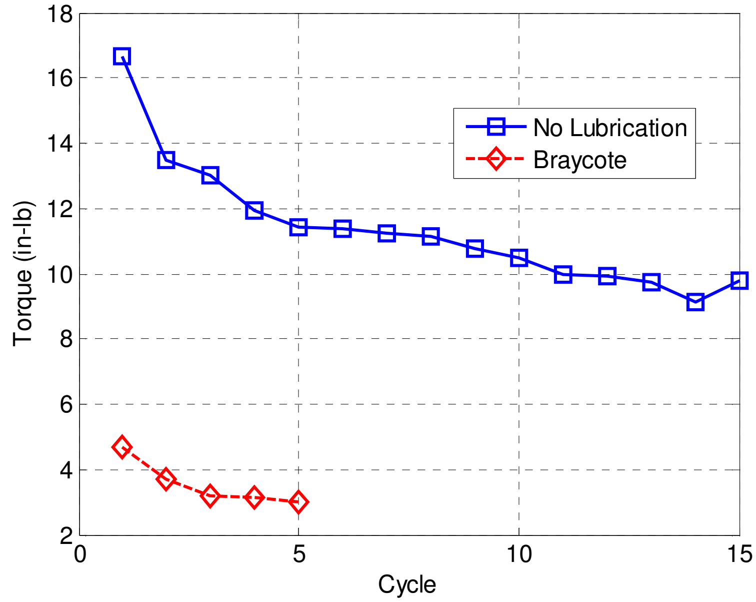

Figure D-260: NAS1021N4 Lubrication Comparison Removal Prevailing Torque; Unseated

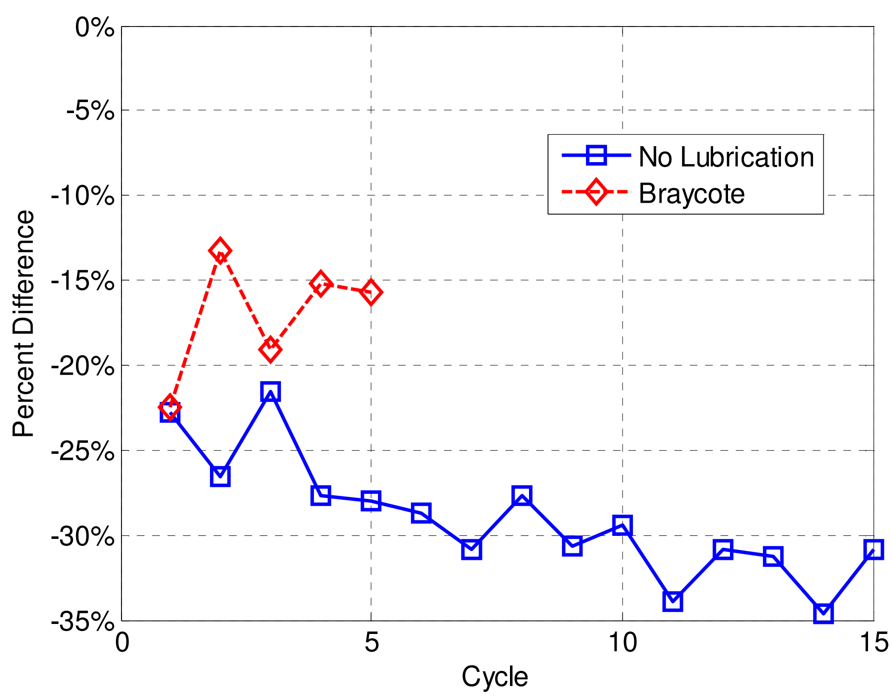

Figure D-261: NAS1021N4 Lubrication Comparison Percent Difference; Unseated

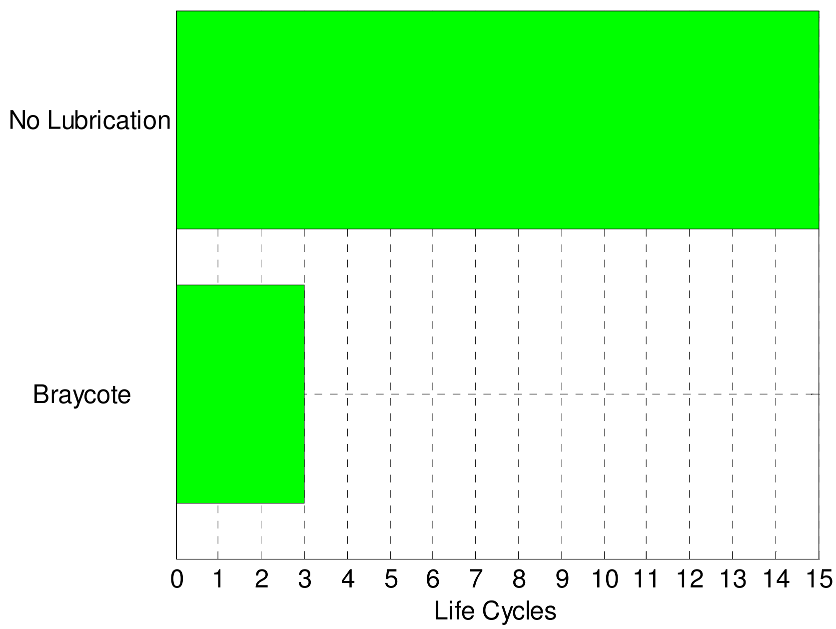

Figure D-262: NAS1021N4 Lubrication Comparison Life; Unseated

D.10.2 66% Y Preload

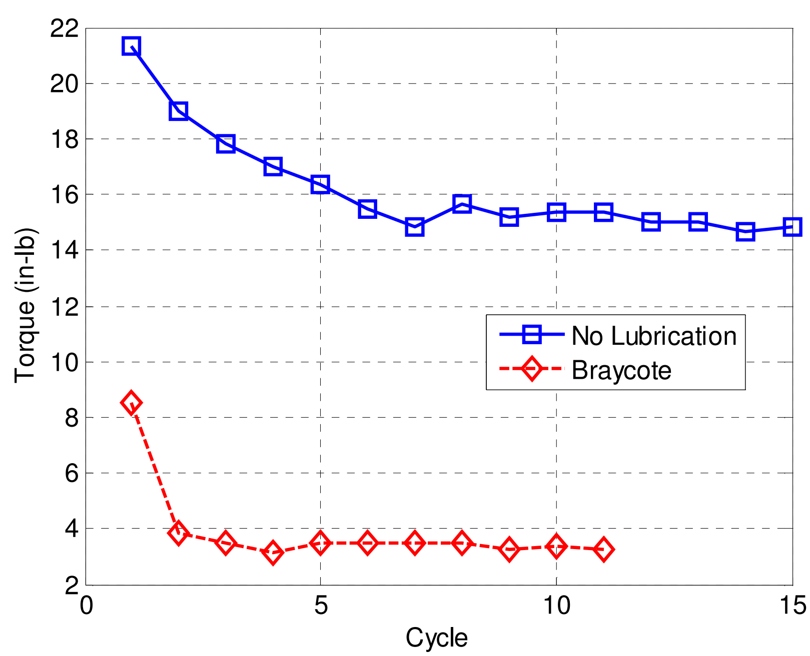

Figure D-263: NAS1021N4 Lubrication Comparison Assembly Prevailing Torque; 66% Y Preload

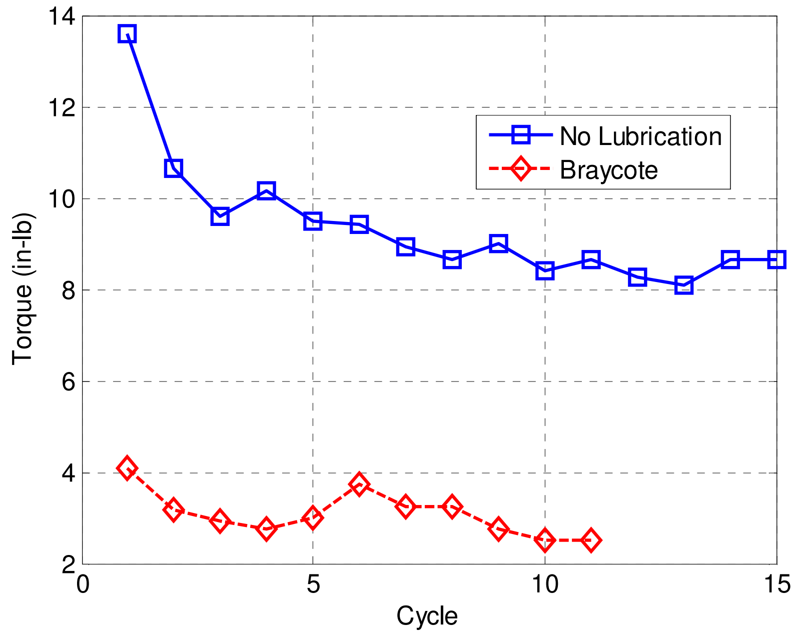

Figure D-264: NAS1021N4 Lubrication Comparison Removal Prevailing Torque; 66% Y Preload

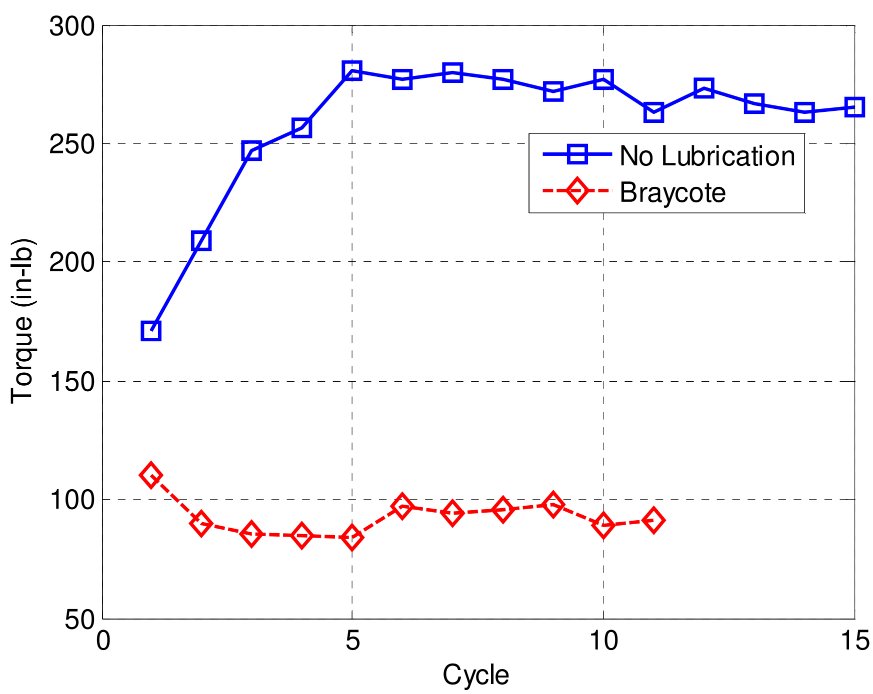

Figure D-265: NAS1021N4 Lubrication Comparison Tightening Torque; 66% Y Preload

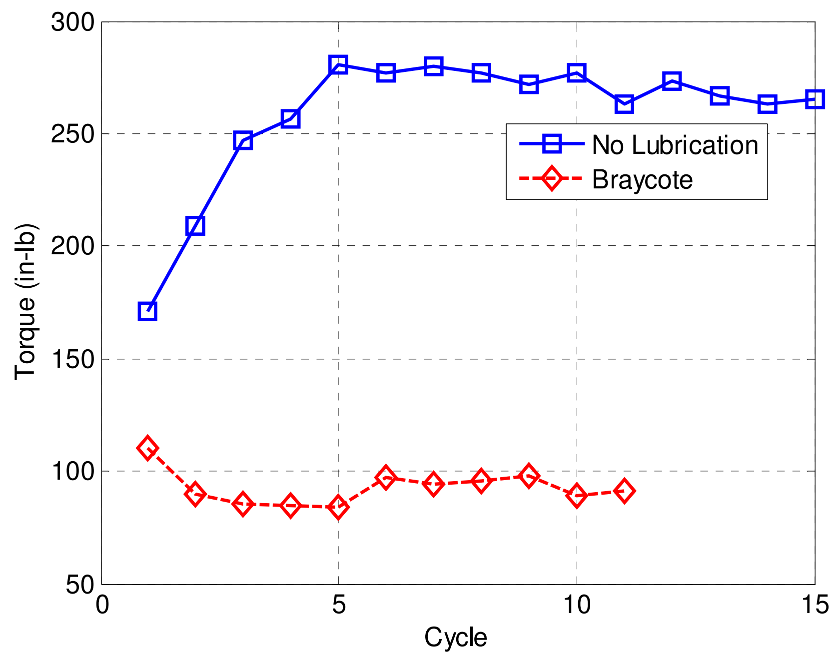

Figure D-266: NAS1021N4 Lubrication Comparison Breakloose Torque; 66% Y Preload

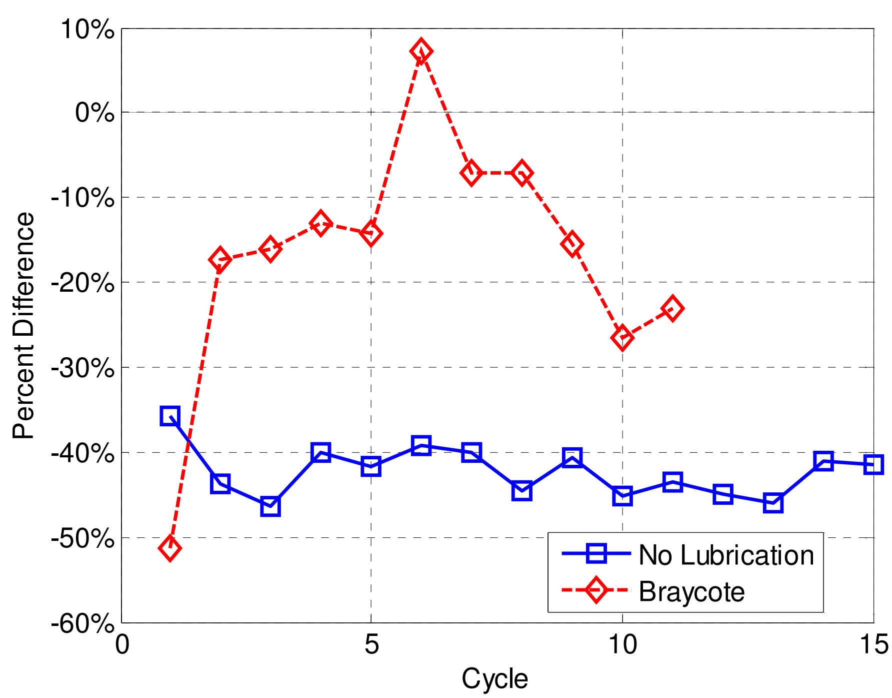

Figure D-267: NAS1021N4 Lubrication Comparison Percent Difference; 66% Y Preload

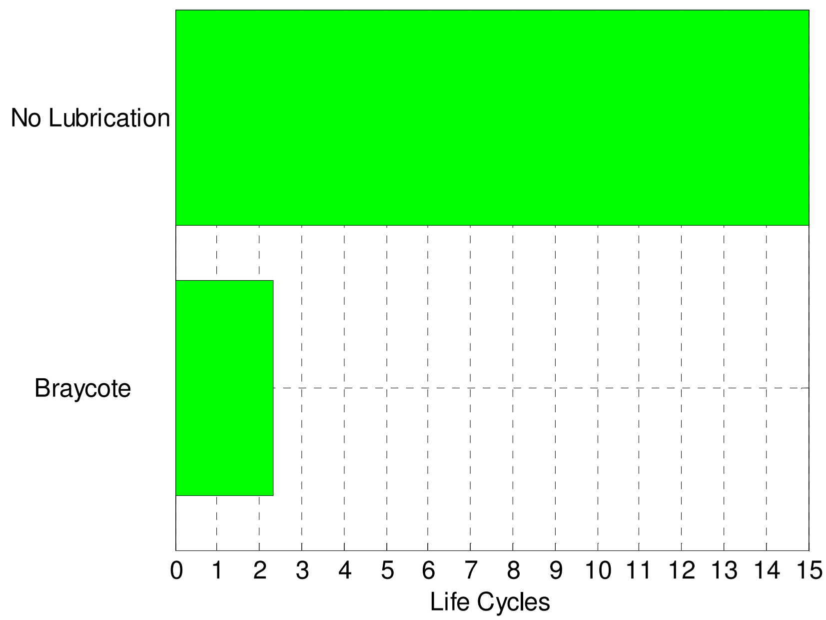

Figure D-268: NAS1021N4 Lubrication Comparison Life; 66% Y Preload

D.10.3 75% Y Preload

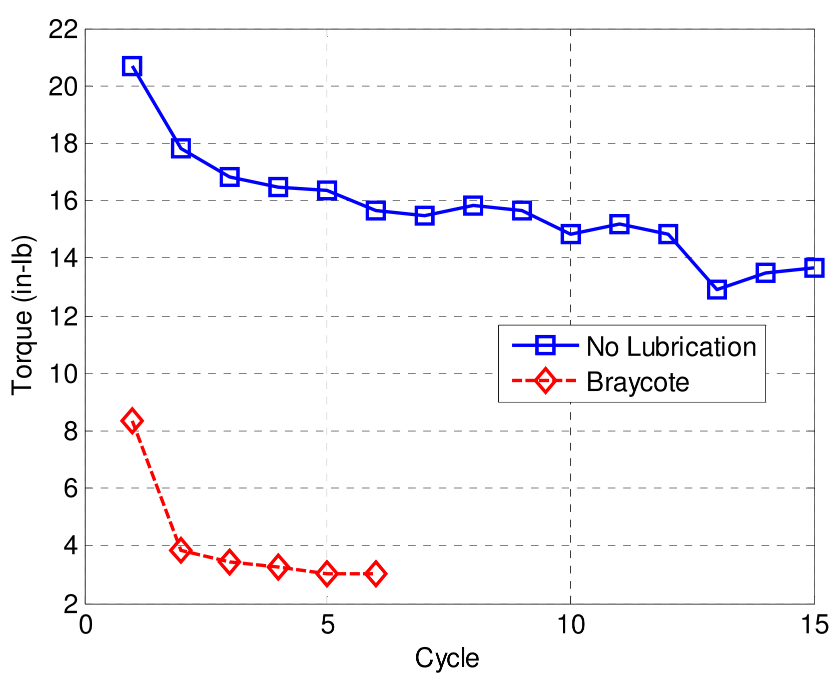

Figure D-269: NAS1021N4 Lubrication Comparison Assembly Prevailing Torque; 75% Y Preload

Appendix D (Continued)

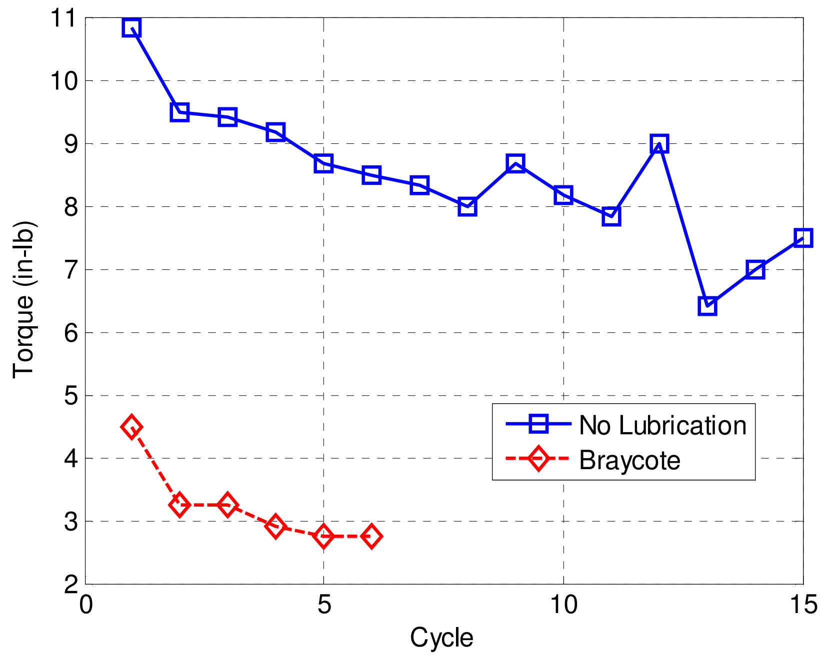

Figure D-270: NAS1021N4 Lubrication Comparison Removal Prevailing Torque; 75% Y Preload

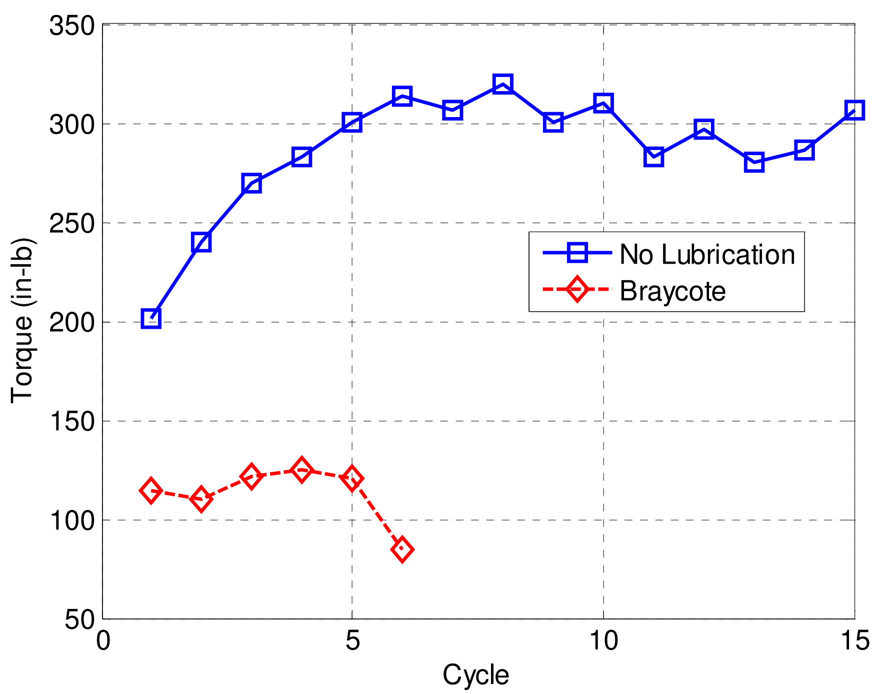

Figure D-271: NAS1021N4 Lubrication Comparison Tightening Torque; 75% Y Preload

Appendix D (Continued)

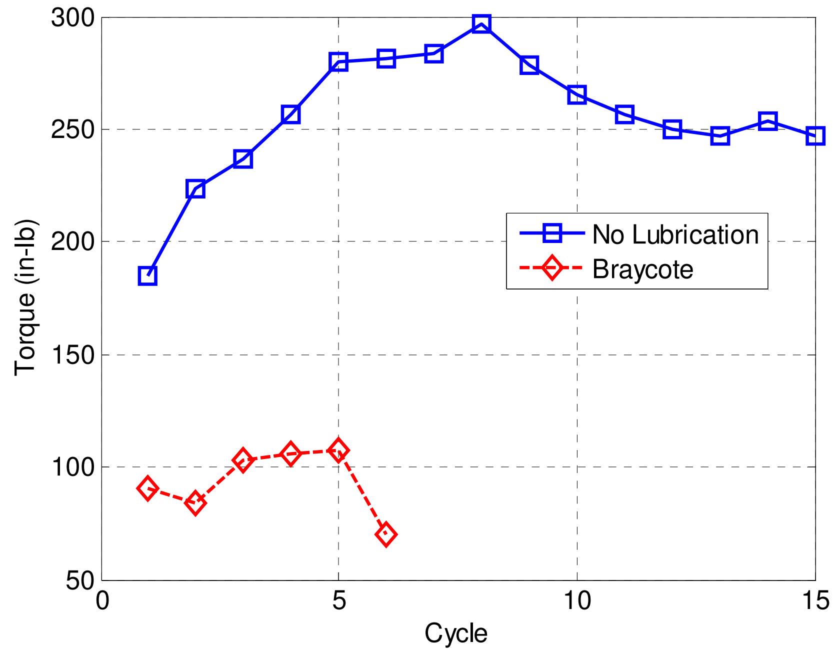

Figure D-272: NAS1021N4 Lubrication Comparison Breakloose Torque; 75% Y Preload

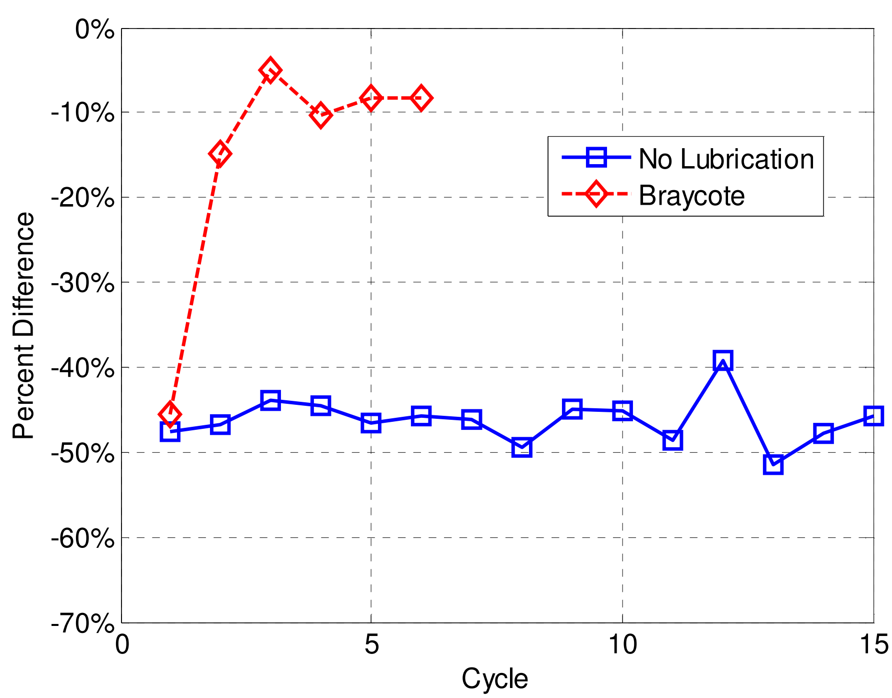

Figure D-273: NAS1021N4 Lubrication Comparison Percent Difference; 75% Y Preload

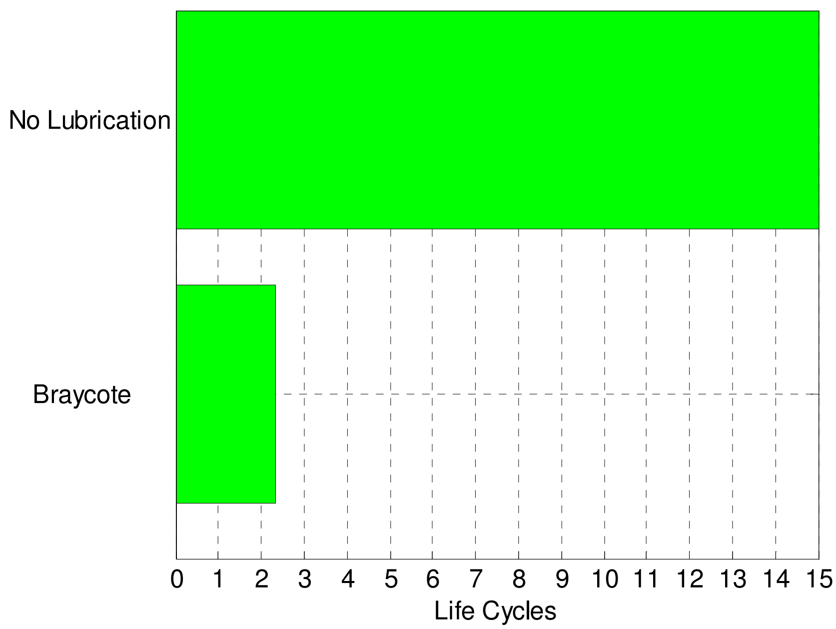

Figure D-274: NAS1021N4 Lubrication Comparison Life; 75% Y Preload

D.10.4 85% Y Preload

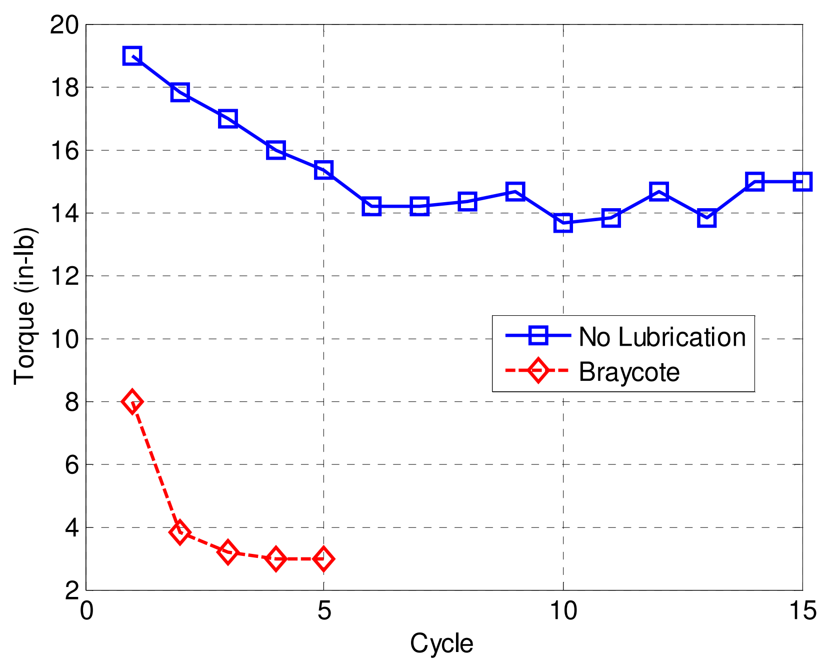

Figure D-275: NAS1021N4 Lubrication Comparison Assembly Prevailing Torque; 85% Y Preload

Appendix D (Continued)

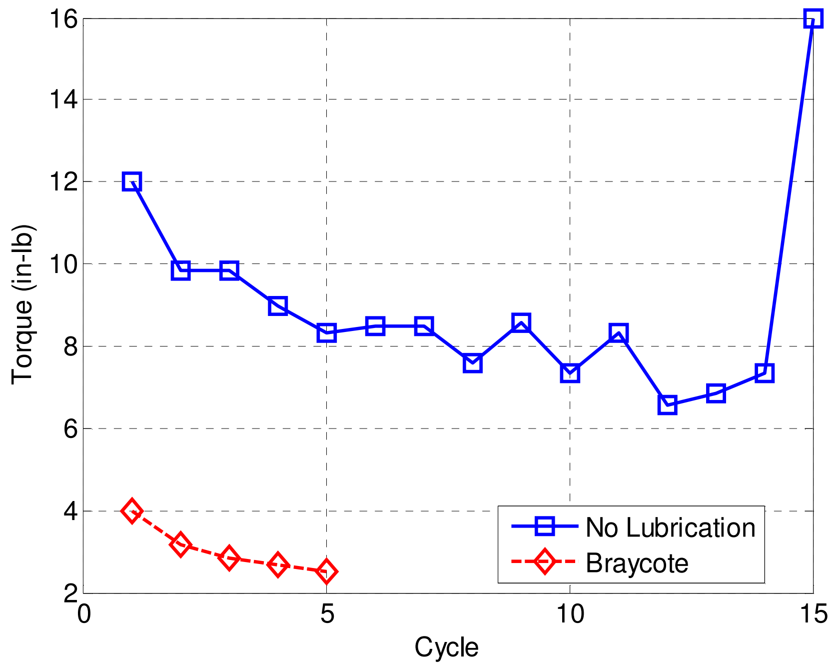

Figure D-276: NAS1021N4 Lubrication Comparison Removal Prevailing Torque; 85% Y Preload

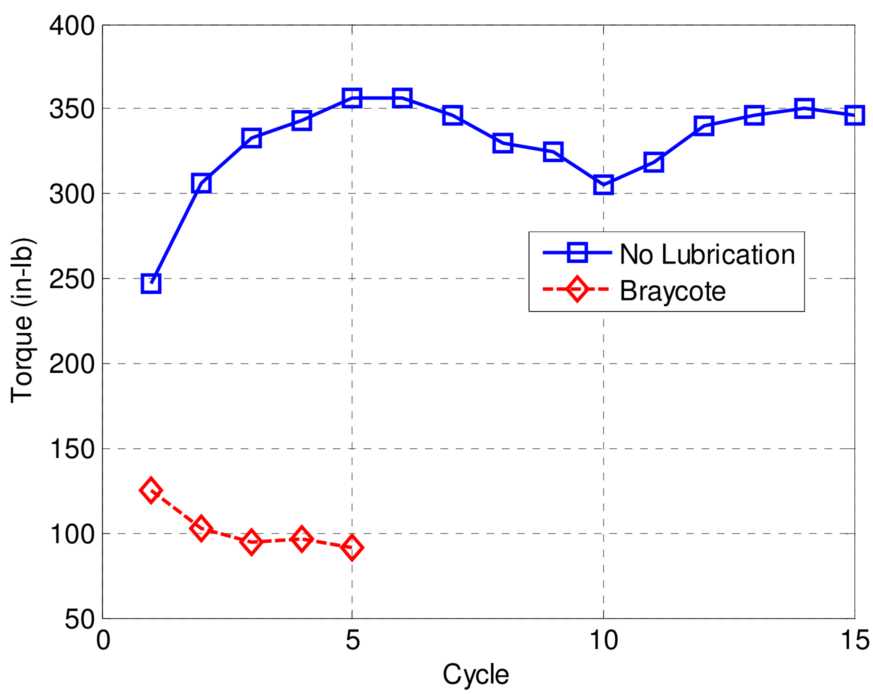

Figure D-277: NAS1021N4 Lubrication Comparison Tightening Torque; 85% Y Preload

Appendix D (Continued)

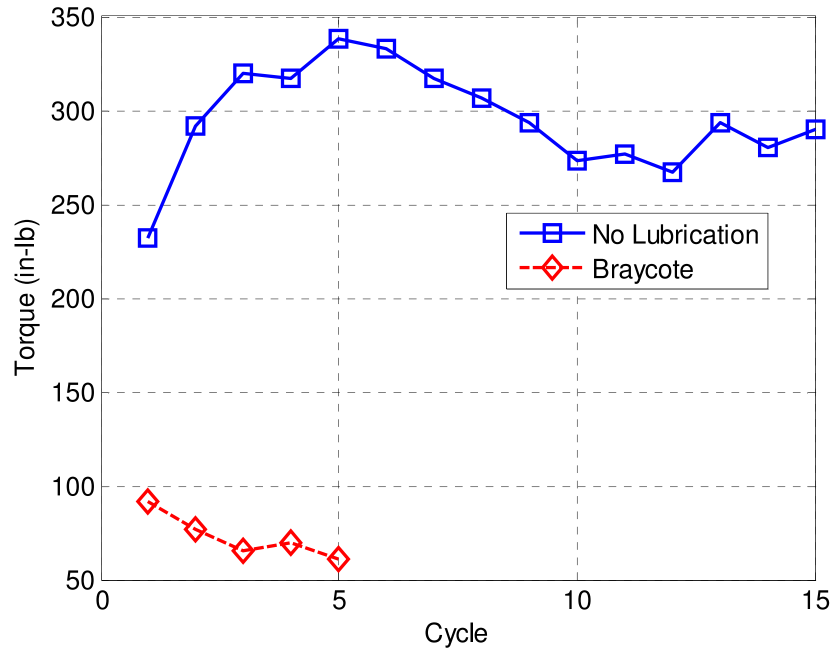

Figure D-278: NAS1021N4 Lubrication Comparison Breakloose Torque; 85% Y Preload

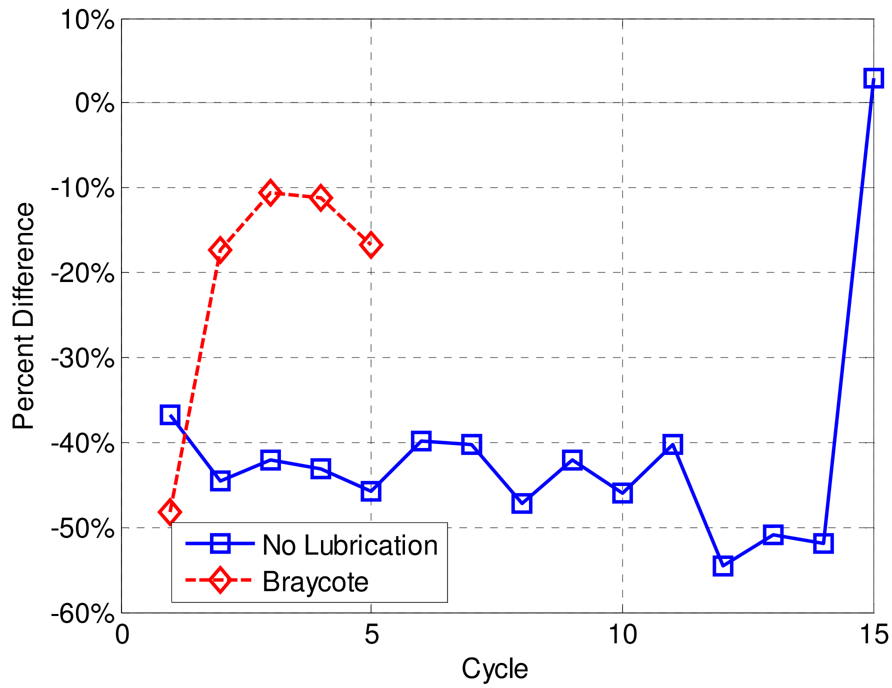

Figure D-279: NAS1021N4 Lubrication Comparison Percent Difference; 85% Y Preload

Appendix D (Continued)

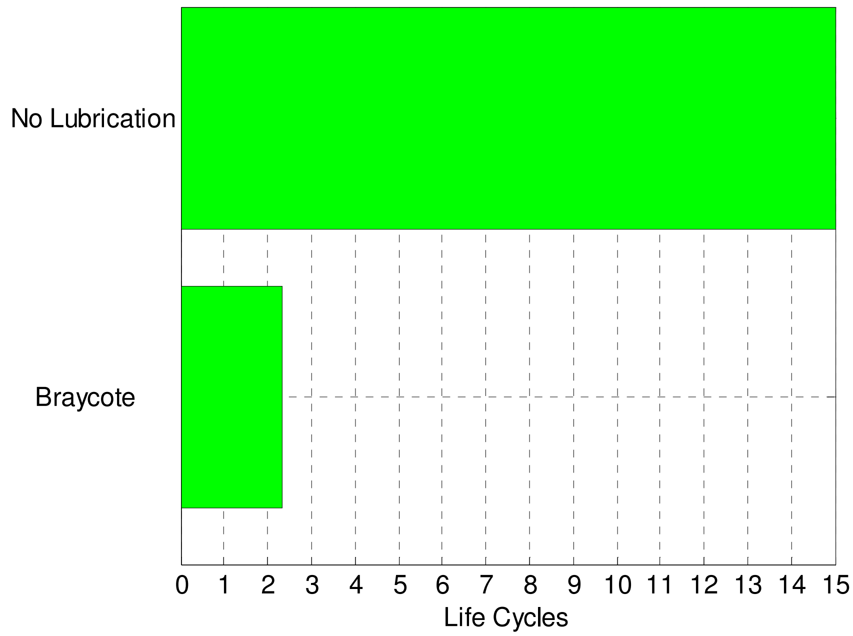

Figure D-280: NAS1021N4 Lubrication Comparison Life; 85% Y Preload

D.10.5 Averaged Preload Comparison

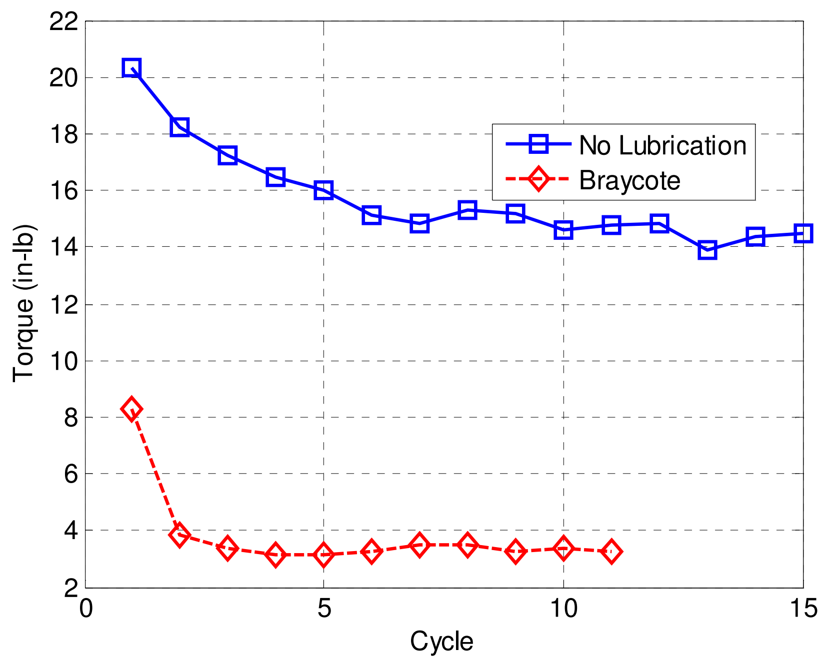

Figure D-281: NAS1021N4 Lubrication Comparison Assembly Prevailing Torque; Preload Average

Appendix D (Continued)

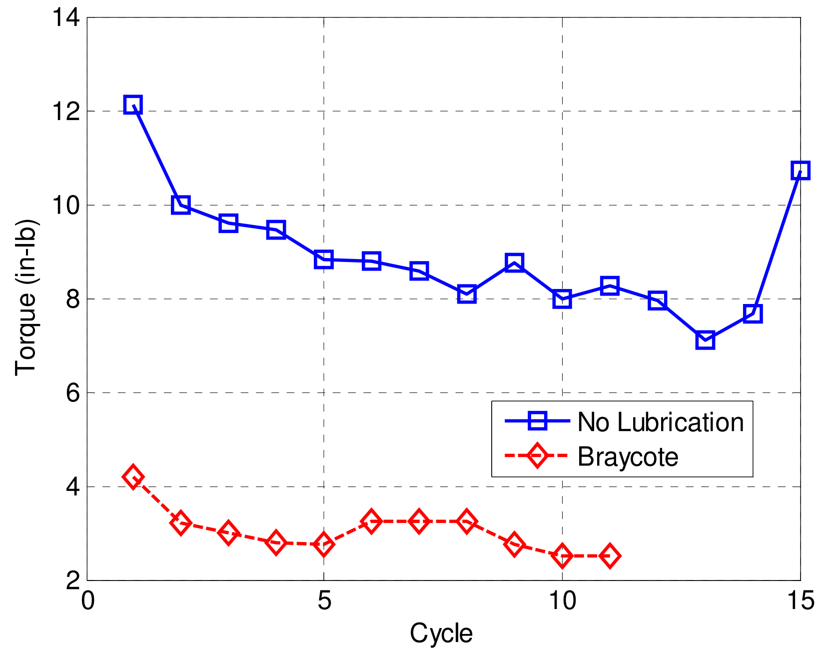

Figure D-282: NAS1021N4 Lubrication Comparison Removal Prevailing Torque; Preload Average

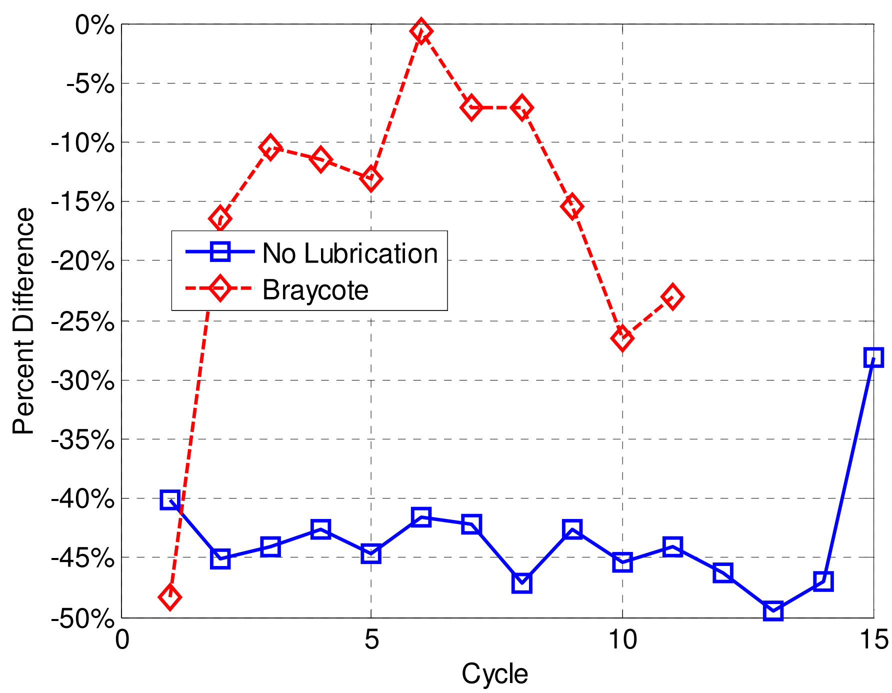

Figure D-283: NAS1021N4 Lubrication Comparison Percent Difference; Preload Average

Appendix D (Continued)

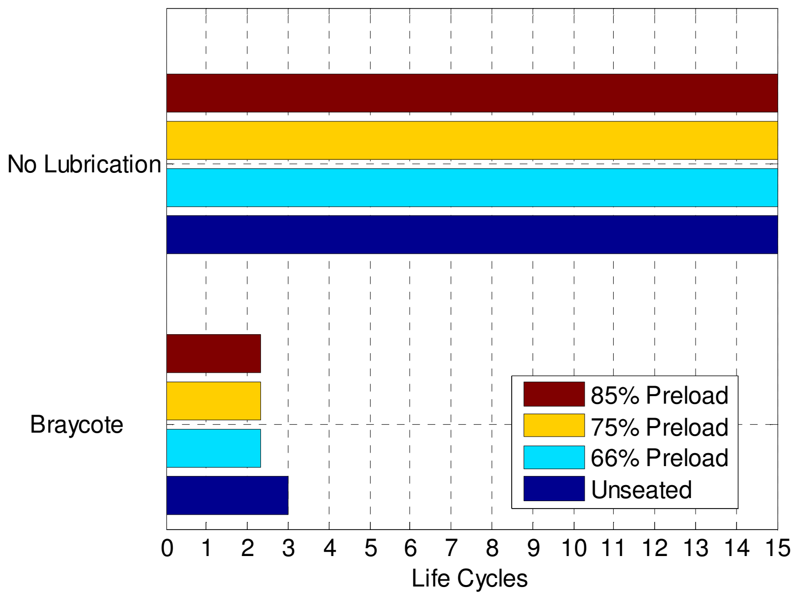

Figure D-284: NAS1021N4 Lubrication Comparison; Life

D.11 Grade 8

D.11.1 Unseated

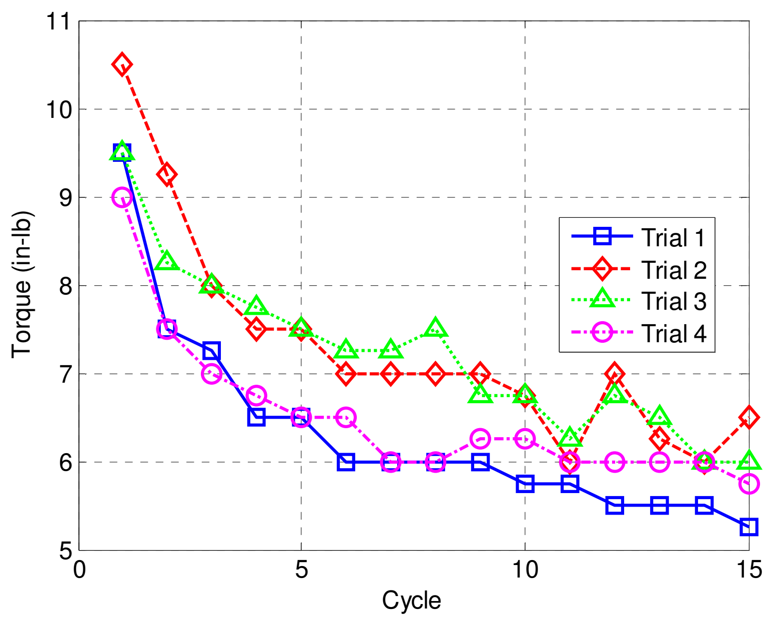

Figure D-285: Grade 8 Assembly Prevailing Torque; Unseated

Appendix D (Continued)

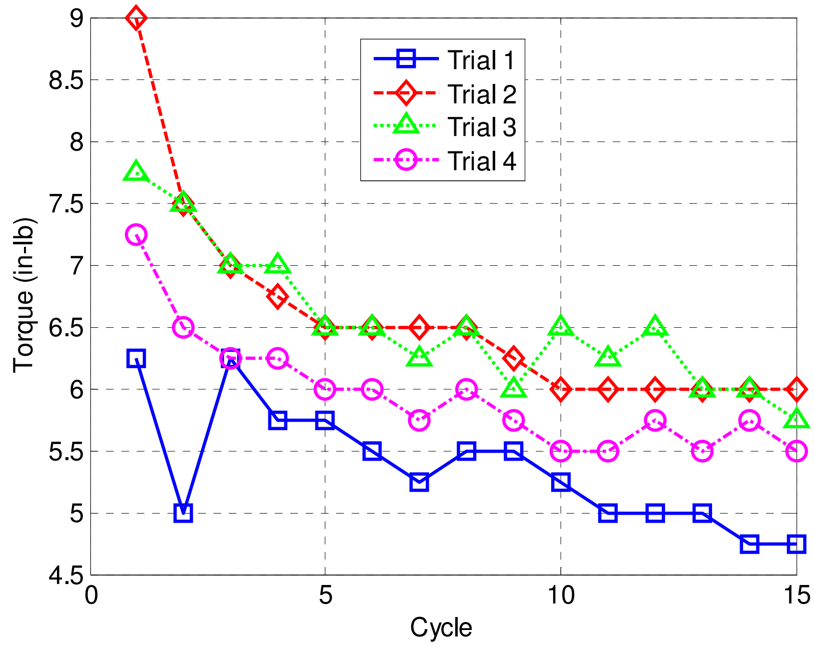

Figure D-286: Grade 8 Removal Prevailing Torque; Unseated

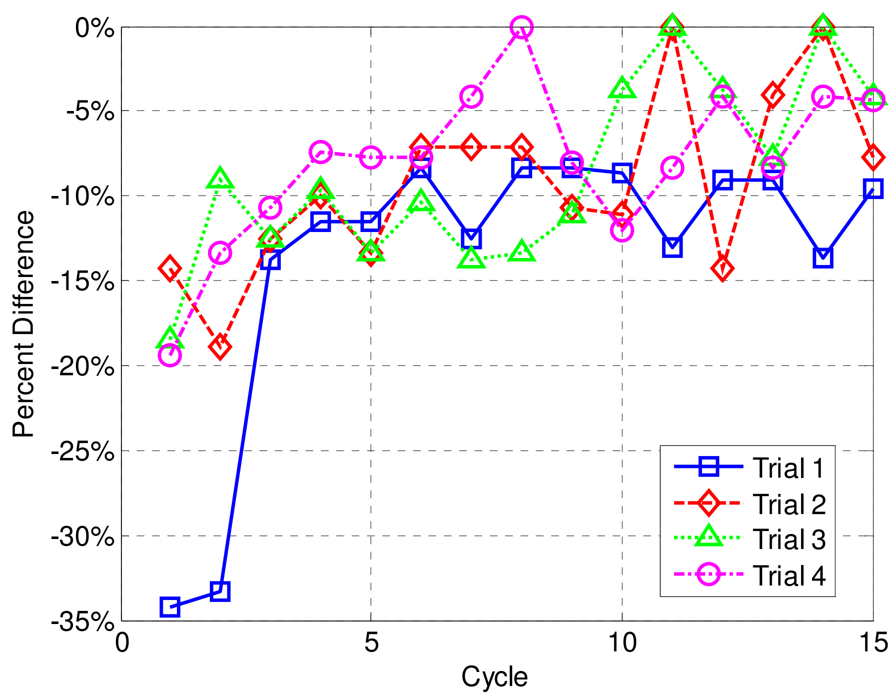

Figure D-287: Grade 8 Percent Difference; Unseated

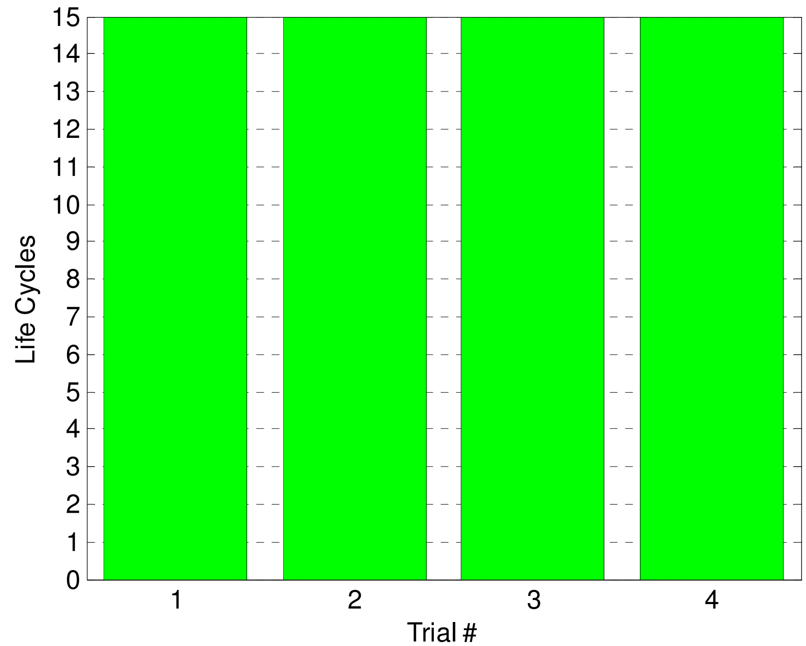

Figure D-288: Grade 8 Life; Unseated

D.11.2 66% Y Preload

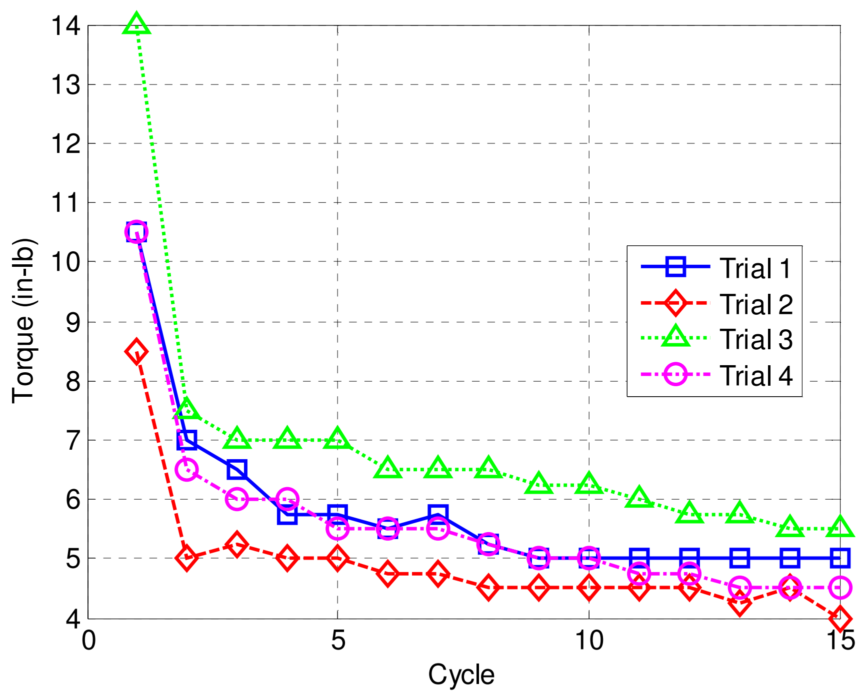

Figure D-289: Grade 8 Assembly Prevailing Torque; 66% Y Preload

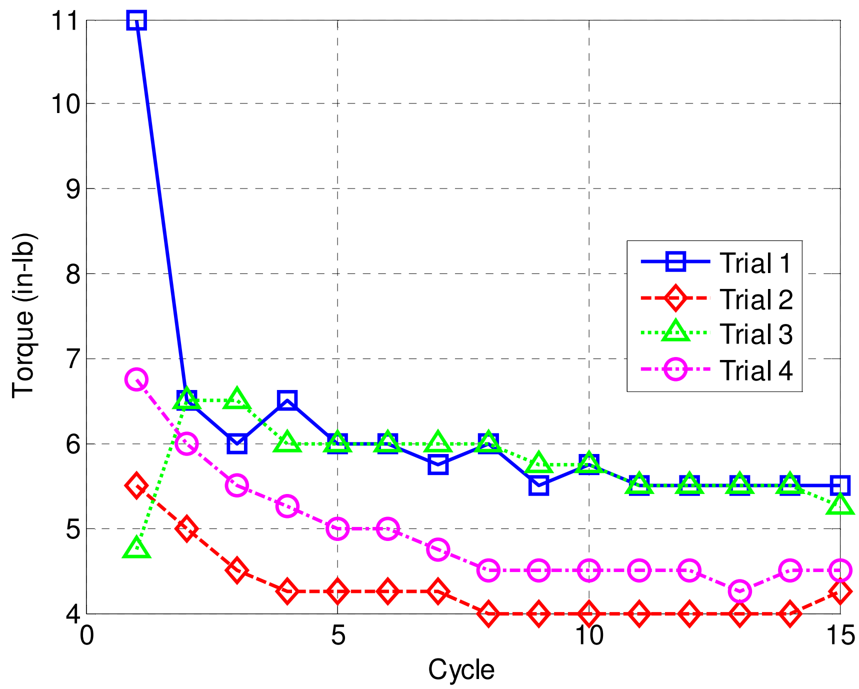

Figure D-290: Grade 8 Removal Prevailing Torque; 66% Y Preload

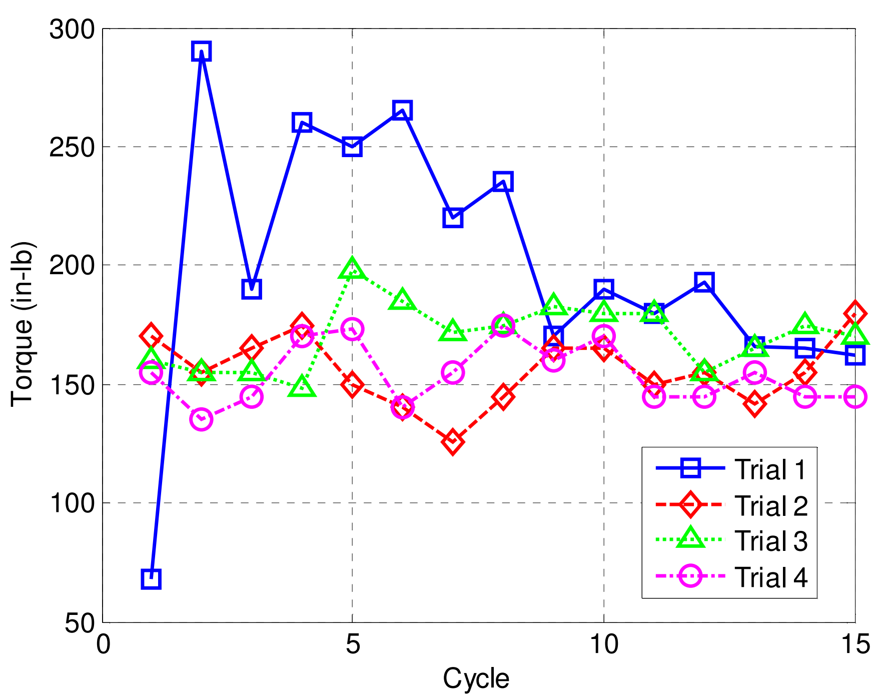

Figure D-291: Grade 8 Tightening Torque; 66% Y Preload

Appendix D (Continued)

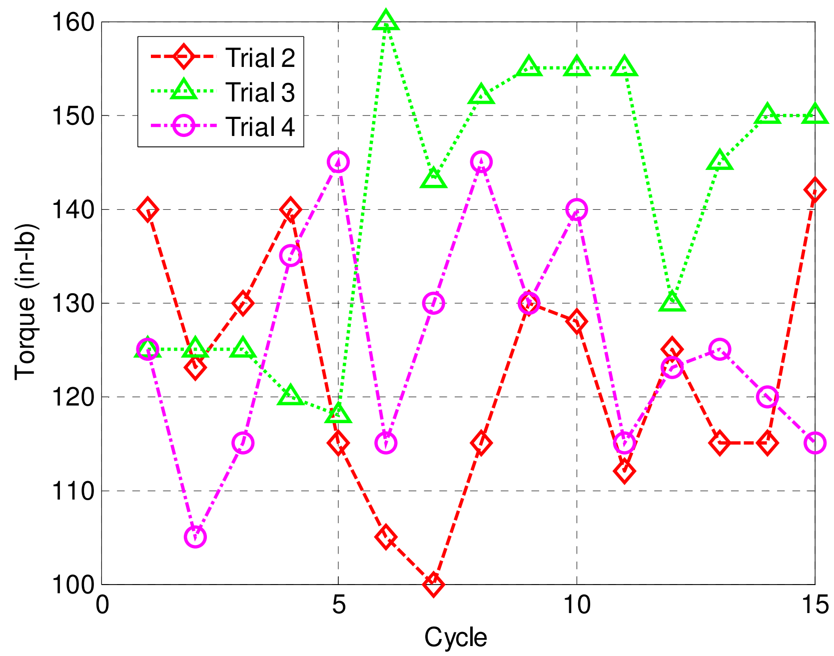

Figure D-292: Grade 8 Breakloose Torque; 66% Y Preload

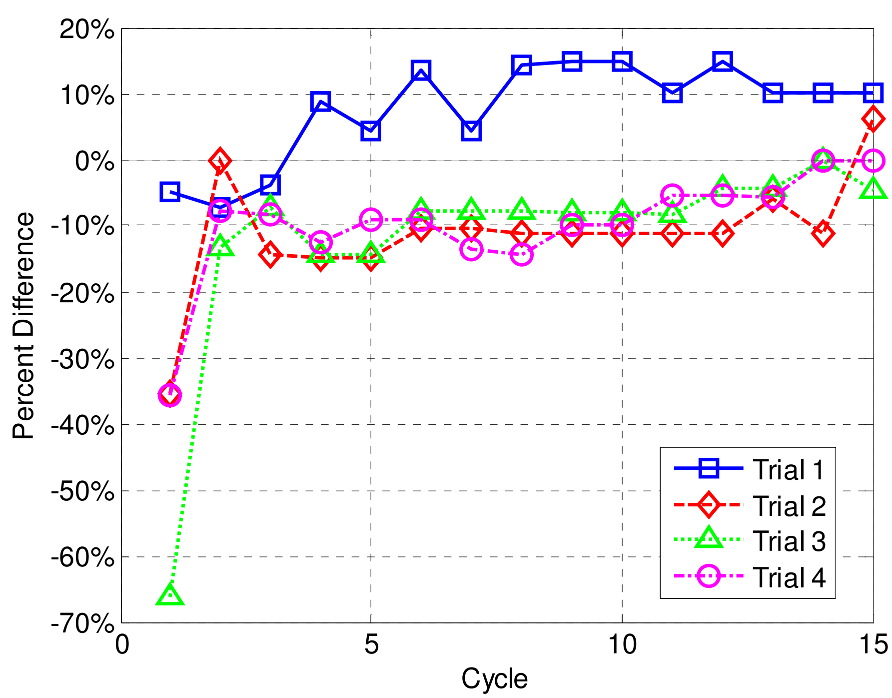

Figure D-293: Grade 8 Percent Difference; 66% Y Preload

Appendix D (Continued)

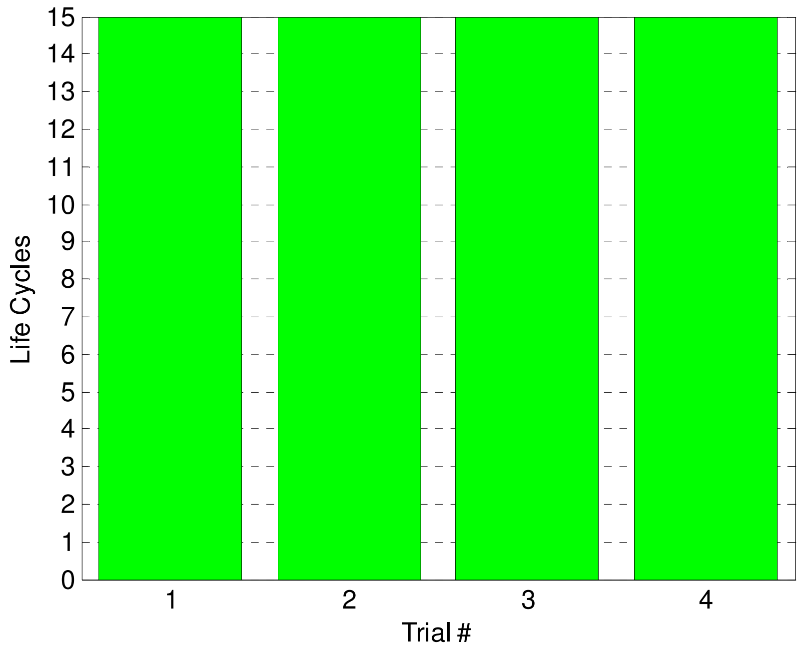

Figure D-294: Grade 8 Life; 66% Y Preload

D.11.3 75% Y Preload

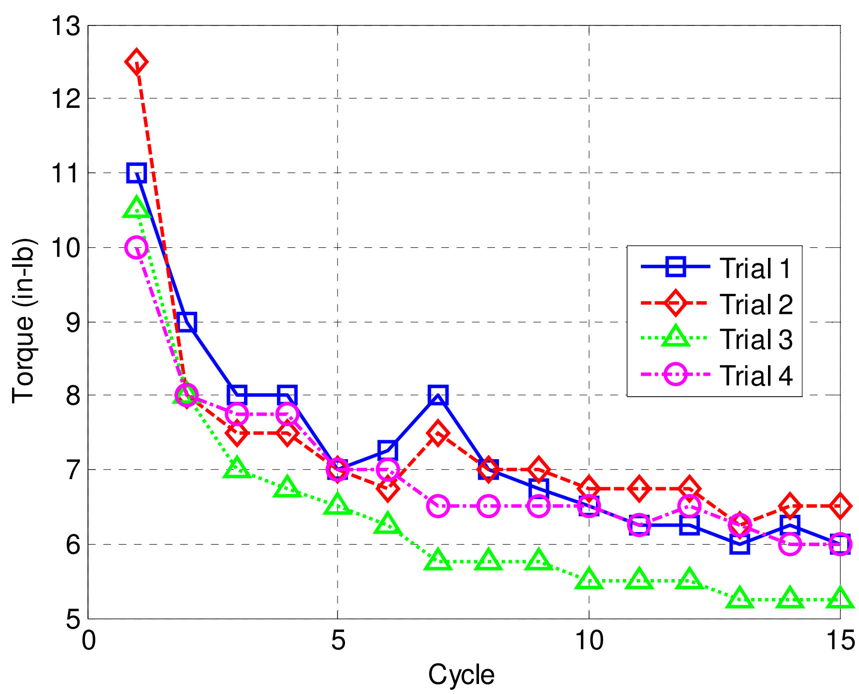

Figure D-295: Grade 8 Assembly Prevailing Torque; 75% Y Preload

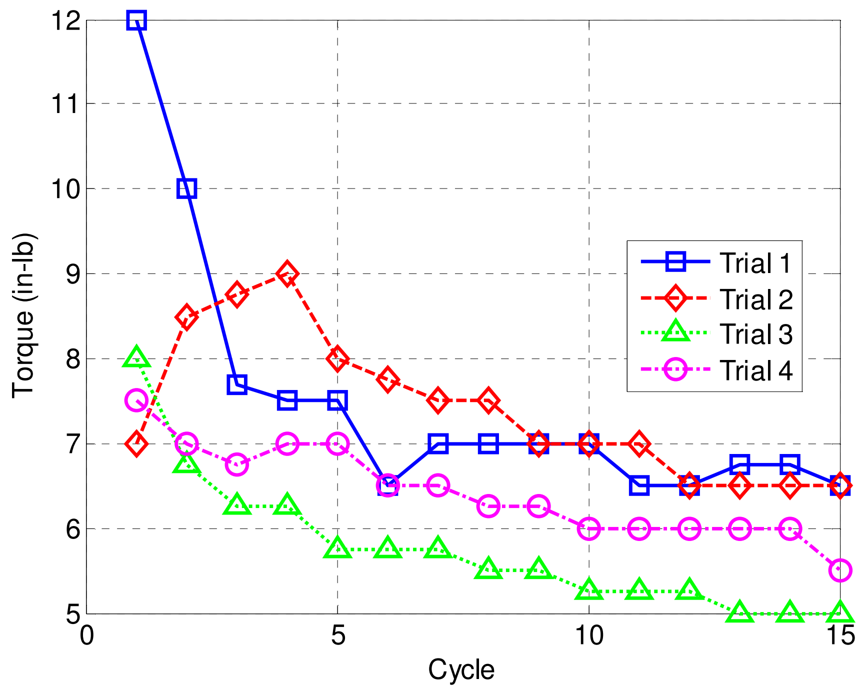

Figure D-296: Grade 8 Removal Prevailing Torque; 75% Y Preload

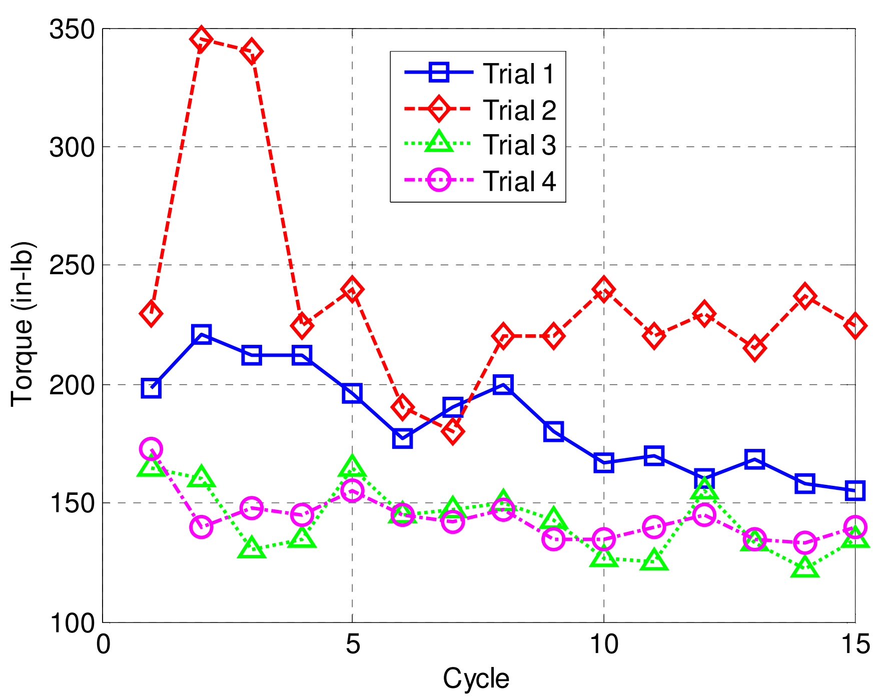

Figure D-297: Grade 8 Tightening Torque; 75% Y Preload

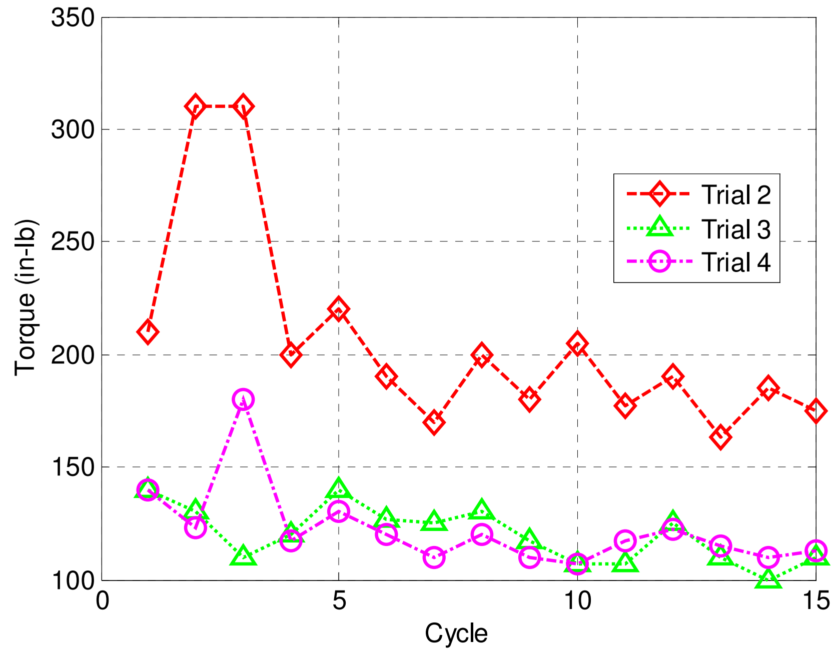

Figure D-298: Grade 8 Breakloose Torque; 75% Y Preload

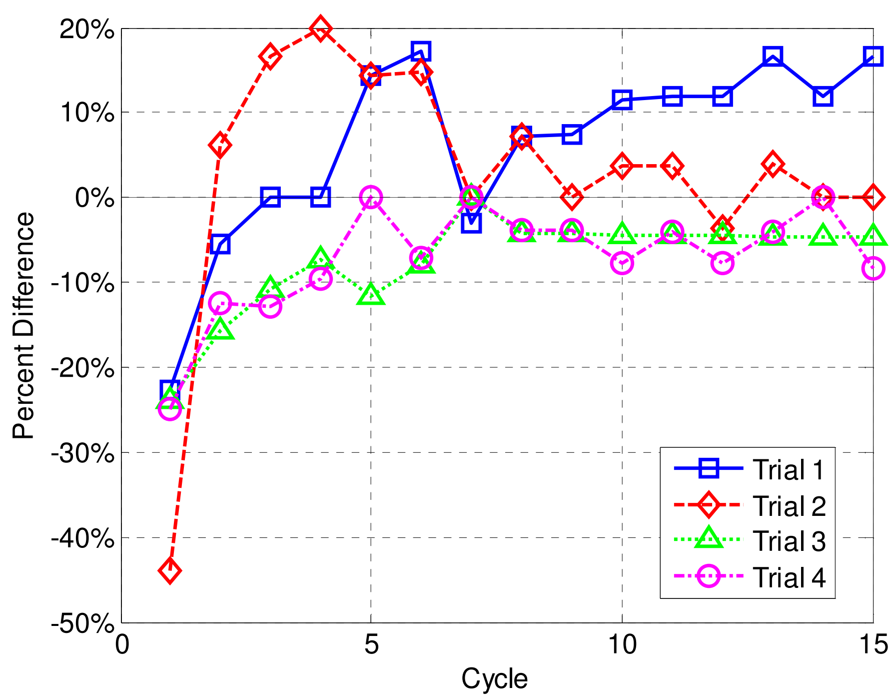

Figure D-299: Grade 8 Percent Difference; 75% Y Preload

Appendix D (Continued)

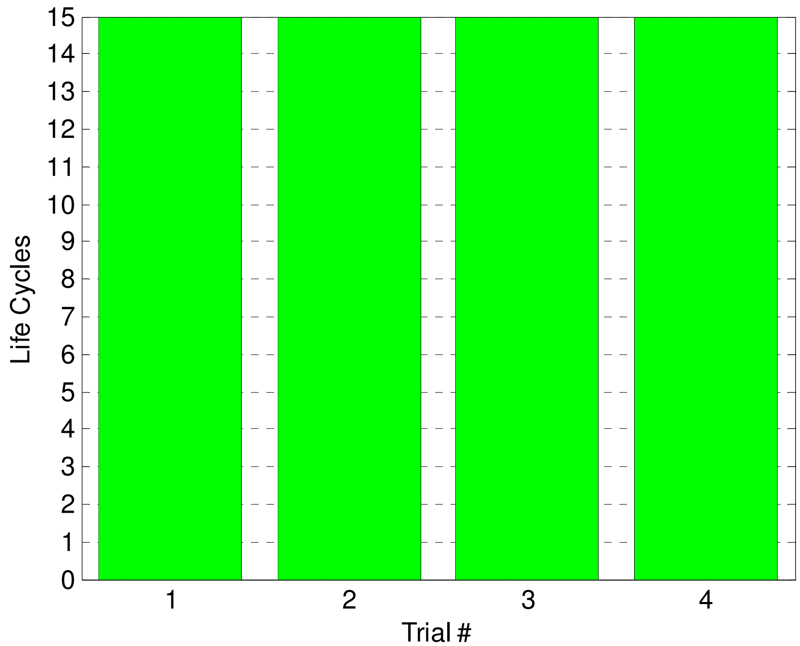

Figure D-300: Grade 8 Life; 75% Y Preload

D.11.4 85% Y Preload

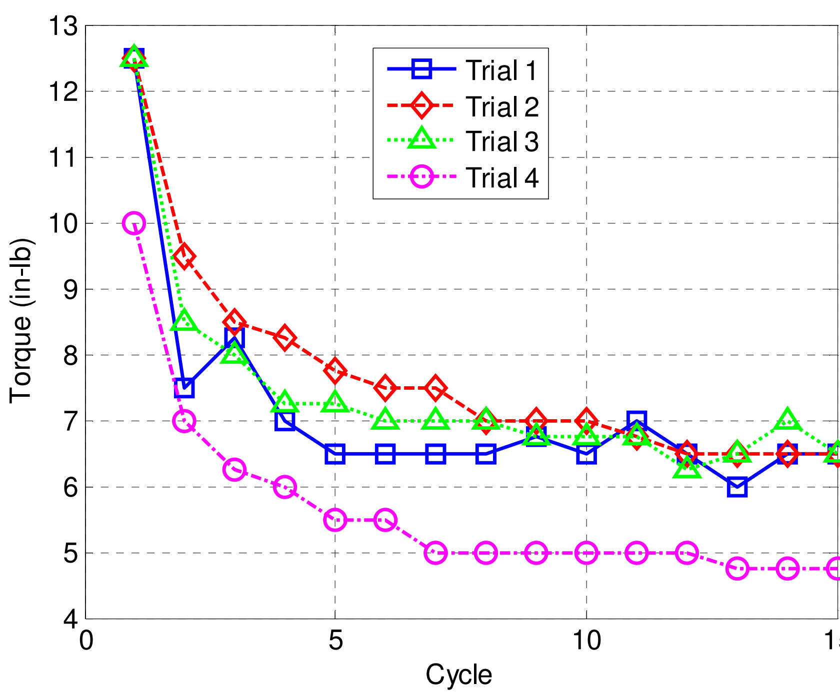

Figure D-301: Grade 8 Assembly Prevailing Torque; 85% Y Preload

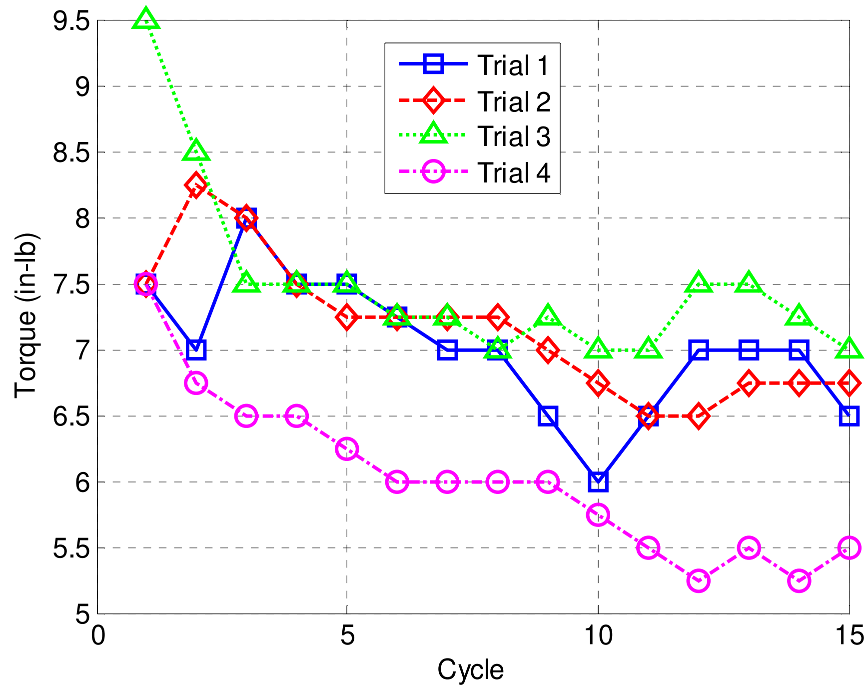

Figure D-302: Grade 8 Removal Prevailing Torque; 85% Y Preload

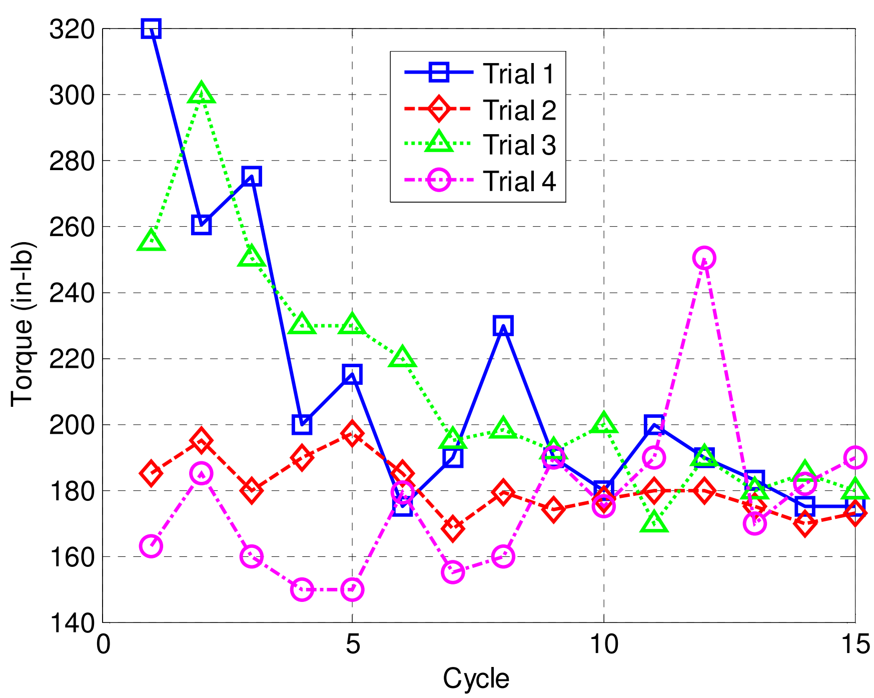

Figure D-303: Grade 8 Tightening Torque; 85% Y Preload

Appendix D (Continued)

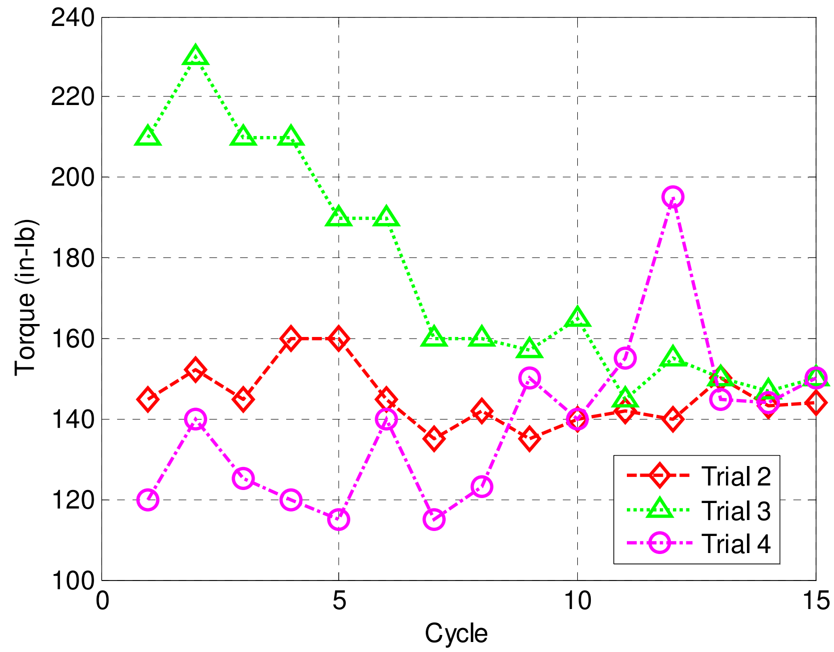

Figure D-304: Grade 8 Breakloose Torque; 85% Y Preload

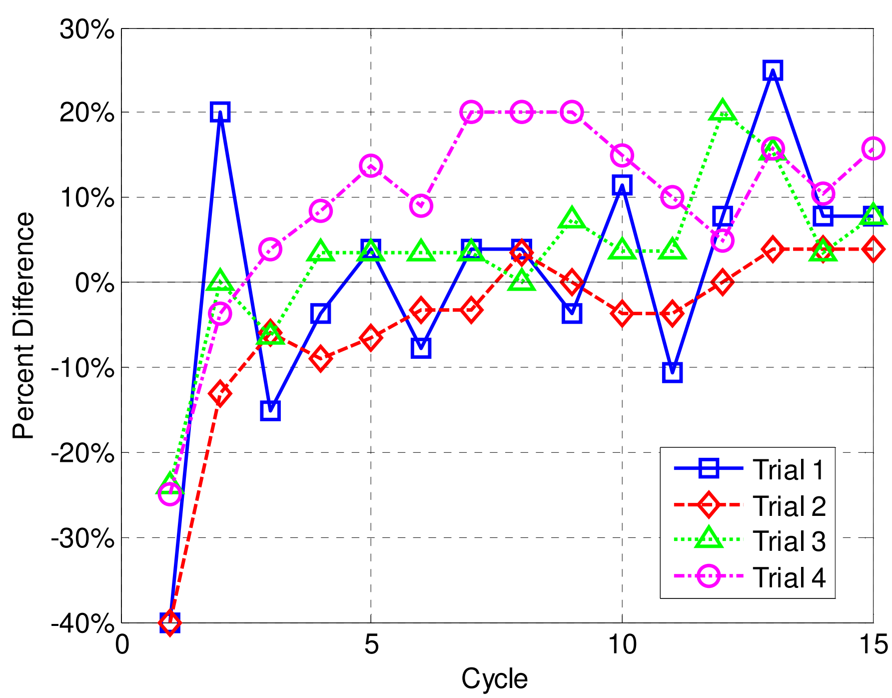

Figure D-305: Grade 8 Percent Difference; 85% Y Preload

Appendix D (Continued)

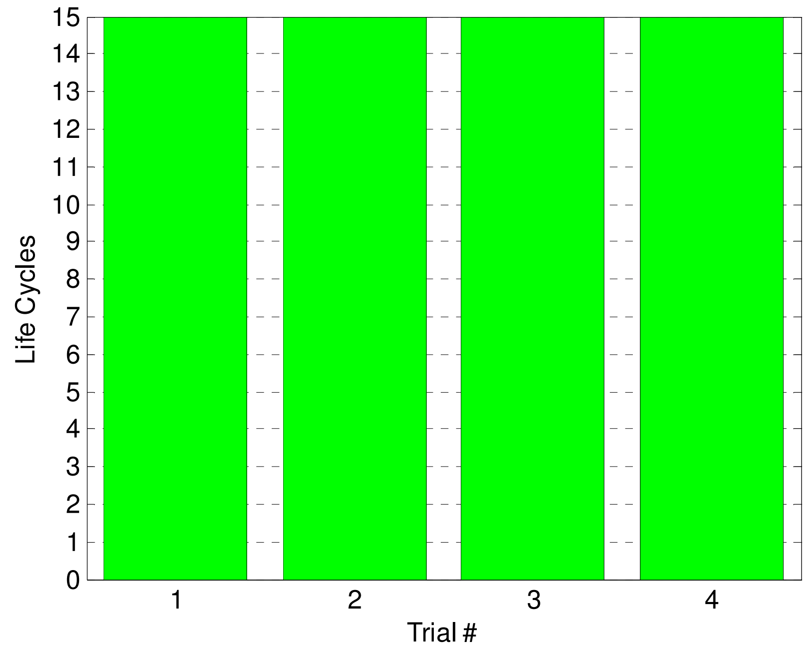

Figure D-306: Grade 8 Life; 85% Y Preload

D.11.5 Preload Averages

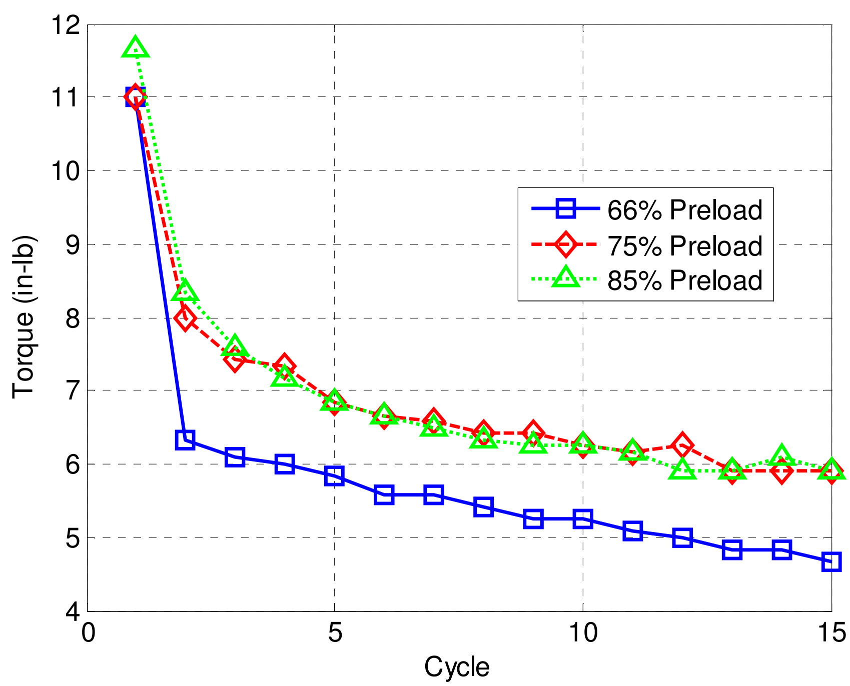

Figure D-307: Grade 8 Assembly Prevailing Torque; Preload Average

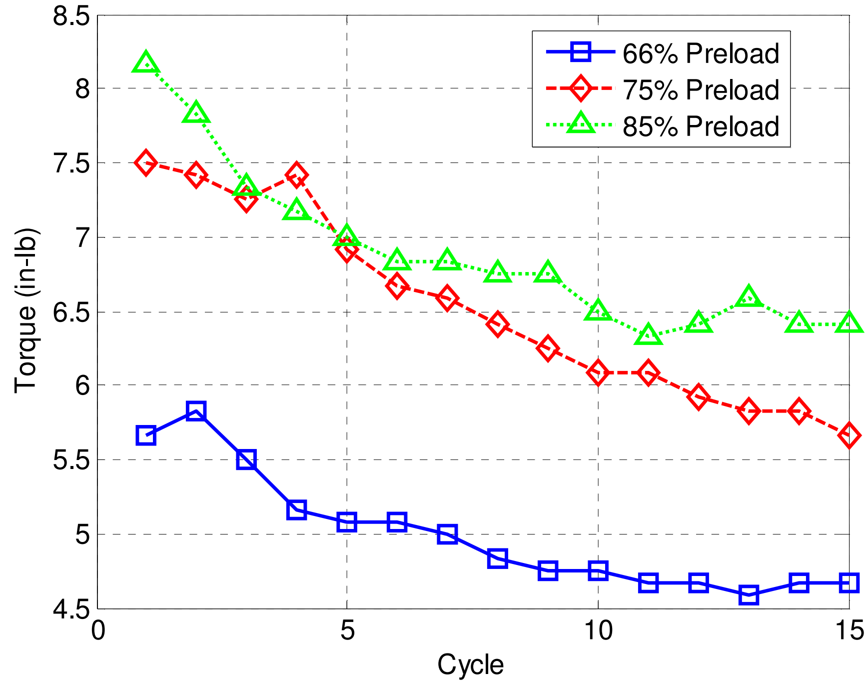

Figure D-308: Grade 8 Removal Prevailing Torque; Preload Average

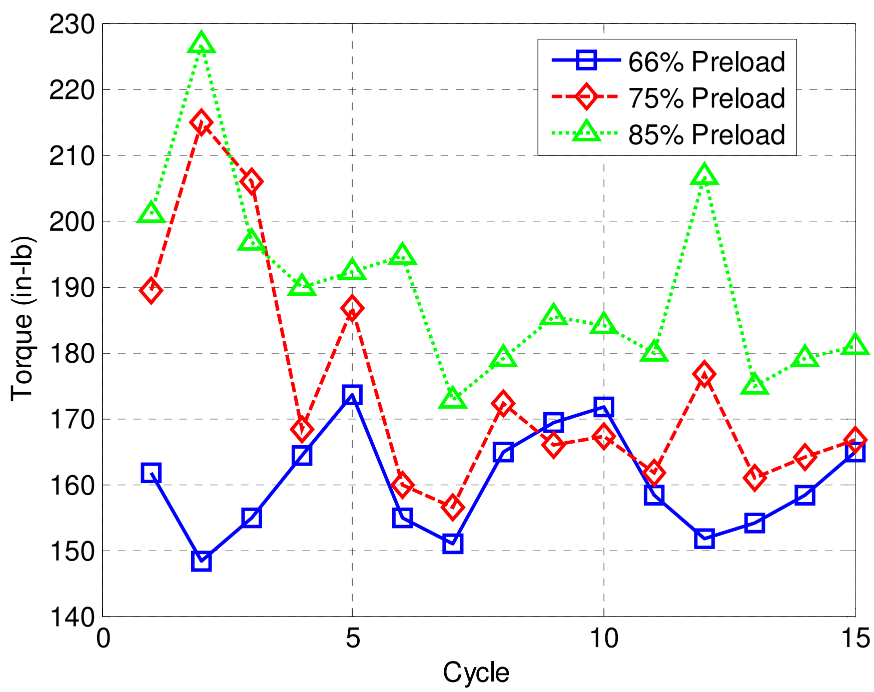

Figure D-309: Grade 8 Tightening Torque; Preload Average

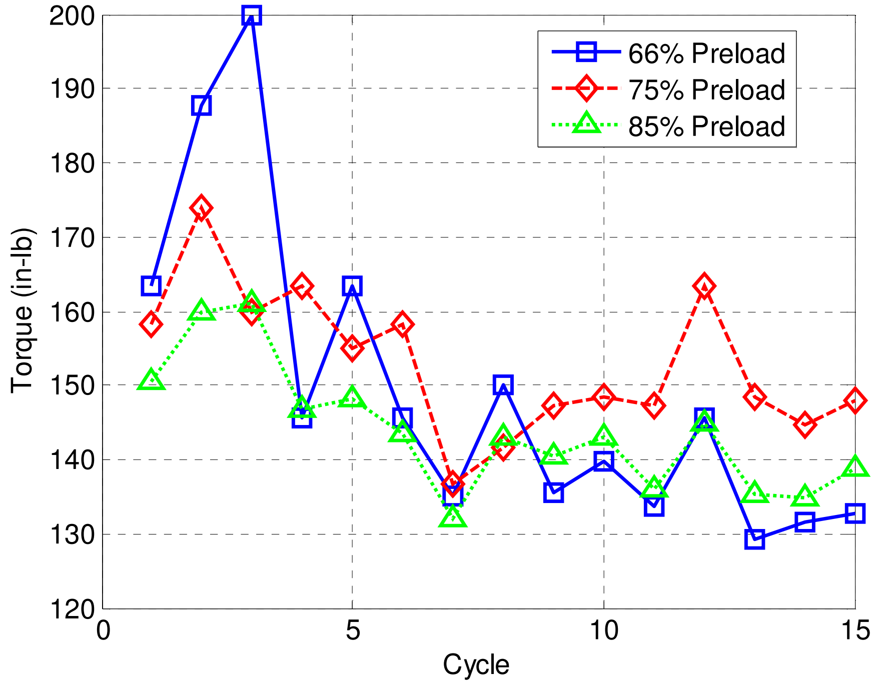

Figure D-310: Grade 8 Breakloose Torque; Preload Average

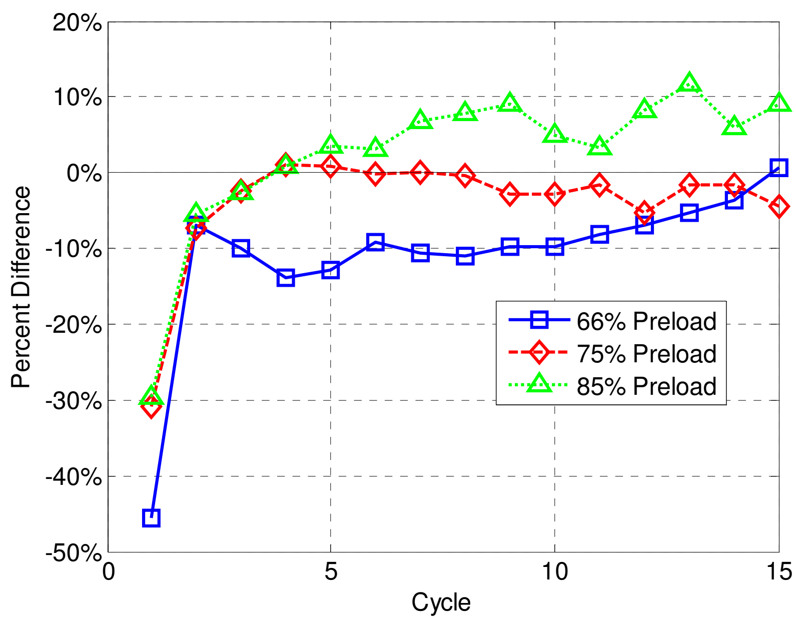

Figure D-311: Grade 8 Percent Difference; Preload Average

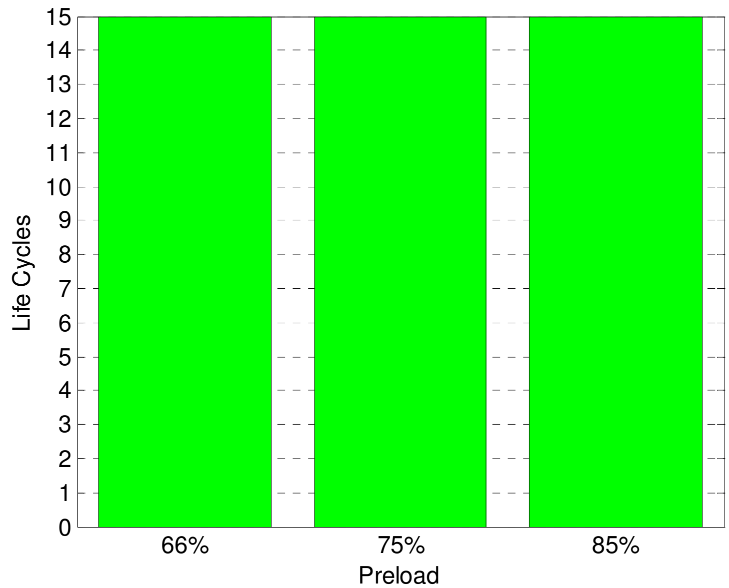

Figure D-312: Grade 8 Life; Preload Average

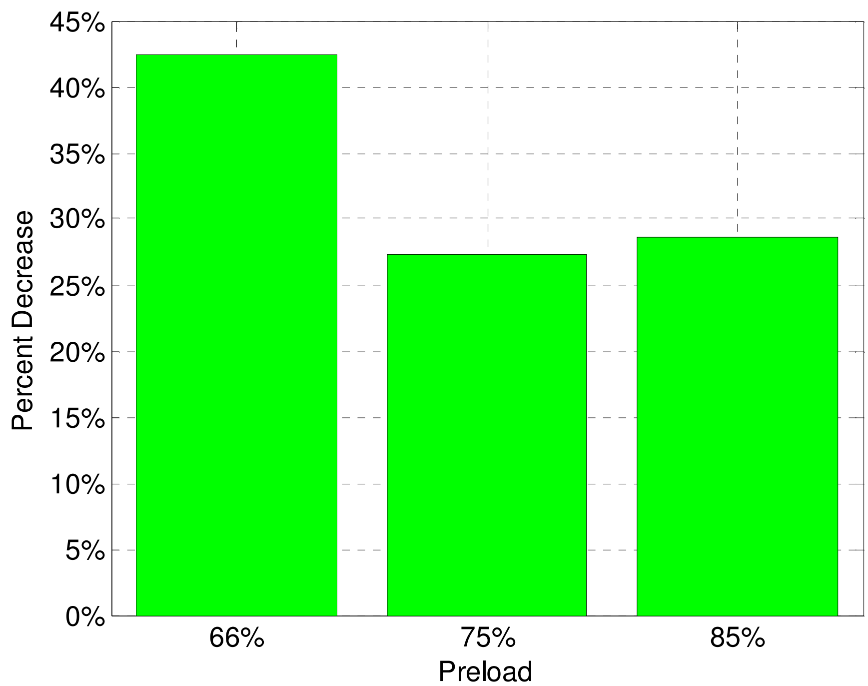

Figure D-313: Grade 8 Percent Decrease of Assembly Prevailing Torque from Cycle 1 to 2; Preload Average

Appendix E: Locknut Average Standard Deviations

E.1 MS21043-4

Table E-1: MS21043-4; Unseated

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	0.8574024	0.8039184	0.96425705	0.024982	0.029890339
Median	16.25	11.75	15.88	-0.305333	-0.006588826
Maximum	19	14.13	19.31	-0.249487	0.043957431
Minimum	15.56	10.88	15.13	-0.346683	-0.078159341

Table E-2: MS21043-4; 66% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.5412941	13.0013105	17.2272896	0.8854545	0.09719118
Median	11.67	243.67	208.67	8.9666667	-0.282017544
Maximum	17	262	229.67	10.5	-0.081196581
Minimum	10.7	213.67	160	7.33	-0.474048174

Table E-3: MS21043-4; 75% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	2.0433383	17.470787	14.6365431	0.8666221	0.103896692
Median	9.5	261.66667	221.67	6.5	-0.33743842
Maximum	16	302.5	250	8.67	-0.180020704
Minimum	8.67	240	196.67	5	-0.59375

Appendix E (Continued)

Table E-4: MS21043-4; 85% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.7642191	16.623463	21.1595935	1.4270751	0.057575859
Median	14.75	330	278.33	9.25	-0.42
Maximum	19	355	315	12.83	-0.260119048
Minimum	12.67	303.33	243.33	7.5	-0.47875

Table E-5: MS21043-4; Averaged

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.6332155	13.8227492	16.617419	0.8519518	0.064300527
Median	12.08	275.33	232.78	8.0138889	-0.324379508
Maximum	16.83	305.06	264.56	10.27	-0.226080372
Minimum	10.972222	257.89	208.33	6.67	-0.498789868

E.2 NAS1291-4

Table E-6: NAS1291-4; Unseated

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	0.7080882	1.2606766	0.56902085	0.042879	0.025713822
Median	16.88	12.25	17.75	-0.311166	0.039302298
Maximum	19.31	15.44	18.75	-0.235625	0.068013393
Minimum	16.25	10.38	16.63	-0.376977	-0.034722746

Appendix E (Continued)

Table E-7: NAS1291-4; 66% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.5560491	17.9502192	16.5454257	0.9515835	0.050653992
Median	14.17	201.33	176.67	11.08	-0.215075155
Maximum	19.67	230	202.67	14.5	-0.094461538
Minimum	12.67	169	144.67	10.33	-0.302020202

Table E-8: NAS1291-4; 75% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.9382294	17.235708	17.9820761	1.9710403	0.049168273
Median	15.33	233	203.33	13.33	-0.127931904
Maximum	20.83	248.33	215.67	17.58	-0.05008135
Minimum	12.83	186.33	159	10.17	-0.207692308

Table E-9: NAS1291-4; 85% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.1391105	21.838962	21.2402846	1.5759395	0.079358288
Median	12.83	253.33	222.5	12.233333	-0.069444444
Maximum	16.67	275	240	14.25	0.020186335
Minimum	11.5	201.66667	171.67	8.5	-0.263257576

Appendix E (Continued)

Table E-10: NAS1291-4; Averaged

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.4704321	18.4956214	18.299365	1.3216432	0.036684902
Median	13.89	229.11	200.94444	12.411111	-0.128833449
Maximum	19.06	243	217.11111	15.64	-0.091262104
Minimum	12.5	187	159	10.27	-0.203247859

E.3 NAS1805-4

Table E-11: NAS1805-4; Unseated

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	7.810653	7.5939976	8.20493373	0.139575	0.134441181
Median	11.75	12	10.75	-0.11	-0.052323481
Maximum	24.63	26.63	24.5	0.17	0.135497835
Minimum	4	3	3.5	-0.349167	-0.303030303

Table E-12: NAS1805-4; 66% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	7.8924757	30.5026411	25.86544	10.050588	0.231598316
Median	19	165.67	147.67	14.83	-0.077777778
Maximum	30.33	231.67	189	35.5	0.361640212
Minimum	2.5	120.33	104.67	2	-0.5

Appendix E (Continued)

Table E-13: NAS1805-4; 75% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	7.2471493	32.103044	32.8279014	6.5707592	0.202896185
Median	13.17	170	149.33	11.67	-0.042246642
Maximum	20	215	190	21.67	0.365079365
Minimum	1.5	121.66667	100	2	-0.244346297

Table E-14: NAS1805-4; 85% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	5.6861484	21.825865	20.8541555	4.5296145	0.207491489
Median	16	172	142.33	11.67	-0.04962963
Maximum	19.83	210	176.5	20.08	0.4
Minimum	3	131.66667	105	5	-0.403831418

Table E-15: NAS1805-4; Averaged

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	6.7137443	27.4074039	25.779507	6.755816	0.144379412
Median	16.67	169.22	146.64	12.72	-0.030128208
Maximum	21.89	208.89	185.16667	24.805556	0.195375649
Minimum	2.5	125.11	103.22222	3	-0.351282903

Appendix E (Continued)

E.4 MS17825-4

Table E-16: MS17825-4; Unseated

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	0.9684789	0.502701	0.68844632	0.043613	0.035460193
Median	4.81	4.25	4.63	-0.144643	-0.051015406
Maximum	8.5	6.06	7.25	-0.1088	-0.00280112
Minimum	4.63	4	4.5	-0.276718	-0.146765351

Table E-17: MS17825-4; 66% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	0.9203797	32.149389	39.8597758	0.4461253	0.062127266
Median	4	240	220.67	3.67	-0.098039216
Maximum	7.42	260.33	297.5	4.92	-0.076252723
Minimum	3.67	149.67	132.33	3.33	-0.336805556

Table E-18: MS17825-4; 75% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.0571844	34.660494	41.8005999	0.3450935	0.076286773
Median	4.38	255	154.67	3.75	-0.136111111
Maximum	8.33	290	231.67	4.83	-0.11111
Minimum	4	172.33	106.88	3.5	-0.418981481

Appendix E (Continued)

Table E-19: MS17825-4; 85% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.1558693	29.046846	38.6953637	0.398202	0.119267601
Median	5.25	278.33	187.5	4.5	-0.120454545
Maximum	9.67	307.5	265	5.42	5.55112E-17
Minimum	4.75	198	129.33	3.92	-0.437962963

Table E-20: MS17825-4; Averaged

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.0294381	28.3204158	22.779249	0.3076472	0.077444815
Median	4.47	256.78	187.39	3.9722222	-0.129930019
Maximum	8.47	273.64	231.64	5.06	-0.079166667
Minimum	4.17	173.33	152.66667	3.78	-0.397916667

E.5 MS21044D4

Table E-21: MS21044D4; Unseated

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	2.1134244	1.25716	1.78104409	0.057763	0.0249296
Median	16	12.25	15.88	-0.214299	-0.04402464
Maximum	22.25	15.81	19.94	-0.096633	0.002008929
Minimum	13.13	10.75	12.75	-0.309504	-0.104675638

Appendix E (Continued)

Table E-22: MS21044D4; 66% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	2.2231665	63.4255177	58.2232824	1.5618919	0.028677519
Median	17.5	295	243.33	8	-0.53015873
Maximum	23.33	363.33	321.67	12.67	-0.451178451
Minimum	15.67	180	155	7.17	-0.550113883

Table E-23: MS21044D4; 75% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.9266167	66.419124	62.2590665	1.0635661	0.035976617
Median	17.5	348.33	306.67	8.33	-0.511213518
Maximum	23.33	405	366.67	11.67	-0.41603561
Minimum	15.5	220.83	185	7.67	-0.571171171

Table E-24: MS21044D4; 85% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	2.1387518	53.898911	55.4149331	1.2232319	0.064490665
Median	15.83	366.66667	336.67	8	-0.515178571
Maximum	23.17	420	386.67	11.5	-0.346296296
Minimum	14.25	245	213.33	6.5	-0.559770115

Appendix E (Continued)

Table E-25: MS21044D4; Averaged

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	2.0466993	59.8569969	56.775241	1.1311162	0.025998851
Median	17	350.56	296.11111	8.1944444	-0.513401447
Maximum	23.27	390	352.22222	11.944444	-0.465066815
Minimum	15.64	215.27	184.64	7.33	-0.542814499

E.6 NAS1021N4

Table E-26: NAS1021N4; Unseated

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.9071776	1.8443137	1.50844843	0.034715	0.033594003
Median	15.5	11.13	14.75	-0.293803	-0.032526882
Maximum	21.63	16.69	19.63	-0.215039	0.038392857
Minimum	13.88	9.13	13.75	-0.346321	-0.093136305

Table E-27: NAS1021N4; 66% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.8225609	29.1535028	27.2003313	1.3232955	0.028426344
Median	15.33	266.67	246.67	8.92	-0.416973039
Maximum	21.33	280.33	263.33	13.58	-0.358089669
Minimum	14.67	170.83	160.83	8.08	-0.463191763

Appendix E (Continued)

Table E-28: NAS1021N4; 75% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.8277187	29.854379	26.9759838	1.0469533	0.027137146
Median	15.67	296.66667	256.67	8.5	-0.461843588
Maximum	20.67	320	296.67	10.83	-0.391954023
Minimum	12.92	201.66667	185	6.42	-0.515350389

Table E-29: NAS1021N4; 85% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.5248558	27.348686	26.9970277	2.2954598	0.1279817
Median	14.67	340	293.33	8.5	-0.430977983
Maximum	19	356.66667	338.33	16	0.028846154
Minimum	13.67	246.66667	231.67	6.58	-0.546666667

Table E-30: NAS1021N4; Averaged

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.6645563	27.2612737	24.541432	1.2515368	0.04702367
Median	15.11	298.89	265	8.75	-0.441191637
Maximum	20.33	315.56	292.22222	12.138889	-0.281254489
Minimum	13.92	206.39	192.5	7.111	-0.495230376

Appendix E (Continued)

E.7 Grade 8

Table E-31: Grade 8; Unseated

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	0.96	0.52	0.77	0.04	0.03
Median	6.56	5.94	6.88	-0.08	0.04
Maximum	9.63	7.56	9.19	-0.04	0.08
Minimum	5.88	5.5	6.19	-0.22	-0.05

Table E-32: Grade 8; 66% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.47	7.57	6.11	0.38	0.09
Median	5.42	158.33	128.33	4.83	-0.09
Maximum	11	173.67	141	5.83	0.01
Minimum	4.67	148.33	117.67	4.58	-0.47

Table E-33: Grade 8; 75% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.25	16.79	20.31	0.62	0.08
Median	6.42	167.33	145.67	6.42	-0.01
Maximum	11	215	200	7.5	0.01
Minimum	5.92	156.33	129.33	5.67	-0.31

Appendix E (Continued)

Table E-34: Grade 8; 85% Y Preload

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.43	13.71	9.53	0.52	0.1
Median	6.33	185.33	148.33	6.75	0.05
Maximum	11.67	226.67	174	8.17	0.12
Minimum	5.92	172.67	136.67	6.33	-0.3

Table E-35: Grade 8; Averaged

	Assembly Prevailing (in-lbs)	Tightening (in-lbs)	Breakloose (in-lbs)	Removal Prevailing (in-lbs)	Percent Difference between Assembly Prevailing and Removal Prevailing
St Dev	1.38	9.35	8.24	0.5	0.09
Median	6.06	173.56	143	6	-0.02
Maximum	11.22	196.67	161.11	7.111	0.02
Minimum	5.5	160	132	5.58	-0.35

Appendix F: Preload Calculations

F.1 NAS1004-29A

- 0.2% Yield Strength: 100,000psi
- Tensile Stress Area: 0.0364 in^2
- 100% Preload:

$$100{,}000psi * 0.0364in^2 = 3640lb \tag{Equation F-1}$$

- 66% Y Preload:

$$(100{,}000psi * 0.0364in^2) * 0.66 = 2400lb \tag{Equation F-2}$$

- 75% Y Preload:

$$(100{,}000psi * 0.0364in^2) * 0.75 = 2730lb \tag{Equation F-3}$$

- 85% Y Preload:

$$(100{,}000psi * 0.0364in^2) * 0.85 = 3100lb \tag{Equation F-4}$$

F.2 Grade 8

- 0.2% Yield Strength: 130,000psi
- Tensile Stress Area: 0.0364 in^2
- 100% Preload:

$$130{,}000psi * 0.0364in^2 = 4730lb \tag{Equation F-5}$$

- 66% Y Preload:

$$(130{,}000psi * 0.0364in^2) * 0.66 = 3120lb \tag{Equation F-6}$$

- 75% Y Preload:

$$(130{,}000psi * 0.0364in^2) * 0.75 = 3550lb \tag{Equation F-7}$$

- 85% Y Preload:

$$(130{,}000psi * 0.0364in^2) * 0.85 = 4020lb \tag{Equation F-8}$$

Appendix G: Test Plan

G.1 Materials

Table G-1: Materials

Part Number	Description	QTY
MS17825-4	0.25-28 locknut	12
NASM21043-4	0.25-28 locknut	12
MS21044D4 (NAS1021H4)	0.25-28 locknut	12
NAS1021N4	0.25-28 locknut	12
NAS1291-4	0.25-28 locknut	12
NAS1805-4	0.25-28 locknut	12
Grade 8 Locknut	0.25-28 locknut	12
NAS1149	ID-0.25 OD-0.5 washer	72
Grade 8 Washer	ID-0.25 OD-0.75 washer	12
NAS1004	0.25-28 bolt	72
Grade 8 Bolt	0.25-28 bolt	12
Cotton Swab		As required
Degreaser	MEK	As required
Lubricant(s)	Castrol Braycote 601 EF (Perfloutoether) 3-in-1 Multi-Purpose Oil (Naphthenic Oil)	As required As required
Torque Wrench(es)	Torque wrench (0 - 600 in-lbs) Torque wrench (0 - 250 in-lbs) Torque wrench (0 - 75 in-lbs) Torque wrench (0 - 30 in-lbs) Torque wrench (0 - 12 in-lbs)	1 1 1 1 1
Box/Open Wrench	7/16”	1

Appendix G (Continued)

Table G-1 (Continued)

Ratchet Socket(s)	6 Point 5/16" x 3/8" Drive 6 Point 5/16" x 1/4" Drive 6 Point 7/16" x 3/8" Drive 6 Point 7/16" x 1/4" Drive 12 Point 5/16" x 3/8" Drive 12 Point 5/16" x 1/4" Drive	1 1 1 1 1 1
Load Cell	0-5000 lbs Load Cell	1
Fixture	Testing Fixture	1

G.2 Test Procedure

I Test Procedure for MS17825-4
- I.1 Prepare testing fixture
  - I.1.1 Place lower plate in bench vise
  - I.1.2 Place load cell into groove of lower plate
    - I.1.2.1 Ensure load cell is properly zeroed
  - I.1.3 Lay middle plate on top of load cell
    - I.1.3.1 Be sure to align the center hole of middle plate with the hole in the load cell
  - I.1.4 Take top plate and place on top of middle plate
    - I.1.4.1 Be sure lowering bolts are in extended position
      - I.1.4.1.1 For required distance between top and middle plates in order to:
        - I.1.4.1.1.1 Allow sufficient space so that the amount of threads showing after the lock nut is no less than half the diameter of the bolt
        - I.1.4.1.1.2 Allow for lowering of top plate to acquire break away torque of locknut with preload removed
    - I.1.4.2 Be sure bottom of bolts are placed on middle plate
    - I.1.4.3 Be sure to align the center hole of middle plate with the hole of load cell
- I.2 Obtain 4 MS17825-4 locknuts
- I.3 Obtain 4 NAS1004 bolts
- I.4 Obtain 4 NAS1149 washers

Appendix G (Continued)

- I.5 Clean test bolts in ultra-sonic cleaner with MEK for 15 minutes
- I.6 Place Grade 8 washer on test bolt
- I.7 Install test bolt onto fixture
  - I.7.1 Install so head of bolt is on bottom of fixture (closest to load cell)
- I.8 Ensure test bolt's threads are showing through top of fixture with no grip showing, while allowing for the number of threads to show when locknut is tightened (half the bolts diameter, above the locknut)
  - I.8.1 To achieve this loosen or tighten the top plate bolts to lower or rise the top plate
- I.9 Place a NAS1149 washer on end of bolt
- I.10 For Trial 1 – Half Cycle
  - I.10.1 Do not apply Lubricant to locknut
  - I.10.2 Place a washer and a MS17825-4 locknut on test bolt protruding thread from top plate
  - I.10.3 Hand tighten lock nut up to locking feature
  - I.10.4 Begin to run locknut down thread until locking feature fully engaged
    - I.10.4.1 Locking feature is fully engaged when two of the test bolts threads are visible
  - I.10.5 Measure and record Assembly Prevailing Torque
    - I.10.5.1 Average over 1 revolution
  - I.10.6 Place and hold locknut at a preload of 66% Y
    - I.10.6.1 Hold bolt head while turning locknut with torque wrench
    - I.10.6.2 Hold for at least 5 seconds
  - I.10.7 Record Tightening Torque used to achieve preload
  - I.10.8 Lower top plate to remove preload
    - I.10.8.1 Do so by loosening fixture bolts
    - I.10.8.2 Turn each fixture bolt 180° switching fixture bolt in a rotating pattern
  - I.10.9 Measure and record Removal Prevailing (Breakaway) Torque
    - I.10.9.1 Loosen locknut
    - I.10.9.2 Average over 1 revolution
  - I.10.10 Measure and record Assembly Prevailing Verification Torque
    - I.10.10.1 Turn locknut in tightening direction
      - I.10.10.1.1 Average of 1 revolution
  - I.10.11 Loosen and remove locknut from bolt
    - I.10.11.1 Blow out/away any debris from locknut and bolt with compressed air
  - I.10.12 Repeat for 15 cycles or 2 cycles after locking feature failure

Appendix G (Continued)

- I.11 For Trial 2 – Full Cycle
  - I.11.1 Do not apply lubricant to locknut
  - I.11.2 Place a new washer and a new MS17825-4 lock nut on a new test bolt
  - I.11.3 Hand tighten lock nut up to locking feature
  - I.11.4 Begin to run locknut down thread until locking feature fully engaged
    - I.11.4.1 Locknut is fully engaged when two of the test bolt's threads are visible
    - I.11.4.2 Measure and record Assembly Prevailing Torque
      - I.11.4.2.1 Average over 1 revolution
  - I.11.5 Place and hold locknut at preload of 66% Y
    - I.11.5.1 Hold bolt head while turning locknut with torque wrench
    - I.11.5.2 Hold for at least 5 seconds
  - I.11.6 Measure and record Tightening Torque used to achieve preload
  - I.11.7 Do *not* lower plate to remove preload
  - I.11.8 Record Breakloose Torque while under preload
    - I.11.8.1 Hold test bolt head while turning locknut counter clockwise with torque wrench
    - I.11.8.2 Loosen locknut – until preload is fully removed
  - I.11.9 Measure and record Removal Prevailing Torque
    - I.11.9.1 Loosen locknut
      - I.11.9.1.1 Average over 1 revolution
  - I.11.10 Loosen and remove locknut from bolt
    - I.11.10.1 Blow out/away any debris from locknut and bolt with compressed air
  - I.11.11 Repeat for up to 15 cycles or 2 cycles after locking feature failure
- I.12 For Trial 3 – Full Cycle
  - I.12.1 Repeat step 1.11 with new fasteners
- I.13 For Trial 4 – Full Cycle
  - I.13.1 Repeat step 1.11 with new fasteners
- I.14 Repeat for preloads of 75% Y and 85

II Test Procedure for MS21043-4
- II.1 Repeat Step 1 with MS21043-4 in place of MS17825-4

III Test Procedure for MS21044D4 (NAS1021H4)
- III.1 Repeat Step 1 with MS21044D4 (NAS1021H4) in place of MS17825-4

IV Test Procedure for NAS1021N4
- IV.1 Repeat Step 1 with NAS1021N4 in place of MS17825-4

Appendix G (Continued)

V Test Procedure for NAS1291-4

V.1 Repeat Step 1 with NAS1291-4 in place of MS17825-4

VI Test Procedure for NAS1805-4

VI.1 Repeat Step 1 with NAS1805-4 in place of MS17825-4

VII Test Procedure for Granger Locknut

VII.1 Repeat Step 1 with Grade 8 Locknut in place of MS17825-4; Grade 8 bolt in place of NAS1004 bolt; Grade 8 washer in place of NAS1149 washer; and apply 3-IN-ONE(Naphthenic Oil) before placing locknut on test bolt

Appendix H: Manufacturers' Certificates

H.1 MS21043-4

Alcoa Fastening Systems ALCOA

Packing Slip

Packing Slip: 9947963115
Page: 1

Bill To: 5574	Ship To: (1)
M & M AEROSPACE HARDWARE, INC. P.O. BOX 025263 MIAMI FL 33102-5263 USA	M & M AEROSPACE 10000 N.W. 15TH TERRACE MIAMI FL 33172

From:
ALCOA FASTENING SYSTEMS
AEROSPACE PRODUCTS
FULLERTON OPERATIONS
800 SOUTH STATE COLLEGE
FULLERTON CA 92831
USA

Order Contact:

Pack Date	Order #	Cust PO	Ship Via	Weight	Pkgs #
11/25/09	F321887	OHA819			

PACKING SLIP

Line/Rel	Item	U/M	Qty Ordered	Qty To Pack
30-1	AAT880 H41-4	EA	350,000	50,117

C/I: MS21043-4 Rev.2 Cust Date: 02/22/10
PO Item #: Kay Date: 02/17/10
*** TSO C-148 APPVD PART. TSO LABEL REQ'D ***
Lot: M007427-000 COO:MEXICO
Waybill: ____________________ ECCN:9A991 Schedule-B Number:7318.16.0000

The export classification appears above. You are responsible for all related export license requirements.

CHEM & PHYS & MFG C OF C REQ Rev.B
DUAL CERT TO H41-4, 2637654, N8862175/F, Rev.5a
NAS1291A4 AND NAS1291C4 Rev.12
Rev.12 BILL LINE 30,31,32 & 33 TOGETHER

BUYER:CLAUDIA PHONE: 30

ALCOA GLOBAL FASTENERS, INC.
Kaynar Products: Cage Code 15653 • Eagle Products: Cage Code 66776 • Rosan Products: Cage code 66776

ALL CLAIMS REGARDING THIS ORDER MUST BE REPORTED TO SELLER PROMPTLY. CLAIMS FOR CREDIT OR REPLACEMENT OF PARTS MAY BE LIMITED TO THOSE PARTS FOR WHICH TRACEABILITY HAS BEEN MAINTAINED BY THE BUYER. THE SELLER'S MANUFACTURING LOT IDENTIFICATION NUMBER AND RETURN MERCHANDISE AUTHORIZATION (RMA) NUMBER MUST ACCOMPANY ALL RETURNS. ANY CLAIM BASED ON AN ALLEDGED DISCREPANCY IN QUANTITY, QUALITY, ETC. BETWEEN THE GOODS ACTUALLY SHIPPED AND/OR DELIVERED UNDER THESE DOCUMENTS AND THE DESCRIPTION THEREOF IN THESE DOCUMENTS, MUST BE MADE IN WRITING TO SELLER NOT LATER THAN NINETY (90) DAYS AFTER THE SHIPPING DATE APPEARING HEREON. FOR ITEMS CERTIFIED TO BPS-N-70, ALLOY VERIFICATION HAS BEEN PERFORMED ON PARTS WITH A DATE OF MANUFACTURE ON OR AFTER JANUARY 1, 2001. THE RECORDING OF FALSE, FICTITIOUS, OR FRAUDULENT STATEMENTS OR ENTRIES ON THE CERTIFICATE MAY BE PUNISHED AS A FELONY UNDER FEDERAL LAW.

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Figure H-1: MS21043-4 Manufacturer's Certificate Page 1

Date Created: Wed Nov 25 12:42:16 2009 SHIPPER#: 9947963115

CERTIFICATE OF TESTS ABNAHMEPRUEFZEUGNIS CERTIFICAT DE CONTROLE

CERT SERIAL# 000693986

CARPENTER

Carpenter Technology Corporation
101 West Bern Street, Reading, Pa. 19601
Tel: (610) 208-2000 (800) 338-4592

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- THE VALUES AND OTHER TECHNICAL DATA REPRESENT THE RESULTS OF ANALYSES AND TESTS MADE ON SAMPLES COLLECTED FROM THE TOTAL LOT. ORIGINAL DATA RECORDS CAN BE TRACED BY REFERENCE TO THE CARPENTER ORDER NUMBER.
- MATERIAL IS MANUFACTURED FREE FROM MERCURY, RADIUM, ALPHA AND GAMMA SOURCE CONTAMINATION.
- THIS DOCUMENT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN CONSENT OF CARPENTER TECHNOLOGY CORPORATION.

06/11/09

CUSTOMER / BESTELLER / CLIENT

ALCOA FASTENING SYSTEMS
FULLERTON OPERATION
P O BOX 3001
FULLERTON ,CA 92631

SELLER / VERKÄUFER / VENDEUR PAGE 2 OF 3

RAN

CUSTOMER ORDER NO. / BESTELL-NR. / N° DE COMMANDE	CARPENTER NO. / WERKS-NR. / N° DE REFERENCE INTERNE	DATE / DATUM / DATE	WEIGHT / GEWICHT / POIDS
220381926	W50247	06/04/09	1086.00

HEAT NUMBER / SCHMELZE-NR. / N° DE COULEE: 557207

CAPABILITY

1800 F(982 C), 01 HR OIL TREAT
1325 F(718 C), 16 HR AIR COOL

***TESTED AT WESTMORELAND MECHANICAL TESTING AND RESEARCH
COMBINATION STRESS RUPTURE
TEST TEMP 1200 F(649 C)
STRESS, KSI(MPA) 70.0(483)
ELONGATION % 21.4
HOURS 31.6

YIELD STRENGTH, (0.20 %) KSI(MPA) 106.0(731)
TENSILE STRENGTH, KSI(MPA) 154.0(1062)
ELONGATION IN 2.00", % 24.0
REDUCTION OF AREA, % 43.0
HARDNESS , HBW - 317.0

CAPABILITY

1650 F(899 C), 02 HR OIL TREAT
1325 F(718 C), 16 HR AIR COOL

***TESTED AT WESTMORELAND MECHANICAL TESTING AND RESEARCH
COMBINATION STRESS RUPTURE
TEST TEMP 1200 F(649 C)
STRESS, KSI(MPA) 65.0(448)
ELONGATION % 31.4
HOURS 58.9

AFTER MINIMUM TIME UNDER SPECIFIED STRESS, THE STRESS RUPTURE TEST WAS OVERLOADED IN INCREMENTS AS FOLLOWS:

TOTAL HOURS	STRESS KSI(MPA)
48	70.0(483)
56	75.0(517)

YIELD STRENGTH, (0.20 %) KSI(MPA) 98.0(676)
TENSILE STRENGTH, KSI(MPA) 157.0(1082)
ELONGATION IN 2.00", % 26.0
REDUCTION OF AREA, % 51.0
HARDNESS , HBW - 316.0

MATERIAL PRODUCED ON THIS ORDER WAS MELTED AND MANUFACTURED IN THE U.S.A. MATERIAL HAS BEEN MELTED IN USA OR QUALIFYING COUNTRY TO DFARS REQUIREMENTS 252.225-7014 WITH ALTERNATE 1 FOR QUALIFYING COUNTRY 225.872.1.

CONTINUED ON NEXT PAGE

FORM F7-366

SHIPPER#: 9947963115

Figure H-2: MS21043-4 Manufacturer's Certificate Page 2

Date Created: Wed Nov 25 12:42:16 2009 **SHIPPER#: 9947963115**

CERTIFICATE OF TESTS **ABNAHMEPRUEFZEUGNIS** **CERTIFICAT DE CONTROLE**

CERT SERIAL# 000693986

CARPENTER

Carpenter Technology Corporation
101 West Bern Street, Reading, Pa. 19601
Tel: (610) 208-2000 (800) 338-4592

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06/11/09

CUSTOMER / BESTELLER / CLIENT — SELLER / VERKÄUFER / VENDEUR — PAGE 3 OF 3

ALCOA FASTENING SYSTEMS
FULLERTON OPERATION
P O BOX 3001
FULLERTON , CA 92631

RAN

CUSTOMER ORDER NO./BESTELL-NR./N° DE COMMANDE	CARPENTER NO./WERKS-NR./N° DE REFERENCE INTERNE	DATE/DATUM/DATE	WEIGHT/GEWICHT/POIDS
220381926	W50247	06/04/09	1086.00

HEAT NUMBER / SCHMELZE-NR. / N° DE COULEE: 557207

CARPENTER'S QUALITY MANAGEMENT SYSTEM WAS REGISTERED AS OF SEPTEMBER 2, 2004 TO THE REQUIREMENTS OF ISO 9001:2000 APPROVAL CERTIFICATE 07-0869 BY PERFORMANCE REVIEW INSTITUTE. CERTIFICATE OF TEST IS PREPARED IN ACCORDANCE WITH PARAGRAPH 3.1 OF EN 10204 (DIN 50049). WE HEREBY CERTIFY THAT THE ABOVE TEST DATA ARE IN ACCORDANCE WITH THE PURCHASE ORDER AND SPECIFICATION REQUIREMENTS.

DATE REVISED: 06/11/09

MICHELE L. HEFFNER
MET RELEASE/REQUIREMENTS ANALYST
CARPENTER TECHNOLOGY CORPORATION

[redacted]

FORM F2-365

This certification is made to the customer printed on this form. Carpenter neither makes, nor assumes responsibility for, any representation or certification to other parties.
[illegible]
[illegible]

SHIPPER#: 9947963115

Figure H-3: MS21043-4 Manufacturer's Certificate Page 3

Alcoa Fastening Systems

ALCOA

Packing Slip

Packing Slip: 9947963115
Page: 2

Bill To: 5574
M & M AEROSPACE
HARDWARE, INC.
P.O. BOX 025263
MIAMI FL 33102-5263
USA

Ship To: (1)
M & M AEROSPACE
10000 N.W. 15TH TERRACE
MIAMI FL 33172

From:
ALCOA FASTENING SYSTEMS
AEROSPACE PRODUCTS
FULLERTON OPERATIONS
800 SOUTH STATE COLLEGE
FULLERTON CA 92831
USA

Order Contact:

Pack Date	Order #	Cust PO	Ship Via	Weight	Pkgs #
11/25/09	F321887	OHA819			

PACKING SLIP

Line/Rel	Item	U/M	Qty Ordered	Qty To Pack
	5-592-5155			

MATERIAL COMPLIES WITH DFARS 252.225-701
4 REQUIREMENTS, "PREFERENCE FOR
DOMESTIC SPECIALTY METALS" WITH ITS ALTE
RNATE 1 WHERE APPLICABLE.
****ALLOWABLE SHIPPING TOLERANCE = +5%-1
0% ****** CHEM & PHYS & MFG C OF C
REQ "MUST STATE COUNTRY OF ORIGIN WHERE
PARTS WERE MANUFACTURED ON
CERTIFICATION FOR EACH LOT NUMBER" ALL I
TEMS ON THIS PO MUST BE NEW AND TO
THE LATEST REV MFGS NAME & LOT# MUST APP
EAR ON PACKING SLIP ON ALL PAPER
WORK FOR ALL ITEMS.
****
****
IF UNDER 150 # SHIP VIA FED EX GROUND SE
RVICE: BILL RECIPIENT ACCT:
0331-0149-0. IF OVER 150 # USE FED X N
AT'L(WATKINS) ACCT. # 018757. CUST

ALCOA GLOBAL FASTENERS, INC.

Kaynar Products: Cage Code 15653 • Eagle Products: Cage Code 66776 • Rosan Products: Cage code 66776

ALL CLAIMS REGARDING THIS ORDER MUST BE REPORTED TO SELLER PROMPTLY. CLAIMS FOR CREDIT OR REPLACEMENT OF PARTS MAY BE LIMITED TO THOSE PARTS FOR WHICH TRACEABILITY HAS BEEN MAINTAINED BY THE BUYER. THE SELLER'S MANUFACTURING LOT IDENTIFICATION NUMBER AND RETURN MERCHANDISE AUTHORIZATION (RMA) NUMBER MUST ACCOMPANY ALL RETURNS. ANY CLAIM BASED ON AN ALLEDGED DISCREPANCY IN QUANTITY, QUALITY, ETC. BETWEEN THE GOODS ACTUALLY SHIPPED AND/OR DELIVERED UNDER THESE DOCUMENTS AND THE DESCRIPTION THEREOF IN THESE DOCUMENTS, MUST BE MADE IN WRITING TO SELLER NOT LATER THAN NINETY (90) DAYS AFTER THE SHIPPING DATE APPEARING HEREON. FOR ITEMS CERTIFIED TO BPS-N-70, ALLOY VERIFICATION HAS BEEN PERFORMED ON PARTS WITH A DATE OF MANUFACTURE ON OR AFTER JANUARY 1, 2001. THE RECORDING OF FALSE, FICTITIOUS, OR FRAUDULENT STATEMENTS OR ENTRIES ON THE CERTIFICATE MAY BE PUNISHED AS A FELONY UNDER FEDERAL LAW.

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Figure H-4: MS21043-4 Manufacturer's Certificate Page 4

Appendix H (Continued)

Alcoa Fastening Systems ALCOA

Packing Slip

Packing Slip: 9947963115

Page: 3

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M & M AEROSPACE
HARDWARE, INC.
P.O. BOX 025263
MIAMI FL 33102-5263
USA

Ship To: (1)
M & M AEROSPACE
10000 N.W. 15TH TERRACE
MIAMI FL 33172

From:
ALCOA FASTENING SYSTEMS
AEROSPACE PRODUCTS
FULLERTON OPERATIONS
800 SOUTH STATE COLLEGE
FULLERTON CA 92831
USA

Order Contact:

Pack Date	Order #	Cust PO	Ship Via	Weight	Pkgs #
11/25/09	F321887	OHA819			

Line/Rel	Item	U/M	Qty Ordered	Qty To Pack
	REF: MUST BE THEIR PO # "DO NOT PREPAY & ADD TO ANY OF THE ABOVE METHODS" & "CONSOLIDATE SHIPMENTS WHERE EVER APPROP RIATE" DO NOT SHIP PARTS BY ANY OTHER CARRIER THAN THOSE LISTED ABOVE, W ITHOUT PROPER WRITTEN AUTHORIZATION FROM M&M. chem & phys certs			

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ALCOA GLOBAL FASTENERS, INC.

Kaynar Products: Cage Code 15653 • Eagle Products: Cage Code 66776 • Rosan Products: Cage code 66776

ALL CLAIMS REGARDING THIS ORDER MUST BE REPORTED TO SELLER PROMPTLY. CLAIMS FOR CREDIT OR REPLACEMENT OF PARTS MAY BE LIMITED TO THOSE PARTS FOR WHICH TRACEABILITY HAS BEEN MAINTAINED BY THE BUYER. THE SELLER'S MANUFACTURING LOT IDENTIFICATION NUMBER AND RETURN MERCHANDISE AUTHORIZATION (RMA) NUMBER MUST ACCOMPANY ALL RETURNS. ANY CLAIM BASED ON AN ALLEDGED DISCREPANCY IN QUANTITY, QUALITY, ETC. BETWEEN THE GOODS ACTUALLY SHIPPED AND/OR DELIVERED UNDER THESE DOCUMENTS AND THE DESCRIPTION THEREOF IN THESE DOCUMENTS, MUST BE MADE IN WRITING TO SELLER NOT LATER THAN NINETY (90) DAYS AFTER THE SHIPPING DATE APPEARING HEREON. FOR ITEMS CERTIFIED TO BPS-N-70, ALLOY VERIFICATION HAS BEEN PERFORMED ON PARTS WITH A DATE OF MANUFACTURE ON OR AFTER JANUARY 1, 2001. THE RECORDING OF FALSE, FICTITIOUS, OR FRAUDULENT STATEMENTS OR ENTRIES ON THE CERTIFICATE MAY BE PUNISHED AS A FELONY UNDER FEDERAL LAW.

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Figure H-5: MS21043-4 Manufacturer's Certificate Page 5

Alcoa Fastening Systems ALCOA

Packing Slip

Packing Slip: 9947963115
Page: 1

Bill To: 5574	Ship To: (1)
M & M AEROSPACE HARDWARE, INC. P.O. BOX 025263 MIAMI FL 33102-5263 USA	M & M AEROSPACE 10000 N.W. 15TH TERRACE MIAMI FL 33172

From:
ALCOA FASTENING SYSTEMS
AEROSPACE PRODUCTS
FULLERTON OPERATIONS
800 SOUTH STATE COLLEGE
FULLERTON CA 92831
USA

Order Contact:

Pack Date	Order #	Cust PO	Ship Via	Weight	Pkgs #
11/25/09	F321887	OHA819			

CERTIFICATION

Line/Rel	Item	U/M	Qty Ordered	Qty To Pack
30-1	AAT880 H41-4	EA	350,000	50,117

C/I: MS21043-4 Rev. 2 Cust Date: 02/22/10
PO Item #: Kay Date: 02/17/10
*** TSO C-148 APPVD PART. TSO LABEL REQ'D ***
Lot: M007427-000 COO:MEXICO
Waybill: ______________ ECCN:9A991 Schedule-B Number:7318.16.0000

The export classification appears above. You are responsible for all related export license requirements.

CHEM & PHYS & MFG C OF C REQ Rev.8
DUAL CERT TO H41-4, 2637654, N8862175/F, Rev.5a
NAS1291A4 AND NAS1291C4 Rev.12
Rev.12 BILL LINE 30,31,32 & 33 TOGETHER

BUYER:CLAUDIA PHONE: 30

CERTIFICATE OF CONFORMANCE
This is to certify that all items noted above were produced in conformance with the contract, drawing specifications, and other applicable documents. All required process certifications, chemicals and physical test reports are on file subject to examination. **This document must not be reproduced except in full and relates only to the items tested.**

[redacted]
CHRISTOPHER FREDRICKSON
Quality Manager
Fullerton Operations

ALCOA GLOBAL FASTENERS, INC.
Kaynar Products: Cage Code 15653 • Eagle Products: Cage Code 66776 • Rosan Products: Cage code 66776

ALL CLAIMS REGARDING THIS ORDER MUST BE REPORTED TO SELLER PROMPTLY. CLAIMS FOR CREDIT OR REPLACEMENT OF PARTS MAY BE LIMITED TO THOSE PARTS FOR WHICH TRACEABILITY HAS BEEN MAINTAINED BY THE BUYER. THE SELLER'S MANUFACTURING LOT IDENTIFICATION NUMBER AND RETURN MERCHANDISE AUTHORIZATION (RMA) NUMBER MUST ACCOMPANY ALL RETURNS. ANY CLAIM BASED ON AN ALLEDGED DISCREPANCY IN QUANTITY, QUALITY, ETC. BETWEEN THE GOODS ACTUALLY SHIPPED AND/OR DELIVERED UNDER THESE DOCUMENTS AND THE DESCRIPTION THEREOF IN THESE DOCUMENTS, MUST BE MADE IN WRITING TO SELLER NOT LATER THAN NINETY (90) DAYS AFTER THE SHIPPING DATE APPEARING HEREON. FOR ITEMS CERTIFIED TO BPS-N-70, ALLOY VERIFICATION HAS BEEN PERFORMED ON PARTS WITH A DATE OF MANUFACTURE ON OR AFTER JANUARY 1, 2001. THE RECORDING OF FALSE, FICTITIOUS, OR FRAUDULENT STATEMENTS OR ENTRIES ON THE CERTIFICATE MAY BE PUNISHED AS A FELONY UNDER FEDERAL LAW.

CUSTOMER'S COPY

Figure H-6: MS21043-4 Manufacturer's Certificate Page 6

Alcoa Fastening Systems

ALCOA

Packing Slip

Packing Slip: 9947963115

Page: 2

Bill To: 5574
M & M AEROSPACE
HARDWARE, INC.
P.O. BOX 025263
MIAMI FL 33102-5263
USA

Ship To: (1)
M & M AEROSPACE
10000 N.W. 15TH TERRACE
MIAMI FL 33172

From:
ALCOA FASTENING SYSTEMS
AEROSPACE PRODUCTS
FULLERTON OPERATIONS
800 SOUTH STATE COLLEGE
FULLERTON CA 92831
USA

Order Contact:

Pack Date	Order #	Cust PO	Ship Via	Weight	Pkgs #
11/25/09	F321887	OHA819			

Line/Rel	Item	U/M	Qty Ordered	Qty To Pack
	5-592-5155			

CERTIFICATION

MATERIAL COMPLIES WITH DFARS 252.225-701
4 REQUIREMENTS, "PREFERENCE FOR
DOMESTIC SPECIALTY METALS" WITH ITS ALTE
RNATE 1 WHERE APPLICABLE.
****ALLOWABLE SHIPPING TOLERANCE = +5%-1
0% ****** CHEM & PHYS & MFG C OF C
REQ "MUST STATE COUNTRY OF ORIGIN WHERE
PARTS WERE MANUFACTURED ON
CERTIFICATION FOR EACH LOT NUMBER" ALL I
TEMS ON THIS PO MUST BE NEW AND TO
THE LATEST REV MFGS NAME & LOT# MUST APP
EAR ON PACKING SLIP ON ALL PAPER
WORK FOR ALL ITEMS.
****
****
IF UNDER 150 # SHIP VIA FED EX GROUND SE
RVICE: BILL RECIPIENT ACCT:
0331-0149-0. IF OVER 150 # USE FED X N
AT'L(WATKINS) ACCT. # 018757. CUST

CERTIFICATE OF CONFORMANCE

This is to certify that all items noted above were produced in conformance with the contract, drawing specifications, and other applicable documents. All required process certifications, chemicals and physical test reports are on file subject to examination. **This document must not be reproduced except in full and relates only to the items tested.**

[redacted]

CHRISTOPHER FREDRICKSON
Quality Manager
Fullerton Operations

ALCOA GLOBAL FASTENERS, INC.

Kaynar Products: Cage Code 15653 • Eagle Products: Cage Code 66776 • Rosan Products: Cage code 66776

ALL CLAIMS REGARDING THIS ORDER MUST BE REPORTED TO SELLER PROMPTLY. CLAIMS FOR CREDIT OR REPLACEMENT OF PARTS MAY BE LIMITED TO THOSE PARTS FOR WHICH TRACEABILITY HAS BEEN MAINTAINED BY THE BUYER. THE SELLER'S MANUFACTURING LOT IDENTIFICATION NUMBER AND RETURN MERCHANDISE AUTHORIZATION (RMA) NUMBER MUST ACCOMPANY ALL RETURNS. ANY CLAIM BASED ON AN ALLEDGED DISCREPANCY IN QUANTITY, QUALITY, ETC. BETWEEN THE GOODS ACTUALLY SHIPPED AND/OR DELIVERED UNDER THESE DOCUMENTS AND THE DESCRIPTION THEREOF IN THESE DOCUMENTS, MUST BE MADE IN WRITING TO SELLER NOT LATER THAN NINETY (90) DAYS AFTER THE SHIPPING DATE APPEARING HEREON. FOR ITEMS CERTIFIED TO BPS-N-70, ALLOY VERIFICATION HAS BEEN PERFORMED ON PARTS WITH A DATE OF MANUFACTURE ON OR AFTER JANUARY 1, 2001. THE RECORDING OF FALSE, FICTITIOUS, OR FRAUDULENT STATEMENTS OR ENTRIES ON THE CERTIFICATE MAY BE PUNISHED AS A FELONY UNDER FEDERAL LAW.

CUSTOMER'S COPY

Figure H-7: MS21043-4 Manufacturer's Certificate Page 7

Alcoa Fastening Systems ALCOA

Packing Slip

Packing Slip: 9947963115
Page: 3

Bill To: 5574
M & M AEROSPACE
HARDWARE, INC.
P.O. BOX 025263
MIAMI FL 33102-5263
USA

Ship To: (1)
M & M AEROSPACE
10000 N.W. 15TH TERRACE
MIAMI FL 33172

From:
ALCOA FASTENING SYSTEMS
AEROSPACE PRODUCTS
FULLERTON OPERATIONS
800 SOUTH STATE COLLEGE
FULLERTON CA 92831
USA

Order Contact:

Pack Date	Order #	Cust PO	Ship Via	Weight	Pkgs #
11/25/09	F321887	OHA819			

Line/Rel	Item	U/M	Qty Ordered	Qty To Pack
	REF: MUST BE THEIR PO # "DO NOT PREPAY & ADD TO ANY OF THE ABOVE METHODS" & "CONSOLIDATE SHIPMENTS WHERE EVER APPROP RIATE" DO NOT SHIP PARTS BY ANY OTHER CARRIER THAN THOSE LISTED ABOVE, W ITHOUT PROPER WRITTEN AUTHORIZATION FROM M&M. chem & phys certs			

CERTIFICATION

CERTIFICATE OF CONFORMANCE
This is to certify that all items noted above were produced in conformance with the contract, drawing specifications, and other applicable documents. All required process certifications, chemicals and physical test reports are on file subject to examination. **This document must not be reproduced except in full and relates only to the items tested.**

[redacted]
CHRISTOPHER FREDRICKSON
Quality Manager
Fullerton Operations

ALCOA GLOBAL FASTENERS, INC.
Kaynar Products: Cage Code 15653 • Eagle Products: Cage Code 66776 • Rosan Products: Cage code 66776

ALL CLAIMS REGARDING THIS ORDER MUST BE REPORTED TO SELLER PROMPTLY. CLAIMS FOR CREDIT OR REPLACEMENT OF PARTS MAY BE LIMITED TO THOSE PARTS FOR WHICH TRACEABILITY HAS BEEN MAINTAINED BY THE BUYER. THE SELLER'S MANUFACTURING LOT IDENTIFICATION NUMBER AND RETURN MERCHANDISE AUTHORIZATION (RMA) NUMBER MUST ACCOMPANY ALL RETURNS. ANY CLAIM BASED ON AN ALLEDGED DISCREPANCY IN QUANTITY, QUALITY, ETC. BETWEEN THE GOODS ACTUALLY SHIPPED AND/OR DELIVERED UNDER THESE DOCUMENTS AND THE DESCRIPTION THEREOF IN THESE DOCUMENTS, MUST BE MADE IN WRITING TO SELLER NOT LATER THAN NINETY (90) DAYS AFTER THE SHIPPING DATE APPEARING HEREON. FOR ITEMS CERTIFIED TO BPS-N-70, ALLOY VERIFICATION HAS BEEN PERFORMED ON PARTS WITH A DATE OF MANUFACTURE ON OR AFTER JANUARY 1, 2001. THE RECORDING OF FALSE, FICTITIOUS, OR FRAUDULENT STATEMENTS OR ENTRIES ON THE CERTIFICATE MAY BE PUNISHED AS A FELONY UNDER FEDERAL LAW.

CUSTOMER'S COPY

Figure H-8: MS21043-4 Manufacturer's Certificate Page 8

Date Created: Wed Nov 25 12:42:15 2009   SHIPPER#: 9947963115

Alcoa Fastening Systems
Aerospace Products
Fullerton Operations
800 S.STATE COLLEGE BLVD
FULLERTON, CA 92831

TEST REPORT

NO. 8138037   Page 1 of 2

Lot No. M007427-000

Supplier Item No. AAT880	Supplier Part No. H41-4	
Interchange Part No. 2637654 Rev. B	Interchange Part No. 525-595-9006 Rev. N	Interchange Part No. H41-4
Interchange Part No. MS21043-4 Rev. 2	Interchange Part No. N8862175/F Rev. 5a	Interchange Part No. NAS1291A4 Rev. 12
Interchange Part No. NAS1291C4 Rev. 12	Interchange Part No.	Interchange Part No.

Manufactured Quantity 50117	Mfg. Date 06/16/09	Generic Description 6 POINT NUT	Thread Size .2500-28
PLATE/COAT AMS 2410	HEAT TREAT AMS-H-6875	NON-DESTRUCT ASTM E1417 SAMPLE	PERFORMANCE NASM25027
Material Spec. # 1 AMS 5731-L	Mill Heat No. 557207	Control Heat No. AA15641	Material Supplier CARPENTER TECHNOLOGY CORP

Special Process Requirements:
THREADS AND GAUGING PER AS8879 AND
ANSI B1.3M SYS. 22
MIN EQUALS BKWY   MAX EQUALS INST.
*Conforms to AMS5732H after HT Treat
MAGNETIC PERMEABILITY LESS THAN 2.0

TEST RESULTS

---------TEST--------- No. Description	UOM	SAMPLE Number	RESULT Cycle	MINIMUM Value	MAXIMUM Value	PASS/ Fail	MINIMUM Requirement	MAXIMUM Requirement
1 - 010 TORQUE TEST	IN#	1	1	18.45	20.35		3.50	30.00
MIN. 3.50 & MAX 30.0 IN LBS (CYC 1,7,15)			7	13.05	15.05			
			15	12.05	13.05			
		2	1	10.65	9.85			
			7	10.40	9.25			
			15	9.15	8.55			
		3	1	12.45	11.75			
			7	10.90	10.85			
			15	10.50	9.85			
		4	1	12.10	12.45			
			7	13.20	13.05			
			15	13.00	11.75			
		5	1	17.50	17.15			
			7	17.85	18.20			
			15	15.80	17.50			
		6	1	14.65	14.35			
			7	11.65	11.15			
			15	9.95	9.75			
		7	1	12.25	11.40			
			7	10.40	10.25			
			15	11.00	10.20			

TEST RESULTS - Continued on next page.

THIS REPORT MUST NOT BE REPRODUCED EXCEPT IN FULL AND RELATES ONLY TO THE ITEMS TESTED

The product identified on this Certificate has been manufactured, tested and unless otherwise noted, conforms in all respects to the applicable drawings, specifications and standards. Complete reports of physical and chemical tests are on file for examination. If no specified customer quality level is required, goods conform to sellers quality level. All Damages Exceeding Price are Excluded. For items certified to BPS-N-70 alloy verification has been performed on parts with a date of manufacturing on or after January 1, 2001. Quality system sampling plan conforms to the requirement of QAP EQ001, QAP EQ002, QAP EQ003. The recording of false, fictitious, or fraudulent statements or entries on the certificate may be punished as a felony under federal law.

[redacted]

CHRISTOPHER J. FREDRICKSON QA MGR.

SHIPPER#: 9947963115   Rev. 12/02 Form 11199

Figure H-9: MS21043-4 Manufacturer’s Certificate Page 9

Appendix H (Continued)

Date Created: Wed Nov 25 12:42:16 2009 SHIPPER#: 9947963115

Alcoa Fastening Systems ALCOA
Aerospace Products
Fullerton Operations
800 S.STATE COLLEGE BLVD
FULLERTON, CA 92831

TEST REPORT

NO. 8138037 Page 2 of 2

Lot No. **M007427-000**

Supplier Item No. **AAT880**

Supplier Part No. **H41-4**

TEST RESULTS - Continued from previous page.

---------TEST--------- No. Description	UOM	SAMPLE Number	RESULT Cycle	MINIMUM Value	MAXIMUM Value	PASS/ Fail	MINIMUM Requirement	MAXIMUM Requirement
		8	1	15.85	15.60			
			7	15.20	16.25			
			15	15.30	15.95			
		9	1	21.95	21.75			
			7	18.95	19.15			
			15	16.25	16.00			
		10	1	14.00	12.55			
			7	14.20	12.60			
			15	11.80	12.00			
2 - 020 TENSILE TEST	LBS	1	1	4810.00			4580.00	
4580.0 LBF IN MIN.		2	1	4820.00				
		3	1	4820.00				
		4	1	4810.00				
		5	1	4820.00				
		6	1	4820.00				
		7	1	4820.00				
		8	1	4820.00				
		9	1	4810.00				
		10	1	6460.00				
3 - 110 HARDNESS	RC	1	1	38.00	40.00			
HRC 38-44								

THIS REPORT MUST NOT BE REPRODUCED EXCEPT IN FULL AND RELATES ONLY TO THE ITEMS TESTED

The product identified on this Certificate has been manufactured, tested and unless otherwise noted, conforms in all respects to the applicable drawings, specifications and standards. Complete reports of physical and chemical tests are on file for examination. If no specified customer quality level is required, goods conform to sellers quality level. All Damages Exceeding Price are Excluded. For items certified to BPS-N-70 alloy verification has been performed on parts with a date of manufacturing on or after January 1, 2001. Quality system sampling plan conforms to the requirement of QAP EQ001, QAP EQ002, QAP EQ003. The recording of false, fictitious, or fraudulent statements or entries on the certificate may be punished as a felony under federal law.

[redacted]

CHRISTOPHER J. FREDRICKSON QA MGR.

Rev. 12/02 Form 11199

SHIPPER#: 9947963115

Figure H-10: MS21043-4 Manufacturer's Certificate Page 10

Appendix H (Continued)

Date Created: Wed Nov 25 12:42:16 2009 **SHIPPER#: 9947963115**

CERTIFICATE OF TESTS ABNAHMEPRUEFZEUGNIS CERTIFICAT DE CONTROLE

CERT SERIAL# 000693986

CARPENTER

Carpenter Technology Corporation
101 West Bern Street, Reading, Pa. 19601
Tel: (610) 208-2000 (800) 338-4592

- THE RECORDING OF FALSE, FICTICIOUS OR FRAUDULENT STATEMENTS OR ENTRIES ON THIS DOCUMENT MAY BE PUNISHED AS A FELONY UNDER FEDERAL STATUTES INCLUDING FEDERAL LAW, TITLE 18, CHAPTER 47.
- THE VALUES AND OTHER TECHNICAL DATA REPRESENT THE RESULTS OF ANALYSES AND TESTS MADE ON SAMPLES COLLECTED FROM THE TOTAL LOT. ORIGINAL DATA RECORDS CAN BE TRACED BY REFERENCE TO THE CARPENTER ORDER NUMBER.
- MATERIAL IS MANUFACTURED FREE FROM MERCURY, RADIUM, ALPHA AND GAMMA SOURCE CONTAMINATION.
- THIS DOCUMENT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN CONSENT OF CARPENTER TECHNOLOGY CORPORATION.

06/11/09

CUSTOMER / BESTELLER / CLIENT SELLER / VERKÄUFER / VENDEUR PAGE 1 OF 3

ALCOA FASTENING SYSTEMS
FULLERTON OPERATION
P O BOX 3001
FULLERTON ,CA 92631

RAN

CUSTOMER ORDER NO./BESTELL-NR./Nº DE COMMANDE	CARPENTER NO./WERKS-NR./Nº DE REFERENCE INTERNE	DATE/DATUM/DATE	WEIGHT/GEWICHT/POIDS
220381926	W50247	06/04/09	1086.00

HEAT NUMBER / SCHMELZE-NR. / Nº DE COULEE: 557207 AA15641

PRODUCT DESCRIPTION: CONSUMET A286 ANNEALED SEAM FREE CF WIRE FOR HEADING CL
R2 KNIGHTCOTE/SOAP
PART NUMBER: 732105

SPECIFICATION: AMS 5732 REV J (09/ /06) CAP OF
*FAIRCHILD MS 309 CLASS C REV 15 (05/14/08)
AMS 5731 REV L (06/ /06)
FAIRCHILD MS 550 REV 2 (12/10/02)

SIZE 0.342000 IN.(8.69 MM) RD WIRE

PRIMARY HEAT CHEMISTRY(WT%): (TEST METHOD IS SHOWN IN PARENTHESIS)

C (OES) 0.04	MN(XRF) 0.21	SI(XRF) 0.24	P (OES) 0.016	S (OES) 0.001	CR(XRF) 13.88
NI(XRF) 24.32	MO(XRF) 1.18	CU(XRF) 0.08	CO(XRF) 0.19	AL(OES) 0.15	TI(OES) 2.11
V (XRF) 0.17	B (OES) 0.0062				

THE CHEMICAL ANALYSIS OF THIS HEAT HAS BEEN PERFORMED BY THE CARPENTER SPECIALTY ALLOYS CHEMICAL LABORATORY, (CODE NUMBER PRI 100004), WHICH WAS ACCREDITED TO THE ISO/IEC 17025.

MILL HEAT TREATMENT:

TYPE	SOLUTION ANNEAL
TEMP	1800F (982C)
TIME AT TEMP	CONTINUOUS FURNACE
QUENCH	WATER

TENSILE AS SHIPPED, KSI(MPA) 91.5(631)

HARDNESS HRB, - 92.0 (CONVERTED FROM TENSILE STRENGTH)

GRAIN SIZE PER ASTM E112: 7 (KALLINGS)

6/11/09 K324

CONTINUED ON NEXT PAGE

This certification is made to the customer printed on this form. Carpenter neither makes, nor assumes responsibility for, any representation or certification to other parties.
Die vorliegende Zertifizierung ist nur für den in diesem Formular genannten Kunden gültig. Carpenter übernimmt gegenüber Dritten keinerlei Haftung für die ausgewiesenen Daten oder Zertifizierungen.
Ce certificat est uniquement valable pour le client dont le nom est imprimé sur ce formulaire. Carpenter n'assume pas de responsabilité pour une certification vis-à-vis d'une tierce personne.

SHIPPER#: 9947963115

Figure H-11: MS21043-4 Manufacturer's Certificate Page 11

Appendix H (Continued)

H.2 NAS1291-4

CERTIFIED TRUE COPY

ISO Group certifies that the material or parts provided were not:

1. Subjected to conditions of extreme stress, heat or environment.
2. Obtained from any Government or military services.

SIGNATURE: [redacted]

NAME: SCOTT CHALMERS QUALITY INSPECTOR

RFM

REPUBLIC FASTENER MANUFACTURING CORPORATION

1300 RANCHO CONEJO BOULEVARD, NEWBURY PARK, CA 91320 (805)-498-6821

CERTIFICATE OF TEST

WE HEREBY CERTIFY THAT ALL MATERIALS USED IN THE MANUFACTURE OF PARTS COVERED BY THIS REPORT CONFORM TO THE MATERIAL SPECIFICATIONS CALLED FOR BY THE PURCHASE ORDER. WE FURTHER CERTIFY THAT THE PARTS ARE MANUFACTURED IN ACCORDANCE WITH APPLICABLE DRAWINGS OR SPECIFICATIONS CURRENT ON THE DATE OF MANUFACTURE. TEST REPORTS COVERING MATERIALS IN THESE PARTS AND INDICATING CONFORMANCE WITH APPLICABLE SPECIFICATIONS, ARE ON FILE AND SUBJECT TO EXAMINATION. PARTS AS SHIPPED HAVE NEVER BEEN IN CONTACT WITH MERCURY. THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY. PARTS MANUFACTURED IN U.S.A.

B95752

[redacted]

SIGNATURE

QUALITY ASSURANCE REPRESENTATIVE

P.O.	4543R
PART NO.	MS21042L4
QUANTITY ORDERED	78,880
DATE CERT ORDERED	4-16-08
CUSTOMER	On File at ISO Group
LOT NO.	SK274
DESCRIPTION	Hexagon Nut
PROCUREMENT SPEC	NASM25027
ALSO CERTIFIED TO	NAS 1291-4 Rev. 12

CERT-2.REV2

Figure H-12: NAS1291-4 Manufacturer's Certificate Page 1

B95752

RFM
REPUBLIC FASTENER MANUFACTURING CORPORATION
1100 RANCHO CONEJO BOULEVARD, NEWBURY PARK, CA [illegible]

QUALITY CONTROL INSPECTION REPORT

PART NAME	PART NUMBER	REV	NOTES
HEX NUT	MS21042L4	NC	also Conforms to NAS 1291-4 Rev.12

TOTAL LOT QTY	LOT NUMBER	SAMPLE SIZE
78,880	5K274	200 [illegible] 80

INSPECTION LEVELS ACCEPT/REJECT QUANTITIES: MAJOR A – ACCEPT 0, REJECT 1; MAJOR B – ACCEPT 0, REJECT 1; MINOR – ACCEPT 0, REJECT 1; C=0

A.Q.L.	CHARACTERISTIC DESCRIPTION	DEFECT	INSPECTION MEDIA
MAJOR A	SELF-LOCKING FEATURE MISSING	0	VISUAL
MAJOR B	THREAD FIT	0	THREAD GAGE
	BEARING SURFACE SQUARENESS	0	TABLE SQUARENESS GAGE
	SURFACE FINISH, PLATING, OR SURFACE TREATMENT	0	VISUAL
	RIVET HOLE LOCATION AND ALIGNMENT (PLATE NUTS ONLY)	N/A	FUNCTIONAL ALIGNMENT OR VARIABLE GAGE
	OVERALL HEIGHT OF NUT	0	0-6" CALIPER
	LENGTH AND WIDTH	0	0-6" CALIPER
MINOR	DIMENSIONS OF WRENCHING ELEMENT (WRENCHABLE NUTS ONLY)	0	0-6" CALIPER
	LOOSE OR HANGING BURRS	0	VISUAL
	ALL OTHER DIMENSIONAL CHARACTERISTICS NOT COVERED ABOVE	0	SMI

QUANTITY ACCEPTED 78,880 DATE 4-14-08 ACCEPTANCE

RFM
REPUBLIC FASTENER MANUFACTURING CORPORATION
1100 RANCHO CONEJO BOULEVARD, NEWBURY PARK, CA [illegible]

QUALITY CONTROL INSPECTION REPORT

Lot Number 5K274

SAMPLE SIZE	CHARACTERISTIC DESCRIPTION	INSPECTION MEDIA	[illegible]	[illegible]	[illegible]	[illegible]
NUT	MATERIAL: [illegible] HEAT: [illegible] SIZE: [illegible]	VENDOR CERTIFICATIONS ALLOY VERIFICATION	[illegible]	-	Acc	[illegible]
CAP	MATERIAL: HEAT: SIZE:	VENDOR CERTIFICATIONS ALLOY VERIFICATION		N/A		
GASKET	MATERIAL: HEAT: SIZE:	VENDOR CERTIFICATIONS ALLOY VERIFICATION		N/A		
CLIP	MATERIAL: HEAT: SIZE:	VENDOR CERTIFICATIONS ALLOY VERIFICATION		N/A		
15 PCS	[illegible] STAINLESS ONLY) AGED LOAD	TENSILE R/C HARDNESS TESTER		N/A		
15 PCS	[illegible] STEEL ONLY) AUSTEMPERING LOAD 28095	TENSILE R/C HARDNESS TESTER		0	[illegible]	[illegible]
SEE LOG	[illegible] SILVER PLATING LOAD	VISUAL, ADHESION & THICKNESS ASTM B567		N/A		
SEE LOG	[illegible] CAD PLATING LOAD 28905	VISUAL ADHESION & THICKNESS ASTM B567		0	[illegible]	[illegible]
15 PCS	EMBRITTLEMENT RELIEF BAKE [illegible] HOURS MIN. CAD PLATING LOAD 28905	[illegible] HOUR STRESS AT ROOM TEMP. PER NASM1312, TEST 14		0	[illegible]	[illegible]
3 PCS	EMBRITTLEMENT RELIEF BAKE [illegible] HOURS MIN. CAD PLATING LOAD	[illegible] HOUR STRESS AT SERVICE TEMP. PER NASM1312, TEST 14		N/A		
ASQC Z1.4	COLD CHROMATE TREATMENT TYPE II	VISUAL - WORKMANSHIP SALT SPRAY TEST OF AMS-QQ-P-416		0	[illegible]	[illegible]
SEE LOG	PASSIVATED PER AMS-QQ-P-35, AMS2700 STAINLESS STEEL ONLY	VISUAL, SALT SPRAY TEST PER ASTM B117		N/A		
ASQC Z1.4	MAGNETIC PERMEABILITY <2.0 (AIR 1.0) FOR A FIELD STRENGTH = 200 OERSTEDS	INDICATOR PER ASTM A342-04 [illegible]		N/A		
SEE LOG	NONDESTRUCTIVE TESTING DISCONTINUITIES SAMPLE [✓] 100% [ ]	MAGNETIC PARTICLE PER ASTM E1444 OR FLUORESCENT PENET. PER ASTM E1417		0	[illegible]	[illegible]
15 PCS	DRY FILM LUBRICANT PER AS5272 TYPE I BATCH NO. PC08976	VISUAL - WORKMANSHIP ADHESION, THICKNESS SALT SPRAY TEST OF NASM1312, TEST 1		0	[illegible]	[illegible]
4 PCS 15 PCS	MICROSTRUCTURE	SPS-H-70 [ ] NAS3350 [ ]		N/A		
ASQC Z1.4	THREADS PER MIL-S-8879C, AS8879	METHOD B, SYSTEM 22		0	[illegible]	[illegible]

QCIR-006.PUS REV.J 01/13/08

Figure H-13: NAS1291-4 Manufacturer's Certificate Page 2

Appendix H (Continued)

B95752

WireTech, Inc.
6440 E. Canning Street
Los Angeles, CA 90040
Phone (323) 722-4933
Fax (323) 721-8789

SOLD TO

Republic Fasteners
1300 Rancho Conejo Blvd.
Newbury Park, CA 91320
USA

WORK ORDER
054663

CERTIFICATION
HEAT NO.
420520
SALES ORDER / REL
821495 / 1
ISO 9001-2000 REGISTERED
ACCREDITED
MECHANICAL TESTING
CERT # 911.01

CUSTOMER P.O.	CUSTOMER PART	QUANTITY	CARRIERS	LADING NO	SHIPMENT DATE
13075		3,050 Lbs	2	00066130	07/12/2007

SPECIFICATION R104037-108420A
A-4037, AQ, SKFG, CHQ WIRE, SEAM & DECARB FREE, SAIP Zinc Phosphate, Lime & Stearate Coating, Size:0.341/0.343 Specifications: AMS2301H, AMS6300D

CERTIFICATION REQUIREMENTS

Chemical Properties

C	Si	Mn	P	S	Cu	Ni	Cr	Mo
.38 ✓	.25 ✓	.74 ✓	.007 ✓	.01 ✓	.11 ✓	.05 ✓	.06 ✓	.21 ✓

Physical Properties

Grain Size	Jominy 1	Jominy 2	Inclusions	Macro	Cleanliness	Mill Source
6	J1 = 55	J5 = 31	S2-B1-C2	GOOD	FLS=0	Charter

Country of Origin
USA - DFAR Complia

Mechanical Properties

TEST	UNITS	Results
Tensile Strength	KSI	78.1
Yield Strength	KSI	66.5
% Elongation	%	32
% Reduction of Area	%	64.9
Rockwell Hardness B Scale	HRB (s)	82
Decarb (Total)	in	0.00

07-454

[illegible]
REPRODUCTION OF THIS CERTIFICATION IS NOT ALLOWED UNLESS IN FULL.
[illegible]
TEST RESULTS RELATE ONLY TO THE ITEMS TESTED.

Material is free of mercury, radium, or alpha contamination.

page 1 of 1 Mike Martinez 07/12/2007

Figure H-14: NAS1291-4 Manufacturer's Certificate Page 3

REPUBLIC FASTENER MANUFACTURING CORPORATION
1300 RANCHO CONEJO BOULEVARD, NEWBURY PARK, CA 91320 [illegible]

QUALITY CONTROL INSPECTION REPORT

LOT NUMBER	BPS-N-73 ATTRIBUTE PLAN	NOTE	20027 ATTRIBUTE PLAN
SK274	[illegible]	ALL SAMPLES TESTED MUST MEET OR EXCEED THE MINIMUM REQUIREMENTS	[illegible]

PUSH-OUT TEST DATE ______ MIN. ______ POUNDS PUSH-OUT REQUIREMENTS PASS / FAIL STAMP ______

TORQUE-OUT TEST DATE ______ MIN. ______ INCH POUNDS TORQUE OUT REQUIREMENTS PASS / FAIL STAMP ______

WRENCHING TORQUE TEST DATE 4-16-08 MIN. 150 INCH POUNDS WRENCHING TORQUE REQUIREMENTS PASS / FAIL STAMP

160	160	160	160	160
160	160	160	160	160
160	160	160	160	160

TENSILE TEST DATE 4-11-08 STAMP ______
TEST BOLT B104TE-4 20027 REQ. 4200 LBS. BPS-N-75 REQ. ______ LBS.

6200	6200	6200	6200	6200
6200	6200	6200	6200	6200
6200	6200	6200	6200	6200

HIGH = 6200 [✓] PROOF LOAD TEST
LOW = 6200 [ ] TESTED TO FAILURE
R = 0 (RANGE = HIGH MINUS LOW)
X = 6200 (AVERAGE TENSILE STRENGTH)
R x .4 = 0
X - .4R = 6200

QCIR-007.PUB

B95752

REPUBLIC FASTENER MANUFACTURING CORPORATION
1300 RANCHO CONEJO BOULEVARD, NEWBURY PARK, CA 91320 [illegible]

QUALITY CONTROL INSPECTION REPORT

LOT NUMBER	BPS-N-73 ATTRIBUTE PLAN	NOTE	20027 ATTRIBUTE PLAN
SK274	[illegible]		[illegible]

TORQUE TEST DATE 4-16-08 STAMP
TEST BOLT REM1427T4F MAX 30.0 IN. LBS. (1st ON) MIN 3.5 IN. LBS. (1st BRK)

CY	ON	BRK	ON	BRK	ON	BRK	ON	BRK	ON	BRK	ON	BRK	ON	BRK
1	25.0	22.0	15.0	16.0	16.0	17.0	20.0	14.0	18.0	12.0				
7	20.0	12.0	16.0	15.0	10.0	10.0	15.0	14.0	12.0	8.0				
15	18.0	12.0	13.0	15.0	10.0	10.0	14.0	15.0	12.0	9.0				
1	18.0	12.0	18.0	14.0	22.0	17.0	29.0	18.0	15.0	13.0				
7	18.0	12.0	16.0	10.0	15.0	13.0	18.0	14.0	13.0	9.0				
15	18.0	11.0	14.0	8.0	15.0	12.0	20.0	14.0	13.0	10.0				
1	19.0	16.0	15.0	9.0	16.0	16.0	16.0	11.0	24.0	24.0				
7	15.0	10.0	13.0	9.0	10.0	10.0	10.0	9.0	18.0	17.0				
15	14.0	10.0	12.0	10.0	10.0	9.0	9.0	8.0	18.0	16.0				
1														
7														
15														

HARDNESS TEST
CONVERTED FROM 30N SCALE TO HRC DATE 3-14-08 REQUIREMENT: HRC ____ TO 49 MAX STAMP

HRC	43	44	44	45	45	44	44	45	45	44	45	44	43	42	43
30N	62	63	63	64	64	63	63	64	64	63	64	63	62	61.5	62
☆ 15N															

☆ CLIPS AND CLIP NUTS ONLY

QCIR-008.PUB

Figure H-15: NAS1291-4 Manufacturer's Certificate Page 4

Appendix H (Continued)

H.3 NAS1805-4

9546253901 AVIALL INC 10:51:48 a.m. 11–03–2011 4 /10

1. PART OR MATERIAL CERTIFICATION FORM			ATA Specification 106		
2. Seller's Name: B/E AEROSPACE CONSUMABLES MANAGEMENT			3. Reference# SO# 7V0BP0		
4. Organization: Address: 10000 NW 15 TERRACE MIAMI, FL 33172			Phone#: 305-925-2600 FAX#: 305-507-7191 SITA/Wire Code: MIAMMCR Status: SUPPLIER		
5A. Seller's Contract# SO# 7V0BP0			5B. Buyer's Contract# PO# 20107701		

6. Item	7. Description	8. Manufacturer and Part#	9. Eligibility	10. Qty	11. Serial/Batch Number	12. Status
1	LOCKNUT	SPS JENKINS PA NAS1805-4	VARIES	301	AM816	NEW

13A. Remarks STANDARD HARDWARE	
13B. Obtained From SPS TECHNOLOGIES	13C. Last Certificated Agency
14. <u>New Parts/Material Verification:</u> The following signature attests that the part(s) or Material(s) identified above was (were) manufactured by a FAA Production Approval Holder (PAH), or to an industry or commercial standard.	18. <u>Used Repaired or Overhauled Parts Verification:</u> The following signature attests that the documentation specified above or attached is accurate with regard to the item(s) described.
15. Signature [redacted]	19. Signature
16. Name JASON LEWIS / 17. Date 08/03/11	20. Name / 21. Date

NOTICE: The above signature binds the seller and the SIGNER to the accuracy of the information provided in the Form. Should the information provided in the Form contain inaccuracies or misrepresentations, the signer and the SELLER may be liable for damages and are subject to criminal prosecution under state and federal law.

(Revised August 15, 1995)

Figure H-16: NAS1805-4 Manufacturer's Certificate Page 1

9546253901 AVIALL INC 10:52:45 a.m. 11-03-2011 5/10

B/E Aerospace, Inc.

CONSUMABLES MANAGEMENT

P.O. Box 025263, Miami, FL 33102-5263 • Tel: 305.925.2600 • Fax: 305.507.7191
Plant Location: 10000 N.W. 15th Terrace, Miami, FL 33172 • SITA: MIAMMCR
www.beconsumables.com

B/E AEROSPACE

Shipped From: 10000 NW 15 TERRACE, MIAMI, FL 33172

Material Certification

The items set forth on the purchase order referred to below have been visually inspected and the dimensions thereof have been measured by us, and based upon the aforesaid, as well as the representation made to us by the manufacturers of the items subject of such purchase order, we hereby certify that such items are in conformity with all current governmental and manufacturer's requirements, specifications, and drawings. Said items are in new condition and have not been obtained from any U.S. Government or Military source and are traceable to B/E Aerospace, Inc.

FIRM: GEXPRO SERVICES

PURCHASE ORDER#: 20107701

LNE#	QUANTITY	U/M	PART-NUMBER	CUST REF#	LOT-NUMBER	MANUFACTURER	CCODE	CURE DT	EXP DT
1	301	EA	NAS1805-4		AM816	SPS JENKINS PA	56878		

[redacted]/03/11
Jason Lewis
Vice President of Quality

Gexpro 109 Services

Figure H-17: NAS1805-4 Manufacturer's Certificate Page 2

Appendix H (Continued)

6/10 11-03-2011 10:53:28 a.m. AVIALL INC 9546253901

SPS TECHNOLOGIES a PCC company

PACKING LIST & CERTIFICATION

THE PRODUCTS THAT ARE COVERED BY THIS AGREEMENT ARE OF U.S. ORIGIN OR OTHERWISE SUBJECT TO U.S. EXPORT AND OTHER FOREIGN TRADE CONTROLS. THE EXPORT, DEEMED EXPORT, RE-EXPORT, OR RELEASE OF THESE PRODUCTS TO OTHER COUNTRIES OR PARTIES MAY REQUIRE THE PRIOR APPROVAL OF THE U.S. GOVERNMENT. DIVERSION OF THESE PRODUCTS FROM THE AUTHORIZED DESTINATION CONTRARY TO U.S. AND INTERNATIONAL LAW IS PROHIBITED. THE PURCHASER AGREES TO COMPLY WITH APPLICABLE LAWS AND REGULATIONS OF THE UNITED STATES, OTHER RELEVANT JURISDICTIONS, AND PERTINENT INTERNATIONAL ORGANIZATIONS PERTAINING TO THE EXPORT, DEEMED EXPORT, RE-EXPORT, OR RELEASE OF THESE PRODUCTS. ANY VIOLATIONS OF THIS CLAUSE, AS DETERMINED SOLELY BY SPS TECHNOLOGIES, SHALL BE DEEMED A MATERIAL BREACH OF THIS AGREEMENT.

609

PREVENT FRAUD

Any alteration or misuse of this certificate, or any unauthorized rework or modification of the identified products voids all manufacturer's warranties, and may lead to civil damages and/or criminal penalties. To prevent fraud, check for the original embossed seal on the certification.

CUSTOMER NBR 01-0001-00427568-0001

PUBLISHED 04/30/09

ORDER NBR 933746-005

ORDER DATE 01/28/08

P/S # 933746005

PAGE 1

M & M AEROSPACE HARDWARE INC.
10000 N.W. 15TH TERRACE
MIAMI, FL 33172

M & M AEROSPACE HARDWARE INC.
P.O. BOX 025263
MIAMI, FL 33102-5263

SPS TECHNOLOGIES
HIGHLAND AVE.
JENKINTOWN, PA 19046
DATE SHIPPED: ____________

355

[redacted]

OEK254 | S 1/2% 10,NET 30 | A1 | 05/01/09 — PO # OEK254

[redacted]

TRK ANY TRUCKING FIRM | | COL COLLECT | 2751 | 52 | 0103 | 01/28/08

[redacted]

004 0161538 80020-428 NAS1805-4 48943 [redacted]

50/160

SHELF LOCATION 004M6
UNDER 150# SHIP FEDEX GROUND ACCT
#0331-0149-0 MARK COLLECT
OVER 150 LBS SHIP FED EX NATIONAL LTL
ACCT #081757
CHEMICAL AND PHYSICAL CERTS
SHIP VARIANCE +/- 10%
ITEM CODE: A500
TOTAL QUANTITY 100,000 PCS
SARA PADRON/FGH

[redacted]

AM816

LOT NO.			
QUANTITY			
LOT TRACE NO.			

CERTIFICATION OF CONFORMANCE

THE PRODUCTS IDENTIFIED ON THIS CERTIFICATE HAVE BEEN MANUFACTURED, TESTED AND INSPECTED IN ACCORDANCE WITH, AND UNLESS OTHERWISE NOTED BELOW, CONFORM IN ALL RESPECTS TO THE APPLICABLE DRAWINGS, SPECIFICATIONS AND/OR STANDARDS. COMPLETE REPORTS OF PHYSICAL AND CHEMICAL TESTS ARE ON FILE FOR ON-SITE EXAMINATION. SINGLE-ELEMENT GAUGING HAS BEEN PERFORMED WHERE REQUIRED.

QUALITY ASSURANCE | DATE

[redacted]

FREIGHT RECORD	WEIGHT	BOXES	PREPD	COLL.	CARRIER	TYPE	CODE	BILL OF LADING	FREIGHT CHARGE

3003 REV. 6/05

PACKING LIST

Figure H-18: NAS1805-4 Manufacturer's Certificate Page 3

Appendix H (Continued)

9546253901 AVIALL INC 10:55:01 a.m. 11-03-2011 7/10

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SPS TECHNOLOGIES A PCC Company

PACKING LIST & CERTIFICATION

THE PRODUCTS THAT ARE COVERED BY THIS AGREEMENT ARE OF U.S. ORIGIN OR OTHERWISE SUBJECT TO U.S. EXPORT AND OTHER FOREIGN TRADE CONTROLS. THE EXPORT, DEEMED EXPORT, RE-EXPORT, OR RELEASE OF THESE PRODUCTS TO OTHER COUNTRIES OR PARTIES MAY REQUIRE THE PRIOR APPROVAL OF THE U.S. GOVERNMENT. DIVERSION OF THESE PRODUCTS FROM THE AUTHORIZED DESTINATION CONTRARY TO U.S. AND INTERNATIONAL LAW IS PROHIBITED. THE PURCHASER AGREES TO COMPLY WITH APPLICABLE LAWS AND REGULATIONS OF THE UNITED STATES, OTHER RELEVANT JURISDICTIONS, AND PERTINENT INTERNATIONAL ORGANIZATIONS PERTAINING TO THE EXPORT, DEEMED EXPORT, RE-EXPORT, OR RELEASE OF THESE PRODUCTS. ANY VIOLATIONS OF THIS CLAUSE, AS DETERMINED SOLELY BY SPS TECHNOLOGIES, SHALL BE DEEMED A MATERIAL BREACH OF THIS AGREEMENT.

CLAIMS FOR GOODS MUST BE MADE ON RECEIPT OF GOODS.
ALL GOODS SHIPPED AT BUYER'S RISK
NO MATERIAL ACCEPTED FOR RETURN WITHOUT OUR PERMISSION

PREVENT FRAUD
Any alteration or misuse of this certificate, or any unauthorized rework or modification of the identified products voids all manufacturer's warranties, and may lead to civil damages and/or criminal penalties. To prevent fraud, check for the original embossed seal on the certification.

PUBLISHED 04/30/09

ORDER NBR 933746-005

ORDER DATE 01/28/08

CUSTOMER NBR 01-0001-00427568-0001

P/S # 933746005

PAGE 1

M & M AEROSPACE HARDWARE INC.
10000 N.W. 15TH TERRACE
MIAMI, FL 33172

M & M AEROSPACE HARDWARE INC.
P.O. BOX 025263
MIAMI, FL 33102-5263

SPS TECHNOLOGIES
HIGHLAND AVE.
JENKINTOWN, PA 19046
DATE SHIPPED ________

355

OEK254 | S 1/2% 10, NET 30 | AI | 05/01/09 | PO # OEK254

TRK ANY TRUCKING FIRM | COL COLLECT | 2751 | 52 | 0103 | 01/28/08

004 0161938 80020-428 NAS1805-4 [redacted]

UNDER 150# SHIP FEDEX GROUND ACCT
OVER 150 LBS SHIP FED EX NATIONAL LTL
ACCT #084257
CHEMICAL AND PHYSICAL CERTS
SHIP VARIANCE +/- 10%
ITEM CODE: A500
TOTAL QUANTITY 100,000 PCS
SARA PADRON/PGH

AM816

LOT NO.				CERTIFICATION OF CONFORMANCE	QUALITY ASSURANCE	DATE
QUANTITY				THE PRODUCTS IDENTIFIED ON THIS CERTIFICATE HAVE BEEN MANUFACTURED, TESTED AND INSPECTED IN ACCORDANCE WITH, AND UNLESS OTHERWISE NOTED BELOW, CONFORM IN ALL RESPECTS TO THE APPLICABLE DRAWINGS, SPECIFICATIONS AND/OR STANDARDS. COMPLETE REPORTS OF PHYSICAL AND CHEMICAL TESTS ARE ON FILE FOR ON-SITE EXAMINATION. SINGLE-ELEMENT GAUGING HAS BEEN PERFORMED WHERE REQUIRED.		
LOT TRACE NO.						

FREIGHT RECORD	WEIGHT	BOXES	PREPD	COLL.	CARRIER	TYPE	CODE	BILL OF LADING	FREIGHT CHARGE

3003 REV. 6/05 PACKING LIST

Figure H-19: NAS1805-4 Manufacturer's Certificate Page 4

9546253901 AVIALL INC 10:56:43 a.m. 11-03-2011 8/10

SPS TECHNOLOGIES

CERTIFICATE of TEST

Plan Date	Trace No.
02/19/2009	AM816
Cert. Date	Mfg. Lot
04/30/2009	15
SPS Technologies Highland Avenue Jenkintown, Pennsylvania 19046	
Telephone	CAGE
215-572-3000	56878

CERTIFICATION
The products identified on this certificate have been manufactured, tested and inspected in accordance with, and unless otherwise noted below, conform in all respects to the applicable drawings, specifications and/or standards. Complete reports of physical and chemical tests are on file for on-site examination. This certification relates only to the items tested and must not be reproduced except in full.

PREVENT FRAUD!
Any alteration of this certificate, or any unauthorized rework or modification of the identified products, voids all manufacturer's warranties and may lead to civil damages and/or criminal penalties.

Customer Name and Address
M & M AEROSPACE HARDWARE INC.
10000 N.W. 15TH TERRACE
MIAMI, FL 33172

Customer Purchase Order	Dated	Shipper No.	
OEK254	04/30/2009	933746005	
Part No.	Rev.	Insp. Lot Qty	Ship Qty
NAS1805-4	3	52966	50160
Type Part	Marking	Shop Order	Release
NUT		0161938	150

Procurement Spec.	Rev.	Part Description			
NAS3350 CL IIIA EXCEPT	6	1/4-28 UNJF-3B DBL HEX NUT			
Material Spec.	Rev.	Type Material	Steel Date	Material Supplier	Mill Heat No.
AMS 5737	P	A-286	JV220A	CARTECH	556680
LUBRICATION SPEC.	Rev.	NON-DESTRUCTIVE SPEC.		Rev.	
AS5272 TY I	C	ASTM E1417 SAMPLE		05E1	
SURFACE SPEC.	Rev.				
AMS 2700 TYPE 2	C				
Other Specs.					

Material Conditioning
Age Hardened

% CHEMICAL COMPOSITION OF METAL, BASED ON MILL REPORT OF RAW MATERIAL

AL .14	B .006	C .04	CO .4	CR 14.12
CU .15	MN .31	MO 1.18	NI 24.44	P .02
S <.0005	SI .2	TI 2.13	V .27	

FINISH PART TENSILE SAMPLE: 15

MINIMUM U/M
7270 LBS

POUNDS	7270	7270	7270	7270	7270
LOCATION	NO FAILURE	NO FAILURE	NO FAILURE	NO FAILURE	NO FAILURE
POUNDS	7270	7270	7270	7270	7270
LOCATION	NO FAILURE	NO FAILURE	NO FAILURE	NO FAILURE	NO FAILURE
POUNDS	7270	7270	7270	7270	7270
LOCATION	NO FAILURE	NO FAILURE	NO FAILURE	NO FAILURE	NO FAILURE

[redacted]

Page 1 of 3

Leonard J. Brajer
Quality Assurance Representative

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Figure H-20: NAS1805-4 Manufacturer's Certificate Page 5

Appendix H (Continued)

9546253901 AVIALL INC 10:58:11 a.m. 11-03-2011 9/10

SPS TECHNOLOGIES

CERTIFICATE of TEST

Plan Date	Trace No.
02/19/2009	AM816
Cert. Date	Mfg. Lot
04/30/2009	15

CERTIFICATION
The products identified on this certificate have been manufactured, tested and inspected in accordance with, and unless otherwise noted below, conform in all respects to the applicable drawings, specifications and/or standards. Complete reports of physical and chemical tests are on file for on-site examination. This certification relates only to the items tested and must not be reproduced except in full.

PREVENT FRAUD!
Any alteration of this certificate, or any unauthorized rework or modification of the identified products, voids all manufacturer's warranties and may lead to civil damages and/or criminal penalties.

Customer Name and Address
M & M AEROSPACE HARDWARE INC.
10000 N.W. 15TH TERRACE
MIAMI, FL 33172

Procurement Spec.: NAS3350 CL IIIA EXCEPT — Rev. 6

Customer Purchase Order	Dated	Shipper No.	
OEK254	04/30/2009	933746005	
Part No.	**Rev.**	**Insp. Lot Qty**	**Ship Qty**
NAS1805-4	3	52966	50160
Type Part	**Marking**	**Shop Order**	**Release**
NUT		0161938	150
Part Description			
1/4-28 UNJF-3B DBL HEX NUT			

MICRO SAMPLE: 15

GRAIN SIZE: 1 / FINER

GRAIN SIZE 9 / 10
ETCHANT PWA KALLINGS REAGENT
MAGNIFICATION 100-500X
SPECIMEN NUMBER AM816
MATERIAL LOCATION CROSS SECTIONAL
REFERENCE STANDARD NAS3350 CL-IIIA

METALLURGICAL RESULTS SATISFACTORY

MAGNETIC PERMEABILITY SAMPLE: 15

MAXIMUM
2 OERSTEADS

SATISFACTORY

LOCKING TORQUE SAMPLE: 10

CYCLE ## 1ST
MAX ILB 30.0
MIN ILB 3.5

1ST CYC MAX	16.6	14.1	18.9	18.4	20.3
1ST CYC MIN	15.2	11.3	14.1	14.4	14.5
1ST CYC MAX	15.6	14.6	22.1	16.2	17.1
1ST CYC MIN	9.3	11	19.9	14.8	15.3

[redacted]

Page 2 of 3

Leonard J. Brajer
Quality Assurance Representative

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Figure H-21: NAS1805-4 Manufacturer's Certificate Page 6

9546253901 AVIALL INC 10:59:33 a.m. 11–03–2011 10 /10

SPS TECHNOLOGIES

CERTIFICATE of TEST

Plan Date	Trace No.
02/19/2009	AM816
Cert. Date	Mfg. Lot
04/30/2009	15

CERTIFICATION
The products identified on this certificate have been manufactured, tested and inspected in accordance with, and unless otherwise noted below, conform in all respects to the applicable drawings, specifications and/or standards. Complete reports of physical and chemical tests are on file for on-site examination. This certification relates only to the items tested and must not be reproduced except in full.

PREVENT FRAUD!
Any alteration of this certificate, or any unauthorized rework or modification of the identified products, voids all manufacturer's warranties and may lead to civil damages and/or criminal penalties.

Customer Name and Address	Customer Purchase Order	Dated	Shipper No.	
M & M AEROSPACE HARDWARE INC. 10000 N.W. 15TH TERRACE MIAMI, FL 33172	OEK254	04/30/2009	933746005	
	Part No.	Rev.	Insp. Lot Qty	Ship Qty
	NAS1805-4	3	52966	50160
	Type Part	Marking	Shop Order	Release
	NUT		0161938	150
Procurement Spec. / Rev.	Part Description			
NAS3350 CL IIIA EXCEPT / 6	1/4-28 UNJF-3B DBL HEX NUT			

LOCKING TORQUE SAMPLE: 2

	1ST	3RD
CYCLE ##		
MAX ILB	30.0	30.0
MIN ILB	3.5	3.5
1ST CYC MAX	22.1	14.1
1ST CYC MIN	19.9	11.3
3RD CYC MAX	20.4	13.3
3RD CYC MIN	21.9	12.9

LOCKING TORQUE SAMPLE: 2

	5TH	
CYCLE ##		
MAX ILB	30.0	
MIN ILB	3.5	
5TH CYC MAX	18.5	10.3
5TH CYC MIN	15	9.7

THREADS PER AS8879 REV D

IF APPLICABLE, MATERIAL IS DFARS 252.225.7014, ALT 1 COMPLIANT

Page 3 of 3

[redacted]

Leonard J. Brajer
Quality Assurance Representative

Figure H-22: NAS1805-4 Manufacturer's Certificate Page 7

Appendix H (Continued)

H.4 MS17825-4

GREER STOP NUT

Greer Stop Nut, Inc.
481 McNally Drive
Nashville, TN 37211

Phone: 615-832-8375
Fax: 615-331-0065
E-mail: greer@spstech.com

CERTIFICATE OF CONFORMANCE

Date of Certification: March 1, 2011
Sold To: On File at ISO Group

Purchase Order No: 179230
Customer Part No: MS17825-4 Rev. H — Item No: 001
Greer Part No: F12NEC-0428 — Nomenclature: Nut, Self-Locking, Hexagon
Lot No/Serial No: 0501930-420 — Qty. Manufactured: 49,511 — Qty. Shipped: 15,000
Manufacturing Date: 2-05-11

Material: 1137 — Material Specification: ASTM A108, AMS 5024H — Material Supplier: Nelsen Steel Company
Mill Heat No: 20103280 — Greer Steel Date: CJ691C
Material Marking: G
Nylon Conforms to ASTM D4066-94B, 96A, 99, 01A Group 1 Class 1

Procurement Specification: NASM25027 NEW — Thread Spec: AS-8879 Rev D

Surface Finish: Cadmium & Yellow Chromate — Surface Finish Specification: AMS-QQ-P-416 Type II Class 2, Rev. C

Axial Tensile Strength: 3,500 lbs. — Testing Exceeded: 3,500 lbs. — Specification: MS17825-4 Rev. H
Sample Size: 10

Locking Torque Specification: NASM25027 NEW — Sample Size: 10
1st Cycle Max. Locking Requirement: 30.0 in. lbs.
1st Cycle Min. Breakaway Requirement: 3.5 in. lbs.
Tested Range of Samples:
1st Cycle Max. Locking: 5.0-6.0 in. lbs. ONE CYCLE ONLY
1st Cycle Min. Bkwy: 5.0-6.0 in. lbs.

Non-Destructive Testing: Magnetic Particle Inspection — Specification: ASTM E-1444-05
Acceptance Criteria: NASM25027 NEW — Sample Size: 33

Magnetic Particle Inspection in accordance with MT2000 Rev. 11 DTD 3-11-10 as modified by MT69811 Rev. 5 DTD 5-5-10

Page 1 of 2

Figure H-23: MS17825-4 Manufacturer's Certificate Page 1

Appendix H (Continued)

Hardness Requirement: N/A Specification: N/A Hardness Results: N/A Sample Size: N/A

Conforms Dimensionally: MS17825-4 Rev. H Sample Size: 32

The products identified on this certificate have been manufactured, tested and inspected in accordance with, and unless noted above, conforms in all respects to the applicable drawings, specifications and/or standards. Complete reports of physical and chemical tests are on file for on-site examination. If no specified customer quality level is required, goods conform to seller's quality level. Reproduction *except in full is strictly prohibited* without written approval of Greer Stop Nut. All *damages exceeding price* are excluded. Mercury free clause: We certify that no possibility exists for mercury contamination to occur during manufacture, assembly or testing of parts on this contract. This document relates only to the items tested. Parts were manufactured in the United States of America. Sample plans are carried out to current standard/specification revision.

G and Green Nylon are Trademarks of Greer Stop Nut, Inc.

[redacted]

Fran Glover
Quality Assurance Coordinator

CERTIFIED TRUE COPY
ISO Group certifies that the material or parts provided were not:
1. Subjected to conditions of extreme stress, heat or enviroment.
2. Obtained from any Goverment or military services.
SIGNATURE: [redacted]
NAME: GUY PEYTON QUALITY INSPECTOR

CERTIFIED TRUE COPY
ISO Group certifies that the material or parts provided were not
1. Subjected to conditions of extreme stress, heat or environment
2. Obtained from any Government or military services
SIGNATURE: [redacted]
NAME: SCOTT CHALMERS QUALITY INSPECTOR

COC1 3/30/98 Page 2 of 2

Figure H-24: MS17825-4 Manufacturer's Certificate Page 2

Appendix H (Continued)

H.5 MS21044D4

GREER STOP NUT

Greer Stop Nut
481 McNally Drive
Nashville, TN 37211

Phone: 615-832-8375
Fax: 615-331-5070

CERTIFICATE OF CONFORMANCE

Date of Certification: July 27, 2011

Sold To: On File at ISO Group

Purchase Order No: OXH302

Customer Part No: MS21044D4 Rev. H & NASM21044 Rev. 1 Item No: 001

Greer Part No: NMJ-0428 Nomenclature: Nut, Self-Locking, Hexagon

Lot No/Serial No: 0501960-080 Qty. Manufactured: 54,520 Qty. Shipped: 27,500

Manufacturing Date: 7-27-11

Material: 2024 T4 Aluminum Material Specification: AMS QQ-A-225/6A Material Supplier: NICHOLS WIRE

Mill Heat No: K844836 Greer Control No: AJ438F

Material Marking: N/A

Nylon Conforms to ASTM D4066-94B, 96A, 99, 01A Group 1 Class 1

Procurement Specification: NASM25027 NEW Thread Spec: AS-8879 Rev D

Surface Finish: Anodize & Blue Dye Surface Finish Specification: MIL-A-8625 Type 2, Class 2 Rev. F

Axial Tensile Strength: 4,580 lbs. Testing Exceeded: 4,580 lbs. Specification: MS21044D4 Rev. H & NASM21044 Rev. 1

Sample Size: 15

Locking Torque Specification: NASM25027 NEW Sample Size: 15

1st Cycle Max. Locking Requirement: 30.0 in. lbs.
15th Cycle Min. Breakaway Requirement: 3.5 in. lbs.

Tested Range of Samples:

1st Cycle Max. Locking:	10-15 in. lbs.
1st Cycle Min. Bkwy:	7-15 in. lbs.
7th Cycle Max. Locking:	5-10 in. lbs.
7th Cycle Min. Bkwy:	5-10 in. lbs.
15TH Cycle Max. Locking:	4-10 in. lbs.
15th Cycle Min. Bkwy:	4-7 in. lbs.

Non-Destructive Testing: Liquid Penetrant Inspection Spec: ASTM E1417-05E1

Acceptance Criteria: NASM25027 NEW Sample Size: 32

Fluorescent Penetrant Inspection in accordance with PT2000 Rev. 14 DTD 12-22-09 as modified by PT69811 Rev. 10 DTD 7-29-10

Page 1 of 2

Figure H-25: MS21044D4 Manufacturer's Certificate Page 1

Appendix H (Continued)

Hardness Requirement: N/A Specification: N/A Hardness Results: N/A Sample Size: N/A

Conforms Dimensionally: MS21044D4 Rev. H & NASM21044 Rev.1 Sample Size: 32

The products identified on this certificate have been manufactured, tested and inspected in accordance with, and unless noted above, conforms in all respects to the applicable drawings, specifications and/or standards. Complete reports of physical and chemical tests are on file for on-site examination. If no specified customer quality level is required, goods conform to seller's quality level. Reproduction except in full is strictly prohibited without written approval of Greer Stop Nut. All damages exceeding price are excluded. Mercury free clause: We certify that no possibility exists for mercury contamination to occur during manufacture, assembly or testing of parts on this contract. This document relates only to the items tested. Parts were manufactured in the United States of America. Sample plans are carried out to current standard/specification revision.

G and Green Nylon are Trademarks of Greer Stop Nut, Inc.

[redacted]

Fran Glover
Quality Assurance Coordinator

CERTIFIED TRUE COPY
ISO Group certifies that the material or parts provided were not:

1. Subjected to conditions of extreme stress, heat or environment.
2. Obtained from any Government or military services.

SIGNATURE [redacted]

NAME: SCOTT CHALMERS QUALITY INSPECTOR

COC1 3/30/98

Page 2 of 2

Figure H-26: MS21044D4 Manufacturer's Certificate Page 2

Appendix H (Continued)

H.6 NAS1021N4

MACLEAN-ESNA
A MACLEAN-FOGG COMPANY
611 COUNTRY CLUB ROAD
POCAHONTAS, ARKANSAS 72455
(870) 892-5201

TO: On File at ISO Group DATE: 6/19/2009

SUBJECT:

YOUR ORDER NUMBER	OHM855	ITEM NUMBER	1
ESNA ORDER NUMBER	055076		
FSCM/ CAGE NUMBER	019L2		
YOUR PART NUMBER	MS21044N4; AN365-428; NAS1021N4		
CERTIFIED AS	MS21044N4 PER NASM21044 (NEW); AN365-428 REV 4; NAS1021N4 REV 10		
ESNA PART NUMBER	F42NE-048		
QUANTITY	14394		
PACKING LIST NUMBER	48813		
SHOP ORDER NUMBER	40157 - 000		

Gentlemen:

This is to certify that all applicable plating, heat treating, and inspection processing and that all material used in the manufacture of subject parts conform to the specification or drawings received by ESNA and set forth in the subject purchase order; that the parts are of good material and workmanship; and that all necessary records, including chemical and physical where applicable, will be made available for review upon request. The inspection and test reports provided represent the actual attributes of the items furnished on this contract and indicate full compliance with all applicable specification and contract requirements.

This is to certify that the materials supplied against the subject order are free of contamination by presence of mercury.

Very truly yours,

MACLEAN-ESNA
A MACLEAN-FOGG COMPANY

[redacted]

Jim Earley
Quality Assurance Manager

S-58 REV. 5-11-99

Figure H-27: NAS1021N4 Manufacturer's Certificate Page 1

Appendix H (Continued)

MACLEAN-ESNA
A MACLEAN-FOGG COMPANY
POCAHONTAS, ARKANSAS 72455

CERTIFICATE OF QUALITY COMPLIANCE

DATE: 6/19/2009

TO: . On File at ISO Group

ESNA PART NO. F42NE-048
MANUFACTURER'S LOT SIZE 14394 (APPROX. WT. COUNT)
MANUFACTURED UNDER SHOP ORDER NUMBER 40157 - 000
ORIGINATED AS SHOP ORDER NUMBER -

ACCEPTANCE TESTS PER NASM 25027

MATERIAL RAW MATERIAL TYPE .406 DIA 1010 CHQ WIRE DATE MFG: 09-08

RAW MATERIAL CONFORMS TO AMS 5040 AS EVIDENCED BY THE ATTACHED MILL CERTIFICATION. ESNA SHOP ORDER NO. 40157 - 000 MILL HEAT NO. 548800 VENDOR WIRE TECH

RED NYLON IS A TRADEMARK OF ELASTIC STOP NUT. THIS ASSURES TRACEABILITY OF PARTS TO SOURCE. MATERIAL CERTIFICATION WITH HEAT NUMBERS ASSURES TRACEABILITY TO VENDOR OF RAW MATERIAL. NONMETALLIC INSERT CONFORMS TO ASTM D4066-00. (ZYTEL 103)

FINISH FINISH TYPE CADMIUM PLATED TO QQ-P-416F, TYPE II, CLASS 2
LUBRICANT TYPE NO ADDITIONAL LUBRICANT

AXIAL STRENGTH REQUIRED LBS. MINIMUM 4580
EXCEEDS LBS. 5100
ALL SAMPLE PIECES TESTED MEET OR EXCEED MINIMUM REQUIREMENTS.
SAMPLE SIZE 10 PIECES.

WORKMANSHIP CONFORMS DIMENSIONALLY TO MS21044N4 PER NASM21044 (NEW); AN365-428 REV 4; NAS1021N4 REV 10 STANDARD. BEARING SURFACE SQUARENESS AS SPECIFIED PER NASM 25027

DISCONTINUITIES

WITHIN LIMITS PER NASM 25027 AND MIL-STD-271D/ACN 1/ AND REV E/ NOTICE 2/ AND REV F/ NOTICE 1.

MT PER SPEC 725 W	SAMPLE SIZE(MT - PCS):	20
	ACCEPTED(PCS):	20
PT PER SPEC 731	SAMPLE SIZE(PT - PCS):	0
	ACCEPTED(PCS):	N/A

LOCKING TORQUE

MAXIMUM LOCKING(IN. LBS.): 30
MINIMUM BREAKAWAY(IN. LBS.): 3.5
1ST CYCLE MAXIMUM LOCKING(IN. LBS.): 09.0
7TH CYCLE MAXIMUM LOCKING(IN. LBS.): 08.0
15TH CYCLE MAXIMUM LOCKING(IN. LBS.): 07.0
15TH MINIMUM BREAKAWAY(IN. LBS.): 07.0

ALL SAMPLE PIECES MEET OR EXCEED MINIMUM REQTS.
SAMPLE SIZE 10 PIECES

MERCURY FREE CLAUSE WE CERTIFY THAT NO POSSIBILITY EXISTS FOR MERCURY CONTAMINATION TO OCCUR DURING MANUFACTURE, ASSEMBLY, OR TESTING OF PARTS ON THIS CONTRACT.

I CERTIFY THAT THE ABOVE TEST RESULTS AND/OR STATEMENTS ARE CORRECT AND REPRESENT THE PRODUCTS AS SUPPLIED.

CERTIFIED TRUE COPY
ISO Group certifies that the material or parts provided were not:
1. Subjected to conditions of extreme stress, heat or environment.
2. Obtained from any Government or military services.
SIGNATURE: [redacted]
NAME: SCOTT CHALMERS QUALITY INSPECTOR

SIGNATURE [redacted]
[redacted]IM EARLEY, QUALITY ASSURANCE MANAGER

FSCM/CAGE NO. 019L2
COQC-NASM REV. 6-18-01

Figure H-28: NAS1021N4 Manufacturer's Certificate Page 2

H.7 NAS1004-29A

HC PACIFIC
19844 QUIROZ COURT
WALNUT, CA. 91789

ISO 9001 Certified
HC PACIFIC
AS9120 Certified

BAE/AG/20011/MAA.
AUK/SA/20088

Certificate of Conformance

TO: DAN HESS

P.O.: VERBAL

PART No. NAS1004-29A

We certify that the enclosed material was manufactured to applicable industry standards at time of manufacture. Unless otherwise noted, Country of origin is U.S.A Supportive evidence and traceability back to the manufacturer is on file for a period of ten years minimum and will be available for examination upon request. The applicable procurement specification No. is AS7477

Remarks:

Manufacturer CALIF SCREW CORP. Mfg. Lot # 26306

Quantity: 150 PCS.

Date: 06/25/07 [redacted]

Guido A. Fonseca/ Q.A. Supervisor , Carlos Martinez, Insp / José Montufar Insp.

Rinty Sullivan, Quality Assurance Manager

Form HCQCO16 Effective 08-16-04
BLUE

Figure H-29: NAS1004-29A Manufacturer's Certificate Page 1

Appendix H (Continued)

TAG# 40431
60376-B

MANUFACTURERS OF AIRCRAFT FASTENERS AN-MS-NAS

CALIFORNIA SCREW PRODUCTS CORP.

14957 GWEN CHRIS AVE. PARAMOUNT, CALIF. 90723

TEST REPORT

PART NUMBER NAS1004-29A REV. 7 JOB NO. 26306

CUSTOMER HC PACIFIC ORDER NUMBER 60376 ORDER QUANTITY 5000

PROCUREMENT SPECIFICATION AS7477 A LOT QUANTITY* 5200

MATERIAL A-286 MATERIAL SPEC. AMS 5731H HEAT NO. 507063

THREAD SPECIFICATION MIL-S-8879C THREAD SIZE & FORM 1/4-28UNJF3A

SURFACE FINISH/PLATING QQP35C HEAT TREAT SPEC. HEAT TREAT: A-286 SOLUTION AND AGE PER AMS 2759/3

METALLURGICAL EXAMINATION

LAB NO. 12411

GRAIN SIZE 7 HEAD STRUCTURE Accept MICROSTRUCTURE 8 FILLET COLD WORKED Accept

DECARB Accept CARBURIZED Accept GRAIN FLOW HEAD Accept GRAIN FLOW THREAD Accept

THREAD RUN OUT Accept LAPS Accept SEAMS Accept CRACKS Accept

NON-DESTRUCTIVE TESTS

MAGNETIC PERMEABILITY: <2.0

MAGNETIC PARTICLE: N/A FLOURESCENT PENETRANT: ASTME1417-95 ACCEPT 189 REJECT

MECHANICAL TESTS RESULTS

ULTIMATE TENSILE STRENGTH LOCATION OF FAILURE: THREADS MIN. REQ. 5100 LBS.

1. 6740	2. 6730	3. 6750	4. 6790	5. 6810	6. 6770	7. 6840	8. 6740
9.	10.	11.	12.	13.	14.	15.	

SHEAR (SINGLE/DOUBLE) MIN. REQ. LBS.

1.	2.	3.	4.	5.	6.	7.	8.
9.	10.	11.	12.	13.	14.	15.	S

HARDNESS REQ. RC 24-35 HARDNESS RESULTS 29-31 SAMPLE SIZE: 8

STRESS RUPTURE TEST: LOAD: 2520 LBS. RATIO LOAD 158 LBS. AT 1200 F 23 HRS.

FATIGUE TESTS: LOCATION OF FAILURE: N/A CYCLES: N/A MIN. REQ. N/A

LOW LOAD: N/A LBS. HIGH LOAD: N/A LBS. SAMPLE SIZE: N

TORQUE TEST: N/A IN LBS. SAMPLE SIZE: N OTHER: N

CHEMICAL COMPOSITION

MANUFACTURER:	C	SI	MN	P	S	CU	NI	CR	MO	V
	.03	.23	.35	.012	LT.0005	.19	24.42	13.97	1.10	.32
CAR TECH	AL	TI	CO	B						
	.25	2.20	.10	.005						
DIA.: .251										

All items were manufactured under a MIL-I-45208 inspection system as applicable.
CALIFORNIA SCREW PRODUCTS CORP. hereby states that the above product is mercury free.
CALIFORNIA SCREW PRODUCTS CORP. hereby certifies that the above listed material has been produced, sampled, tested and inspected, and marked in accordance with all contract and specification requirements; evidence of which is in the files of our company subject to examination.
*The actual piece count of parts is within ± 2% of the shown lot quantity.

[redacted]
(Name, Signature, Stamp and Date)

Figure H-30: NAS1004-29A Manufacturer's Certificate Page 2

Appendix H (Continued)

CERTIFICATE OF TESTS ABNAHMEPRUEFZEUGNIS CERTIFICAT DE CONTROLE

CARPENTER TECHNOLOGY CORPORATION

CarTech P.O. BOX 14662
READING, PA 19612-4662
U. S. A.

- THE RECORDING OF FALSE, FICTITIOUS OR FRAUDULENT STATEMENTS OR ENTRIES ON THIS DOCUMENT MAY BE PUNISHED AS A FELONY UNDER FEDERAL STATUTES INCLUDING FEDERAL LAW, TITLE 18, CHAPTER 47.
- THE VALUES AND OTHER TECHNICAL DATA REPRESENT THE RESULTS OF ANALYSES AND TESTS MADE ON SAMPLES COLLECTED FROM THE TOTAL LOT: ORIGINAL DATA RECORDS CAN BE TRACED BY REFERENCE TO THE CARPENTER ORDER NUMBER.
- MATERIAL IS MANUFACTURED FREE FROM MERCURY, RADIUM AND ALPHA SOURCE CONTAMINATION.

01/03/95
CUSTOMER / BESTELLER / CLIENT SELLER / VERKÄUFER / VENDEUR PAGE - 1

CALIFORNIA SCREW PRODUCTS CORP
14957 GWEN CHRIS
PARAMOUNT ,CA 90723

CARPENTER TECHNOLOGY CORP

PO BOX 58880
LOS ANGELES ,CA 90058

S/N 26306

CUSTOMER ORDER NO. / BESTELL - NR. / N° DE COMMANDE	CARPENTER NO. / WERKS - NR. / N° DE REFERENCE INTERNE	DATE / DATUM / DATE	WEIGHT / GEWICHT / POIDS
11710	LOS977601 L31171	01/03/95	2030.000

HEAT NUMBER / SCHMELZE-NR. / N° DE COULEE 507063

PRODUCT DESCRIPTION: CONSUMET A286 SOLUTION ANNEALED COLD FINISH SEAM FREE
CF WIRE FOR HEADING CL N2 HVY CU/MOLY SOAP
TENSILE MIN 105.0 / MAX 120.0 KSI

SPECIFICATION: AMS 5731 REV H (07/01/89)
AMS 5732 REV F (10/01/89) (CAPABLE OF)
AMS 5734 REV F (07/01/89) (CAPABLE OF)
AMS 5735 REV J (12/15/74) (CAPABLE OF)
AMS 5737 REV L (07/01/89) (CAPABLE OF)
AMS 5853 REV A (01/01/93)

SIZE 0.251000 IN. RD WIRE

C	MN	SI	P	S	CR
0.03	0.35	0.23	0.012	LT .0005	13.97
NI	**MO**	**CU**	**CO**	**AL**	**TI**
24.42	1.10	0.19	0.10	0.25	2.20
V	**B**				
0.32	0.005				

MILL HEAT TREATMENT:
TYPE - SOLUTION ANNEAL
TEMP 1795F (980C)
TIME AT TEMP CONTINUOUS FURNACE
QUENCH WATER

TENSILE STRENGTH AS SHIPPED, KSI 111.0

GRAIN SIZE PER ASTM E112: 9

CAPABILITY
1650 F, 02 HR OIL TREAT
1325 F, 16 HR AIR COOL

COMBINATION STRESS RUPTURE
TEST TEMP 1200 F
STRESS, KSI 65.0
ELONGATION 32.0
HOURS 48.7

1-9-95
13 CSP RHIR 2550

[redacted]

YIELD STRENGTH, (.20 %) KSI 110.0
TENSILE STRENGTH, KSI 162.0
ELONGATION IN 2.00", % 24.0
REDUCTION OF AREA, % 49.0
HARDNESS , HB - 321.0

CONTINUED ON NEXT PAGE

This certification is made to the customer printed on this form. Carpenter neither makes, nor assumes responsibility for, any representation or certification to other parties.
Die vorliegende Zertifizierung ist nur für den in diesem Formular genannten Kunden gültig. Carpenter übernimmt gegenüber Dritten keinerlei Haftung für die ausgewiesenen Daten oder Zertifizierungen.

Figure H-31: NAS1004-29A Manufacturer's Certificate Page 3

Appendix H (Continued)

CERTIFICATE OF TESTS ABNAHMEPRUEFZEUGNIS CERTIFICAT DE CONTROLE

CARPENTER TECHNOLOGY CORPORATION

CarTech P.O. BOX 14662
READING, PA 19612-4662
U. S. A.

- THE RECORDING OF FALSE, FICTITIOUS OR FRAUDULENT STATEMENTS OR ENTRIES ON THIS DOCUMENT MAY BE PUNISHED AS A FELONY UNDER FEDERAL STATUTES INCLUDING FEDERAL LAW, TITLE 18, CHAPTER 47.
- THE VALUES AND OTHER TECHNICAL DATA REPRESENT THE RESULTS OF ANALYSES AND TESTS MADE ON SAMPLES COLLECTED FROM THE TOTAL LOT. ORIGINAL DATA RECORDS CAN BE TRACED BY REFERENCE TO THE CARPENTER ORDER NUMBER.
- MATERIAL IS MANUFACTURED FREE FROM MERCURY, RADIUM AND ALPHA SOURCE CONTAMINATION.

01/03/95
CUSTOMER / BESTELLER / CLIENT

SELLER / VERKÄUFER / VENDEUR PAGE - 2

CALIFORNIA SCREW PRODUCTS CORP
14957 GWEN CHRIS
PARAMOUNT ,CA 90723

CARPENTER TECHNOLOGY CORP

PO BOX 58880
LOS ANGELES ,CA 90058

CUSTOMER ORDER NO. / BESTELL - NR. / N° DE COMMANDE	CARPENTER NO. / WERKS - NR. / N° DE REFERENCE INTERNE	DATE / DATUM / DATE	WEIGHT / GEWICHT / POIDS
11710	LOS977601 L31171	01/03/95	2030.000

HEAT NUMBER / SCHMELZE-NR. / N° DE COULEE 507063

CAPABILITY

1800 F, 01 HR OIL TREAT
1325 F, 16 HR AIR COOL

COMBINATION STRESS RUPTURE
TEST TEMP 1200 F
STRESS, KSI 70.0
ELONGATION 15.3
HOURS 79.1

AFTER MINIMUM TIME UNDER SPECIFIED STRESS, THE STRESS RUPTURE TEST
WAS OVERLOADED IN INCREMENTS AS FOLLOWS:
TOTAL HOURS STRESS (KSI)
59 75.0

(T)RANSVERSE (L)ONGITUDINAL	L
YIELD STRENGTH, (.20 %) KSI	103.0
TENSILE STRENGTH, KSI	159.0
ELONGATION IN 2.00", %	26.0
REDUCTION OF AREA, %	47.0
HARDNESS , HB	311.0

CAPABILITY

1275 F, 16 HR AIR COOL

(T)RANSVERSE (L)ONGITUDINAL	L
YIELD STRENGTH, (.20 %) KSI	155.0
TENSILE STRENGTH, KSI	183.0
ELONGATION IN 1.00", %	20.0
REDUCTION OF AREA, %	49.0
HARDNESS , HRC	37.0

CARPENTER'S QUALITY MANAGEMENT SYSTEM WAS REGISTERED AS OF DECEMBER 21, 1993
TO THE REQUIREMENTS OF ISO 9002 BY LLOYD'S REGISTER QUALITY ASSURANCE LTD.
I CERTIFY THE ABOVE INFORMATION TO BE A TRUE AND CORRECT RESTATEMENT OF
PORTIONS OF THE APPLICABLE TEST AND ORDER DATA.

ROBERT E. CARNES
SUPERVISOR - METALLURGICAL LAB
CARPENTER TECHNOLOGY CORPORATION

1-9-95 RMJR

13 CSH

[redacted]

[redacted]

MITCH ALLENSPACH
BRANCH MANAGER

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Figure H-32: NAS1004-29A Manufacturer's Certificate Page 4

Appendix H (Continued)

HINDERLITER
HEAT TREATING

18600 OXNARD ST.
TARZANA, CALIF. 91356
PHONE: (818) ~~996-2310~~ • 344-0216 • FAX: (818) 609-9372

METAL TREATING INSTITUTE

CERTIFICATION

CERTIFICATION NUMBER 047865

CUSTOMER PO
30921

SOLD TO
CALIFORNIA SCREW PROD. CORP.
14957 GWEN CHRIS AVE.
PARAMOUNT CA
90723

SHIP TO
CALIFORNIA SCREW PROD. CORP.
14957 GWEN CHRIS AVE.
PARAMOUNT CA
90723

DATE CERTIFIED	CUST. NO.	MATERIAL	PART NO.	REQUIRED HARDNESS
04/10/95	12123	A-286		RC 28 MIN

PROCESS DESCRIPTION	YOUR SPECIFICATIONS
SOLUTION & AGE	AMS 2759/3

QUANTITY	PARTS DESCRIPTION
5,300	P/N NAS 1004-29A REV 7 J/N 26306

PROCESS	FURNACE	TEMPERATURE	TIME AT TEMP.	COOLING METHOD
ALKALINE CLEAN	69			
SOLUTION ANNEAL	9	1800F	01:00	OIL
ALKALINE CLEAN	69			
PRECIPITATION	8	1325F	16:00	GAS FAN COOL ARGON

PIECES TESTED	TESTING INSTRUMENT	HARDNESS RANGE
8	ROCKWELL C SCALE	28 RC TO 30 RC

PLEASE READ TERMS AND CONDITIONS ON REVERSE SIDE CONTAINING LIMITATION OF WARRANTY, LIABILITY AND REMEDIES APPLYING TO THIS TRANSACTION.

HINDERLITER HEAT TREATING, INC.

certifies that the parts listed above have been processed in accordance with the above listed specifications. Processes and test results were obtained through standard approved methods, and the hardness is certified for the parts in their present state of completion.

CHRIS HALL
Plant Superintendent

HHT QA 1

[redacted]

AUTHORIZED SIGNATURE

N0001A 2/87

Figure H-33: NAS1004-29A Manufacturer's Certificate Page 5

Appendix H (Continued)

203543

ACTIVE

MAGNETIC INSPECTION, INC.

9356½ San Fernando Road, Unit B • Sun Valley, CA 91352
(818) 504-0677 • FAX (818) 504-1559

SOLD TO: CALIFORNIA SCREW PRODUCTS
14957 GWENCHRIS AVE. P.O. BOX 228
PARAMOUNT , CA 90723
(310) 633-6626

TERMS: net 30

DATE	CUSTOMER P.O.	PACKAGING METHOD
05-05-1995	31884	3 Pan

QUANTITY	PART NO.	DESCRIPTION	UNIT	AMOUNT
5200 200#	NAS1004-29A REV.7 26306	*PENE PASS SALT SPRAY	[redacted]	
	Salt Spray 13 pcs Acc: 13	Rej: 0		

MATERIAL / HEAT TREAT / STATUS OF PARTS A-286/FINAL

TOTAL [redacted]

PASSIVATE QQ-P-35C 104 ASTM-B117-90/Type VIII

Other

MAGNETIC SPECIFICATIONS

Acceptance Criteria

Accepted	Rejected	Accepted	Rejected	Accepted	Rejected	Accepted	Rejected	Accepted	Rejected	Accepted	Rejected	Accepted	Rejected

Reason Rejected

FLOURESCENT PENETRANT SPECIFICATIONS

Acceptance Criteria /ASTM E 1417/95

Accepted	Rejected	Accepted	Rejected	Accepted	Rejected	Accepted	Rejected	Accepted	Rejected	Accepted	Rejected	Accepted	Rejected
189	0												

Reason Rejected

Unless value of a part being processed has been declared prior to processing our liability for scrap, defective work or rework liability is limited to three times our processing charge. Salvage work is accepted on a best effort basis with our liability being limited to the charge for processing unless prior written arrangements have been made.

ACTIVE MAGNETIC INSPECTION COMPANY'S GUARANTEE CEASES IF CLAIMS ON THESE PARTS ARE NOT REGISTERED WITHIN 10 DAYS OF RECEIPT, OR IF FURTHER PROCESSING HAS BEEN DONE.

QC Mgr JAMES E. JORDAN

[redacted]

CERTIFIED LEVEL III INSPECTOR

We hereby certify the parts listed herein have been processed per the specifications noted as required by the purchase order.

CERTIFICATION

Figure H-34: NAS1004-29A Manufacturer's Certificate Page 6

Appendix H (Continued)

CALIFORNIA SCREW PRODUCTS CORP.
P.O. BOX 228
14957 GWEN CHRIS AVENUE
PARAMOUNT, CALIFORNIA 90723
(310) 633-6626 • FAX (310) 633-2082

CERTIFICATE OF CONFORMANCE

We certify that all items/material shipped on Purchase order 60376 JOB #26306 to the HC PACIFIC company were manufactured under a MIL-I-45208A inspection system as applicable and they are in compliance to all applicable blue print/ specification requirements of part number NAS1004-29A in the qty of 5200 pcs. Test reports, data sheets, inspection records or other types of objective evidence are on file for a period of 10 years for buyers review.

[redacted]

QUALITY CONTROL MANAGER
CANH DO

DATE 5/9/95

Figure H-35: NAS1004-29A Manufacturer's Certificate Page 7

Appendix I: Summaries of Locknut Individual Testing

I.1 MS21043-4

Assembly Prevailing Torque decreased noticeably between the first and second tightening for each trial with a range of 13-50%. The Removal and Assembly Verification Torques also decreased moderately between the first and second tightening. For the first several cycles the Tightening and Breakloose Torques increased, and then they began a decreasing trend. After a few cycles the Tightening and Breakloose Torques reestablished an increasing trend. Some trials failed before 15 cycles while other lasted all 15. Several failures occurred due to the 6-Point hex of the locknut being damaged and no longer allowing for further tightening.

Conclusion; the locknut performed well. The Prevailing Torques were fairly predictable. The Tightening and Breakloose Torques were not predicable, this could have been caused by lubrication not being distributed at first, then distributed and finally worn away from use. The 6-Point hex damage was likely the result of the steel used to create the locknut was softer than the metal used for the socket.

I.2 NAS1291-4

Assembly Prevailing Torque decreased noticeably between the first and second tightening for each trial with a range of 20-33%. The Assembly Prevailing Torque remained steady for the first several cycles after the Cycle 1 decrease. Then it began to decrease in a predicable fashion. The Tightening and Breakloose Torques increased throughout most of the trials fairly steadily. The Removal Torques tended to fluctuate slightly throughout the trials, though with an over-all pattern of decreasing trend. There were regularly metal particles present after the first tightenings, most likely the locknut's finish being worn off.

Conclusion; this locknut faired very well, the best all-metal type locknut. The behavior of the locknut was mostly predicable and few surprises. The metal shavings were most likely just the finish on the underside of the locknut being worn off the locknut when being tightened on the washer for the first time.

I.3 NAS1805-4

The Assembly Prevailing Torque either remained unchanged or increased between the first and second tightening. Both Assembly Verification and Removal Prevailing Torques increased between first and second tightening. Around Cycle 4 or 5 the Prevailing Torques began to decrease. When loss in measured torque began, it occurred very rapidly over the next cycles until failure. Thin continuous straight chips of metal from the test bolt's tread were created during Cycle 3 due to the locknut. After each cycle there was a noticeable amount of metal filings/particles. Upon inspection of bolt threads after locknut failure, the first 1/3 of the bolt's threads had been noticeably shaved down. Half Cycle Trials failed earlier than Full Cycle Trials.

Appendix I (Continued)

Conclusion; the locknut was very good for the first few cycles, with little to no degradation in the measurements, though by Cycle 4 that changed drastically. Galling may be a reason of the change in measured values. The damage to the bolt had a large effect on the measurements. The locknut was held to a Rockwell C Scale rating of 49, where the bolt's rating was much lower at 32. With the locknut being a noticeably higher hardness than the bolt is what lead to the bolt's thread damage. The small metal particles were possibly due to the locknut's coating wearing off. Reasons for Full Cycles trial lasting longer than Half Cycles could be that the Half Cycle Removal Torque measurements are recorded from the segment of threads of the bolt which experience the full force of the preload. In the Full Cycle, that portion of the bolt is being used to measure the Breakloose Torque, and the Removal Torque in measured from a segment of the bolt which experiences limited preload forcing.

I.4 MS17825-4

Assembly Prevailing Torque decreased noticeably between the first and second tightening for each trial with a range of 25-45%. The Removal and Assembly Verification Prevailing Torques also decreased from the first tightening. Over-all all three had a steady decreasing trend throughout the trials. The Tightening and Breakloose Torques were not very predicable between trials. Different trials had different patterns. Some patterns were oscillatory, others increased then decreased, and others only decreased. This locknut had strange behavior.

Appendix I (Continued)

Conclusion; the strange behavior may be attributed to the design of the locknut. It is a slotted locknut with a nylon insert. The slotted portion reduced the amount of the locknut that possessed threads by what appears to be about half. The nylon is a ring insert, which is also slotted, has less material to be utilized for preventing loosening of the locknut. Also since it is slotted it is meant to be pair with locking wire when in use.

I.5 MS21044D4

Assembly Prevailing Torque decreased between the first and second tightening for each trial with a range of 10-15%. The Assembly Verification and Removal Torques had a slight decreasing trend throughout the trials. The Tightening and Breakloose Torques had steady increases in measured values throughout the trial. Generally there was an appearance of small chips of the green nylon after the Assembly Prevailing Torque measurement of the 2^{nd} Cycle on many of the trials. The locknut survived 15 cycles for unseated. 66% Y Preload, and 75% Y Preload; averaging about 13.75 cycles at 85% Y Preload.

Conclusion; the locknut performed very well. Most of the data was predictable, save the sharp rises in the Tightening and Breakloose Torques, which may have been caused by the lubrication being worn away in the earlier cycles. The green nylon ring deformed differently than the red nylon of NAS1021N4, the green nylon created a cone like appearance up and out of the locknut, shaped like: / \, where the red nylon did not. There a difference in the two nylons.

Appendix I (Continued)

I.6 NAS1021N4

Assembly Prevailing Torque decreased between the first and second tightening for each trial by about 10%. Assembly Verification and Removal Torques also decreased noticeably between the first and second tightening. The locknut performed very well. The Tightening Torque steadily increased then by cycle 5 it plateaued. Breakloose Torque increased to cycle 5 then decreased to cycle 12, where it leveled off. The locknut survived all 15 cycles for all preloads.

Conclusion; the red nylon was the best performing aerospace locknut. There seems to be a difference between the behaviors of the nylon inserts between NAS1021N4 and MS21044D4.

I.7 Grade 8

The Assembly Prevailing Torque decreased significantly for all trials between the first and second tightening from 18% to 40%. During Trial 1 there was a large difference between the prevailing torque measurement in the tightening direction and the second measurement of the torque in the tightening direction, measured after preload and Removal Prevailing, for the 1st cycle. Afterwards it leveled out. A similar behavior occurred during Trials 2-4, in which the tightening direction prevailing torque was smaller than the loosening direction prevailing torque. These differences were largely negative, which is out of the ordinary since all other locknuts had positive differences. This means that the locknuts performance improved after the tightening and during Removal Prevailing Torque. The Tightening and Breakloose Torques decreased

Appendix I (Continued)

throughout each trial, starting high ending low. The two values were also inconsistent. They would rise and fall randomly with each cycle, never holding to a clear discernible trend. Thus far every locknut has survived all 15 cycles of its respective trial.

Conclusion; the decrease in the Tightening and Breakloose torques could possibly be attributed to the lubrication being further distributed throughout the threads of the locknut and bolt reducing friction. Run-in could be another possible reason for the reduction in these torque values. Since there were many instances of the difference between the tightening/re-tightening and tightening/loosening measurements being negative, the bolt may be creating a grove in the nylon insert creating a path of least resistance in the tightening direction, and getting caught up in the removal direction

Appendix J: Definitions

Assembly Prevailing Torque – Torque required to turn in the assembly or tightening direction once locking feature is fully engaged, but fastener is not seated

Assembly Prevailing Verification Torque (Assem. Ver.) – Torque required to turn in the assembly or tightening direction once locking feature is fully engaged, but fastener is not seated, performed after removal prevailing torque is measured and before fastener is removed from bolt

Breakloose Torque – The torque required to turn when a Preloaded threaded assembly is initially loosened

Life Cycles – Number of reuse cycles locknut survived

Preload – Force applied to locknut while seated, a percentage of bolt's yield

Percent Decrease – The percentage the Assembly Prevailing Torque decreased from cycle 1 to cycle 2

Percent Difference – The percentage difference between Assembly Prevailing Torque and Removal Prevailing Torque during a single cycle

Prevailing Torque – The torque required to turn in either direction to run a nut up or down a thread on nuts with prevailing locking feature, before seating

Removal Prevailing Torque – Torque required to turn in the removal or loosening direction once locking feature is fully engaged, but fastener is not seated

Appendix J (Continued)

Reuse Cycle – Locknut placed on test bolt and subjected to trial requirements then fully removed from test bolt, one on – off cycle of the locknut

Seated – Nut face is engaged with the clamped component's surface

Tightening Torque – The torque required to achieve desired Preload

Trial – A set of up to 15 reuse cycles performed in the manner described by the test plan

Torque-Tension – relates between applied torque and resulting preload

Unseated – Nut face does not engage or touch the clamped component's surface