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Tritium Producing Burnable Absorber Rod (TPBAR) Cutterhead Test Report

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EXECUTIVE SUMMARY

The Tritium Extraction Facility (TEF) Target Rod Preparation (TRP) Tritium Producing Burnable Absorber Rod (TPBAR) Cutterhead is a specialized remote tubing cutter used to breach TPBARs (approximately 0.381 inch outside diameter x 0.336 inch inside diameter 316 stainless steel tubing). The cutterhead was originally designed by an external engineering firm - RTS Wright Industries. The bearing housing and drive plate, the main drive components, are designed to be fabricated from Nitronic 60, an anti-galling stainless steel, and coated with Dicronite® (Tungsten Disulfide) lubricating coating. These parts have galled after a limited number of cycles, damaging the fine 3.25-32 UN threads which drive the system. In some cases, destructive sectioning is required to remove the failed parts from the cutterhead. Cutterheads have been fabricated by multiple machine shops, with some cutterheads failing very quickly and some lasting more than 1,000 cuts. In 2019, Emery Corporation, now Toner Machining Technologies (TMT) was contracted to fabricate four (4) new complete sets of cutterheads. The newly fabricated cutterheads have not been able to pass the required acceptance test without the bearing housing and drive plate threads galling. TMT has tried multiple sets of Nitronic 60 bearing housing and drive plates; all have galled after less than 10 cuts.

Savannah River National Laboratory (SRNL) was requested to inspect failed parts, assist in determining the causes of parts galling, and recommend solutions. SRNL performed dimensional and metallurgical examinations and observed the coating process but was unable to identify the root cause of the failures. Additionally, SRNL fabricated bearing housings and drive plates to test current and alternate designs. All tests were conducted using a TMT fabricated Cutterhead on a TRP test stand, with varied bearing housings and drive plates. SRNL collected temperature, torque, and strain data while testing.

The following summarizes the results of the tests and validations performed:

- All testing by both SRNL and TMT of Nitronic 60 threaded parts (original and modified designs) either galled while cutting, or testing was stopped due to a noticeable increase in torque.
- SRNL and TMT testing of Aluminum Bronze and a hardened steel parts with dry lubrication and/or fluorinated grease were stopped due to a noticeable increase in torque or excessive wear.
- Two sets of bearing housings, fabricated from commercial self-lubricating Sintered Bronze (Oilite), and drive plates, fabricated from hardened stainless steel (17-4 PH), successfully cut 380+ mock TPBARS with minimal degradation.
- Three (3) bearing Housings, fabricated from a specialized sintered Bronze impregnated with a silicone-based oil (CQ-705), and drive plates fabricated from hardened stainless steel (17-4 PH), “pre-lubed" with a small amount of Krytox 143AZ oil successfully cut 300+ mock TPBARs with minimal degradation.
- Four (4) sets of CQ-705 impregnated bronze bearing housings, and 17-4 PH drive plates fabricated by TMT successfully cut 120+ mock TPBARs on different cutterheads and remain in good operating condition.
- One set of drive parts fabricated by TMT with the specialized bronze successfully cut 1,000+ mock TPBARs and remains in good operating condition.
- One of the sintered bronze bearing housings was irradiated to a total of 15 Mrem, a dose typically experienced after cutting four (4) baskets of TPBARs, and was used to successfully cut 120+ mock TPBARs. This bearing housing previously cut 315 TPBARs in another test.
- A second CQ-705 bearing housing was irradiated to a total of 15 Mrem and showed no detectable (less than 0.25 ppm of Volatile Organics) off-gassing.

In summary, the combination of the CQ-705 impregnated bronze bearing housing and hardened stainless steel drive plate lubricated with Krytox 143AZ has proven successful in cutting TPBARs. SRNL recommends this material combination with pre-lubrication be considered as an alternative to the current design of Nitronic 60 bearing housings and drive plates in the TRP Cutterhead.

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LIST OF ABBREVIATIONS

AE	Advanced Engineering
cc	Cubic Centimeter
FOS	Factor of Safety
hr	Hour
L	Liter
M	Mega
ppm	Parts Per Million
psig	Pounds per Square Inch Gauge
REM	Roentgen Equivalent Man
SRNL	Savannah River National Laboratory
SRTE	Savannah River Tritium Enterprise
SST	Stainless Steel
TEF	Tritium Extraction Facility
TMT	Toner Machining Technologies
TRP	Target Rod Preparation
TPBAR	Tritium Producing Burnable Absorber Rod
UN	Unified National (Thread)
VOA GCMS	Volatile Organic Analysis by Gas Chromatography/Mass Spectrometry

1.0 Introduction

The Tritium Extraction Facility (TEF) Target Rod Preparation (TRP) Tritium Producing Burnable Absorber Rod (TPBAR) Cutterhead is a specialized remote tubing cutter used to breach TPBARs (approximately 0.381 inch outside diameter x 0.336 inch inside diameter 316 stainless steel tubing) (6.1). The cutterhead was originally designed by an outside engineering group - RTS Wright Industries. The bearing housing and drive plate, the main drive components, are designed to be fabricated from Nitronic 60, an anti-galling stainless steel, and coated with Dicronite® (Tungsten Disulfide) lubricating coating. These parts have galled after a limited number of cycles, damaging the fine threads (3.25-32 UN) and in some cases requiring destructive sectioning to remove them. Cutterheads have been fabricated by multiple machine shops, with some cutterheads failing very quickly (less than three cuts) and some lasting more than 1,000 cuts. TEF has four functioning cutterheads and one spare unit. The current vendor, Toner Machining Technologies (TMT), formerly Emery Corporation, built two functional cutterheads in the past but is having difficulty fabricating a cutterhead that will cut 300 or more simulated TPBARs.

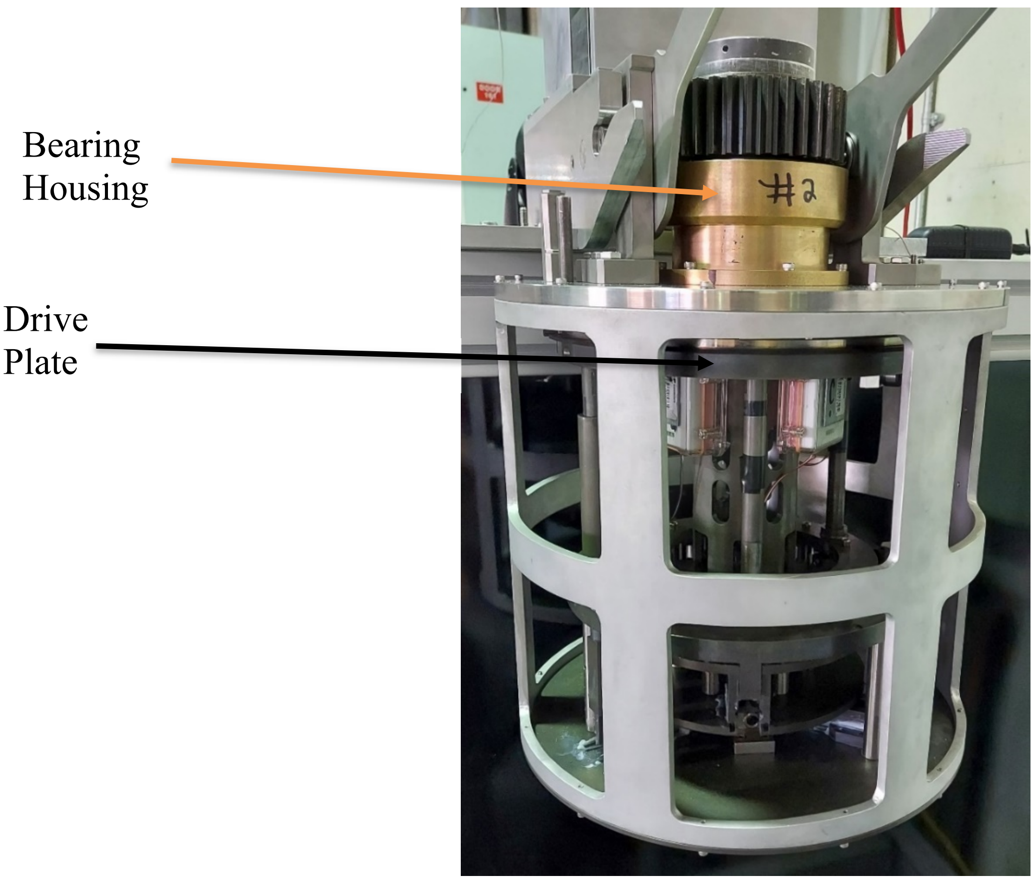

Figure 1-1. Cutterhead with Windows Cut in Shell

In 2011, with RTS Wright Industries out of business, Toner Machining Technologies, then Emery Corporation, was contracted to make two more cutterheads. The engineering specification required acceptance testing. Part of the acceptance testing criteria was to successfully run five (5) cutting cycles of operation using a test stand to cut tubing the same size as a TPBAR. This simulates the operation of the cutterhead in the TRP cell. Both cutterheads passed the acceptance testing at TMT.

In 2019, Toner Machining Technologies was contracted to fabricate four (4) new complete sets of cutterheads but has been unable to successfully pass the acceptance test without the bearing housing and drive plate threads galling. TMT has tested multiple sets of Nitronic 60 bearing housings and drive plates; all have galled after less than 10 cuts. TMT has also tried different material and coating combinations and different fabrication methods (form tapping and grinding threads) with very limited success. A C955 nickel-aluminum-bronze bearing and a hardened 52100 steel drive plate showed merit; however, testing was stopped after 182 cuts due to extensive wear of the C955 bearing housing.

Dimensional inspection of TMT fabricated Cutterhead #9 showed that the part was fabricated within specification of the engineering drawing. A review of the Dicronite® coating process showed that the parts were being coated as specified per the engineering drawings (6.1). Metallurgical evaluations were performed on some spare cutterhead Nitronic® 60 components that failed during testing to identify potential causes of early galling failure. The failed components appear to meet design specification requirements, with no evidence pointing to definitive cause of galling failure. The analyzed components had no identified variation when compared to components performing successfully in service (6.2).

2.0 Experimental Procedure

2.1 Initial Testing

SRNL focused on testing different designs after completing the examinations previously mentioned. SRNL designed and fabricated a Simplified Test Set-up to study drive plate and bearing housing components separate from the full cutterhead assembly. Cutterhead #9 was also modified to accept instrumentation - a torque sensor, strain gauges, and thermocouples.

Initial drive plate and bearing housing experiments were categorized into two groups: Thread Tests and Cut Tests. Thread Tests are performed in the Simplified Test Set-up, where an electric motor drives the threaded parts while an air cylinder applies a load to the bottom face of the drive plate. The applied load is based on the relationship between torque and axial force in threaded connections. SRNL used the torque measured in previous cut tests to determine the axial force to apply with the air cylinder. This is meant to approximate the resistive forces present during the cutting process. Failure in the Simplified Test Set-up suggests that the threaded parts will fail inside of the cutterhead during operation.

A Cut Test is a simplified version of the process used in the TRP cell. The cut test mirrors in-cell operations minus the “un-grip” and “re-grip” processes. The “un-grip” and “re-grip” steps accommodate the external gripper used to position the TPBARs within the cell. These steps are not necessary in testing, because the operator manually positions the mock TPBARs in the cutterhead.

2.2 CQ-705 Sintered Bronze Testing

Cut tests performed at SRNL and TMT showed that Nitronic 60 bearing housings and drive plates lubricated with MOLYKOTE Z Powder (molybdenum disulfide) will gall during the cutting process. Galling caused the bearing housing and drive plate to become stuck together requiring the parts to be cut apart to dissemble. The galling phenomena led SRNL to pursue bearing housing and drive plate combinations fabricated from dissimilar metals. The aim was to have one part fabricated from softer material to prevent the bearing housing and drive plate from galling and locking up. This would prevent a scenario where a TPBAR could become stuck in the cutterhead. For these reasons, SRNL pursued alternate materials for the bearing housing and drive plate.

An Oilite bearing housing and 17-4 PH SST drive plate were fabricated at SRNL and successfully used to cut 300+ mock TPBARs. Oilite is a sintered bronze material that has been impregnated with a hydrocarbon-based oil. It was hypothesized that the harder (17-4 PH) drive plate would wear away the softer material (Oilite), releasing the oil contained within the bearing housing and providing constant lubrication to the threaded drive connection. The 300+ successful cuts indicated that continuously lubricating the threads with oil allowed the parts to function. Unfortunately, the Oilite material cannot be used within this particular Tritium process as it contains a hydrocarbon-based oil, which is not allowed in the Tritium facility. The Hydrogen Isotope Process Science group of SRNL was consulted for alternatives and suggested a few different oils. A Silicone based oil, Conquest West CQ-705, was chosen due to its close viscosity match to the oil found in Oilite, low vapor pressure, chemical stability, and radiation resistance (6.3). SRNL ordered dry sintered bronze stock, contracted a third party to impregnate the bronze with CQ-705, and machined bearing housings out of the material. The goal was to create a part that mechanically behaved the same as Oilite and contained an oil acceptable to Tritium.

CQ-705 tests were performed in two different stages. The first set of tests were conducted at SRS using SRNL fabricated parts in Cutterhead #9, while the second set of tests used TMT fabricated parts and were conducted at the TMT fabrication plant. Test Plan SRNL-RP-2022-00101 (6.5) outlines the testing sequence. From this testing, it was determined that the best indicator of successful operation was the torque required to make a successful cut.

High torque was recorded during initial tests with the CQ-705 impregnated bronze bearing housing and 17-4 PH drive plate with no added lubricant during assembly. Additional parts were fabricated and tested to determine if lubricating the threads, during assembly (pre-lube), with CQ-705 or Krytox 143AZ would reduce the torque during testing and would keep the parts running for a full basket. After applying the CQ-705 pre-lube to both the drive plate and bearing housing threads, an initial high torque was measured, and the torque continued to increase until the testing was stopped due to extremely high torque. Another set of parts had approximately 0.5cc of Krytox 143AZ oil applied to the threads prior to testing. The parts pre-lubed with with Krytox 143AZ oil returned much lower and more consistent torque values during cutting operations. Therefore, it was determined that applying approximately 0.5 cubic centimeters of Krytox 143AZ oil to the threads was needed for successful cutting.

CQ-705 impregnated bearing housings and 17-4 PH drive plates lubricated with Krytox 143AZ were evaluated again at TMT in the second stage of tests. Four (4) sets of parts fabricated by TMT were tested in Cutterheads #9, #10, and #11. Based on information from the first stage of testing, each set of parts was used to make a minimum of 120 cuts at TMT. One set of TMT fabricated parts (drive plate and bearing housing) was tested to 360 cuts (one basket load plus 20%) in Cutterhead #10. Following this test, the bearing housing and drive plate were removed, brought back to SRS, installed into Cutterhead #9, and tested to make an additional 640 cuts for a total of 1,000 cuts on simulated TPBARs.

3.0 Results and Discussion

3.1 Initial Testing Results

SRNL performed Thread Tests on seven sets of threaded parts (Table 3-1) on the simplified test stand. All seven of these sets were fabricated by the SRNL 749-A Machine Shop. Drive plates and bearing housings in Thread Tests #3 and #6 were coated with Dicronite®. It is important to note that parts in Thread Test #3 were machined at the ends of the allowable tolerance per the ANSI/ASME standard to give the most clearance between the two parts.

Due to the prior partial success of pairing a softer C955 bronze bearing housing with a harder 52100 steel drive plate, SRNL fabricated a bearing housing from Oilite bronze and paired it with a hardened 17-4 PH stainless steel drive plate. Oilite is a sintered bronze impregnated with oil which can constantly lubricate the threads as the part wears. The Oilite bearing housing and 17-4 PH drive plate in Thread Test #4 completed 100 cycles in the simplified test set-up under the simulated cut load of 955 lbf. All other material combinations failed at different points during the Thread Tests.

Table 3-1. SRNL Simplified Test Stand Thread Testing Results

Thread Test #	Bearing Housing Material	Drive Plate Material	Lubricant	Thread	Load (lbf)	# of Cycles until binding or galling
1	Nitronic 60 (uncoated)	Nitronic 60 (uncoated)	Molykote (MoS^2)	3.25-32 UN	0, 250	20 cycles (0 lbf) 4 cycles (250 lbf)
2	Nitronic 60 (uncoated)	Nitronic 60 (uncoated)	Molykote (MoS^2)	3.25-32 UN	0	6 cycles (0 lbf)
3	Nitronic 60 (Dicronite®)	Nitronic 60 (Dicronite®)	Molykote (MoS^2)	3.25-32 UN	0, 250	40 cycles (0 lbf) 1 cycle (250 lbf)
4	Oilite	17-4 PH	Impregnated SAE 30	3.25-32 UN	0 - 955	20 cycles (250 lbf) 20 cycles (503 lbf) 19 cycles (755 lbf) 100 cycles (955 lbf) No failure
5	AMPCO	17-4 PH	Molykote (MoS^2)	3.25-32 UN	955	20 cycles (955 lbf)
6	Nitronic 60 (Dicronite®)	Nitronic 60 (Dicronite®)	Krytox 240AC + Molykote (MoS^2)	3.25-32 UN	0, 955	10 cycles (0 lbf) 7 cycles (955 lbf)
7	AMPCO	17-4 PH	Molykote (MoS^2)	3.25-16 ACME	955	27 cycles (955 lbf)

All the Initial Cut Tests were performed in Cutterhead #9, which was instrumented with a torque sensor, strain gauges, and thermocouples. SRNL performed Cut Tests on five sets of threaded parts (Table 3-2), all of which were fabricated by the SRNL machine shop. The Oilite bearing housing and 17-4 PH drive plate (Thread Test #4, Cut Test #2) completed 382 cuts, showing minimal signs of wear and remains in good operating condition. Another Oilite bearing housing was fabricated and showed similar success, cutting without failure or torque increase (Cut Test #5, Table 3-2). All other material combinations either galled while cutting or testing was stopped due to a noticeable increase in torque.

Table 3-2. Cutterhead #9, SRNL TRP Test Stand Cut Testing Results

Cut Test #	Bearing Housing Material	Drive Plate Material	Lubrication	Thread	# of Cuts until binding or galling
1	Nitronic 60 (Dicronite®)	Nitronic 60 (Dicronite®)	Molykote (MoS^2)	3.25-32 UN	7
2	Oilite #1	17-4 PH	Impregnated SAE 30	3.25-32 UN	382, still operational
3	Nitronic 60, Clean-Out Grooves (Dicronite®)	Nitronic 60 (Dicronite®)	Molykote (MoS^2)	3.25-32 UN	7
4	Nitronic 60 (Dicronite®)	Nitronic 60, Reduced Thread Engagement (Dicronite®)	Molykote (MoS^2)	3.25-32 UN	4
5	Oilite #2	17-4 PH	Impregnated SAE 30	3.25-32 UN	301, still operational

3.2 CQ-705 Sintered Bronze Testing Results

All test results are summarized and explained in the below tables. Several detailed graphs of the torque v.s. cut number relationship can be found in Appendix A.

SRNL fabricated two new bearing housings from sintered bearing bronze bar stock (ASTM B438, material designation CT-1000-K6 SAE 841 DRY) impregnated with Conquest West Inc. CQ-705 silicone oil.

CQ-705 Bearing Housing #1 and 17-4 PH Drive Plate #1 were used to cut 368 mock TPBARs and remain in good operating condition (Cut Test #15, Table 3-3). The parts were inspected after the cut test, and no thread damage was observed. The average torque required to cut with CQ-705 Bearing Housing #1 and 17-

4 PH Drive Plate #1 was less than 220 in-lbs (18.33 ft-lbs). These parts were lubricated with Krytox 143AZ during assembly.

The cut test for CQ-705 Bearing Housing #2 and 17-4 PH Drive Plate #2 was stopped after four (4) cuts due to vibration and high torque readings (Cut Test #20, Table 3-3). These parts were not lubricated with Krytox 143AZ during assembly, so the only lubrication present was the oil discharged from the impregnated bronze. The parts were inspected, but no major anomalies were observed. Multiple new parts were made to test CQ-705 and Krytox 143AZ as lubricants to apply during assembly (Table 3-3, 3-4). With no-pre-lube, parts stalled with very few cuts. With the CQ-705 pre-lube, parts would cut at an initial higher torque, and the torque would continue to increase until the testing was stopped due to extremely high torque.

Note that Cut Test numbers listed in the first column of Cut Test Results tables reflect the nomenclature used for data sets and are not successive in all tables. Not all Cut Test numbers are listed, as some data sets were collected while trouble shooting the test stand or exploring material or part combinations that were not intend to be fully tested.

Table 3-3. Cutterhead #9, SRNL TRP Test Stand Cut Testing Results

Cut Test #	Bearing Housing Material	Drive Plate Material	Lubrication	Thread	# of Cuts until stalling or excessive torque
15	CQ-705 #1	17-4 PH #1	CQ-705 Impregnated + Krytox 143AZ Pre-Lube	3.25-32 UN	368 Still operational
20	CQ-705 #2	17-4 PH #2	CQ-705 Impregnated	3.25-32 UN	4 Stopped testing due to vibration and high torque
25	CQ-705 #2	17-4 PH #3	CQ-705 Impregnated + CQ-705 Pre-Lube	3.25-32 UN	133
21	CQ-705 #3	17-4 PH #3	CQ-705 Impregnated + CQ-705 Pre-Lube	3.25-32 UN	101
22	CQ-705 #4	17-4 PH #3	CQ-705 Impregnated + CQ-705 Pre-Lube	3.25-32 UN	85

Cut Test #26 - #28 results indicate that drive plates and bearing housings function when lubricated with approximately 0.5 cubic centimeters (CC) of Krytox 143AZ during assembly (Table 3-4). CQ-705 Bearing Housing #5 was initially tested with no pre-lube and the motor stalled during the 11th cut. The motor direction was reversed and had no issues backing off the stall and then completing the cut. This demonstrates the benefit of using a softer bearing housing with a hardened steel drive plate. The bearing housing will wear rather than gall. After this stall, the Krytox 143AZ pre-lube was added, and all further cuts showed consistently low torque (Cut Test #27, Table 3-4, Figure A5). Slight wear on the threads was noticed, but torque remained low in all three cut tests.

Table 3-4. Cutterhead #9, SRNL TRP Test Stand Cut Testing Results

Cut Test #	Bearing Housing Material	Drive Plate Material	Lubrication	Thread	# of Cuts until stalling or excessive torque
26	CQ-705 #3	17-4 PH #2	CQ-705 Impregnated + Krytox 143AZ	3.25-32 UN	304, still operational
27	CQ-705 #5	17-4 PH #3	CQ-705 Impregnated + Krytox 143AZ	3.25-32 UN	315, still operational
28	CQ-705 #6	17-4 PH #3	CQ-705 Impregnated + Krytox 143AZ	3.25-32 UN	60, still operational

TMT fabricated four (4) sets of CQ-705 bearing housings and 17-4 PH SST drive plates. SRTE and SRNL personnel traveled to TMT to test these parts in Cutterheads #10 and #11(Table 3-5). Torque and temperature data acquisition hardware was incorporated into the test stand located at TMT. Cutterhead #10, with the TMT fabricated parts and Krytox 143AZ pre-lube, successfully made 360 cuts on simulated TPBARs. Again, the bearing housing showed slight wear, but remained functional. Cutterhead #11, with a second set of TMT fabricated parts and Krytox 143AZ pre-lube, successfully cut 120 simulated TPBARs. Cutterhead #9, with a third set of TMT fabricated parts and Krytox pre-lube, successfully cut 120 simulated TPBARs. The fourth set of TMT fabricated parts was also installed into Cutterhead #9 and successfully cut 100 simulated TPBARs. Upon return from TMT, the first CQ-705 bearing housing and drive plate that TMT had made was tested further to 1000 cuts on Cutterhead #9.

High torques for the first 220 cuts at TMT were strictly due to the test set-up at TMT. The gear on the test stand was binding, once this problem was corrected, all the cuts made with the various cutterheads showed low consistent torques.

Table 3-5. TMT Fabricated Parts, Test Stand Cut Testing Results

Cut Test #	Bearing Housing Material *	CH# *	Drive Plate Material	Lubrication	Thread	# of Cuts until stalling or excessive torque
30	CQ-705 #E1	CH#10 CH#9	17-4 PH #E1	CQ-705 Impregnated + Krytox 143AZ Pre-Lube	3.25-32 UN	1001 Still operational
31	CQ-705 #E2	CH#11	17-4 PH #E2	CQ-705 Impregnated + Krytox 143AZ Pre-Lube	3.25-32 UN	120 Still operational
32	CQ-705 #E3	CH#9	17-4 PH #E3	CQ-705 Impregnated + Krytox 143AZ Pre-Lube	3.25-32 UN	120 Still operational
33	CQ-705 #E4	CH#9	17-4 PH #E4	CQ-705 Impregnated + Krytox 143AZ Pre-Lube	3.25-32 UN	100 Still operational

* E as a designator denotes a TMT (Emery) part

The CQ-705 bearing housings were each weighed separately to determine how much of the oil was excreted during cutting operation. CQ-705 #2 was modified to verify that the sintered bronze could be 'staked' to hold the bearing in place, and therefore the post testing weight would not be accurate and was thus left out of the below table. CQ-705 #4 was washed in an ultrasonic bath to test what affect that would have on the oil. The higher volume of oil lost is attributed to this washing.

Table 3-6. CQ-705 Bearing Housings Results

CQ-705 Bearing Housing #	Initial Weight (grams)	Post-testing (grams)	Volume of Oil Lost (Worst Case) (cc)	Approx # of Cuts
1	1141.8	1141.0	0.73	368
3	1116.0	1115.2	0.73	304
4	1130.5	1127.8	2.48	85
5	1147.2	1146.6	0.55	315
6	1133.8	1132.8	0.92	60

It should be noted that the oil that was excreted from the bearing housings stayed on the drive plate (mostly on the male threads, with a very small amount on the top of the face of the drive plate) and no oil was observed on other parts, most importantly below the drive plate.

3.3 Irradiation of CQ-705 Sintered Bronze Testing Results

CQ-705 Bearing Housing #5, which successfully made 315 cuts, was irradiated to 15 Mrem. 15 Mrem was selected based on information from TEF - the radiation the cutterhead sees is 6,725 rem/hr, for a full run 6,725 x 24 hrs x 16 days is about 2.5 Mrem for a complete basket, 4 baskets x 2.5 Mrem is 10 Mrem. Multiplying by a factor of safety (FOS) of 1.5 gets us to 15 Mrem. This bearing housing was then put back into Cutterhead #9 and made 120 successful cuts for a total of 435 cuts. This demonstrated that the radiation exposure did not affect the performance of the bearing housing (Table 3-7).

Table 3-7. CQ-705 Bearing Housings Results

Cut Test #	Bearing Housing Material	Drive Plate Material	Lubrication	Thread	# of Cuts until stalling or excessive torque
27	CQ-705 #5	17-4 PH #3	CQ-705 Impregnated + Krytox 143AZ	3.25-32 UN	315 (pre-rad) 120 (post-rad), still operational

An additional CQ-705 bearing housing was placed into a sealed container. The container was evacuated and backfilled with approximately 5 psig of dry Nitrogen gas. The bearing housing was irradiated to 15 Mrem within the container. A sample of the gas was analyzed using a Gas Chromatograph by the Analytical Characterization & Sample Management group of SRNL. The off-gas sample from this container was compared to a control of pure nitrogen. The test showed that there is less than 0.25 ppm of any organic compounds and is thus acceptable to TEF.

Table 3-8. Volatile Organics Analysis Results

Sample	Results	Method
CQ-705 Bearing Housing #5 Off Gas	<0.25 mg/L (ppm) for all VOA compounds	VOA GCMS
Control Sample (Nitrogen)	<0.25 mg/L (ppm) for all VOA compounds	VOA GCMS

4.0 Conclusions

Test results show that using a CQ-705 impregnated bronze bearing housing and a 17-4PH SST drive plate, lubricated with Krytox 143AZ oil, will allow a cutterhead to cut 300+ mock TPBARs in a clean environment. Radiation tests demonstrated that the parts would function after being subjected to 15 Mrem, and the levels of volatile organics in the off-gas from the irradiated parts are acceptable for the Module Stripper System in TEF. Based on these results, SRNL is confident that the aforementioned parts can be used in a cutterhead in the TRP cell to breach at least one basket of TPBARs.

5.0 Recommendations, Path Forward or Future Work

A design change should be implemented to change the material of the drive plate on drawing AC29327A-001103 from Nitronic 60 to 17-4 PH H900 Stainless Steel (RC 40-48) and to change the material of the bearing housing on drawing AC29327A-001104 from Nitronic 60 to sintered bearing bronze per ASTM B438, material designation CT-1000-K6 SAE 841 DRY, Impregnated with Conquest West Inc. CQ-705 silicone oil. SRNL also recommends that Krytox 143AZ oil be added to the bearing housing and drive plate threads prior to the parts being put into service, and during planned maintenance.

Future work could include

- Pursuing a more commercially available material for the bearing housing.
- Investigating the use of the vacuum system in the TRP module to pull air across the Cutterhead motor to prevent overheating.

6.0 References

6.1 SRNL-L3310-2021-00017 Rev. 0, Tungsten Disulfide (DICRONITE®) Dry Lubricant Review and Coating Applicator Visit, November 23, 2021

6.2 SRNL-L3320-2022-00001, Rev 0, Metallurgical Evaluation of Nitronic® 60 TEF Cutterhead Components

6.3 SRNL-L1110-2022-00001 - Chemical and Radiation Stability of Highly Aromatic Silicone Oils, February 18, 2022

6.4 AC29327A, TRP Equipment Vendor file

6.5 SRNL-RP-2022-00101, Test Plan for TPBAR Cutterhead Bearing Housing Replacement Material

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B. Califf

Appendix A. Cutterhead Torque Data

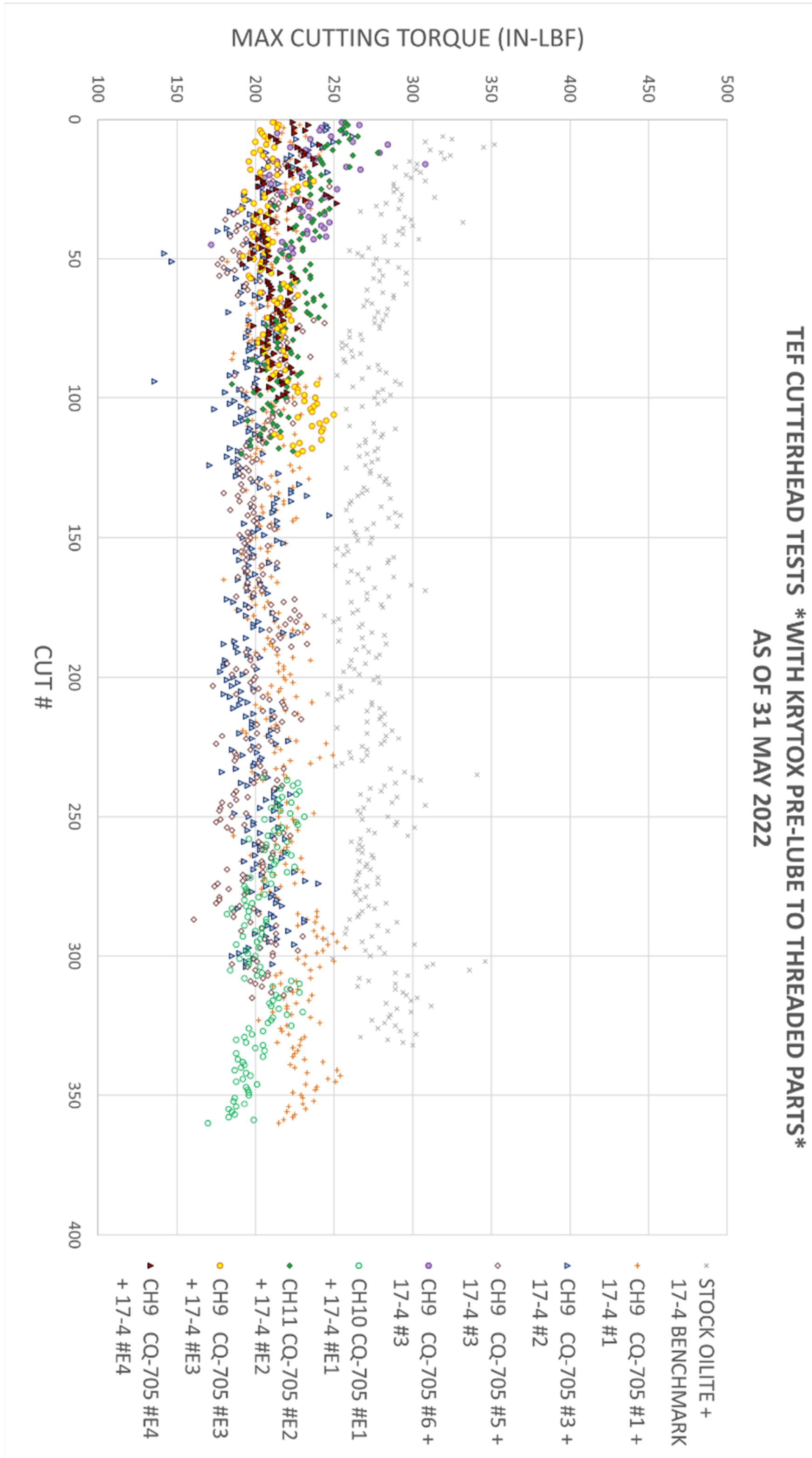

Figure A-1. TEF Cutterhead Krytox Lubricated Tests

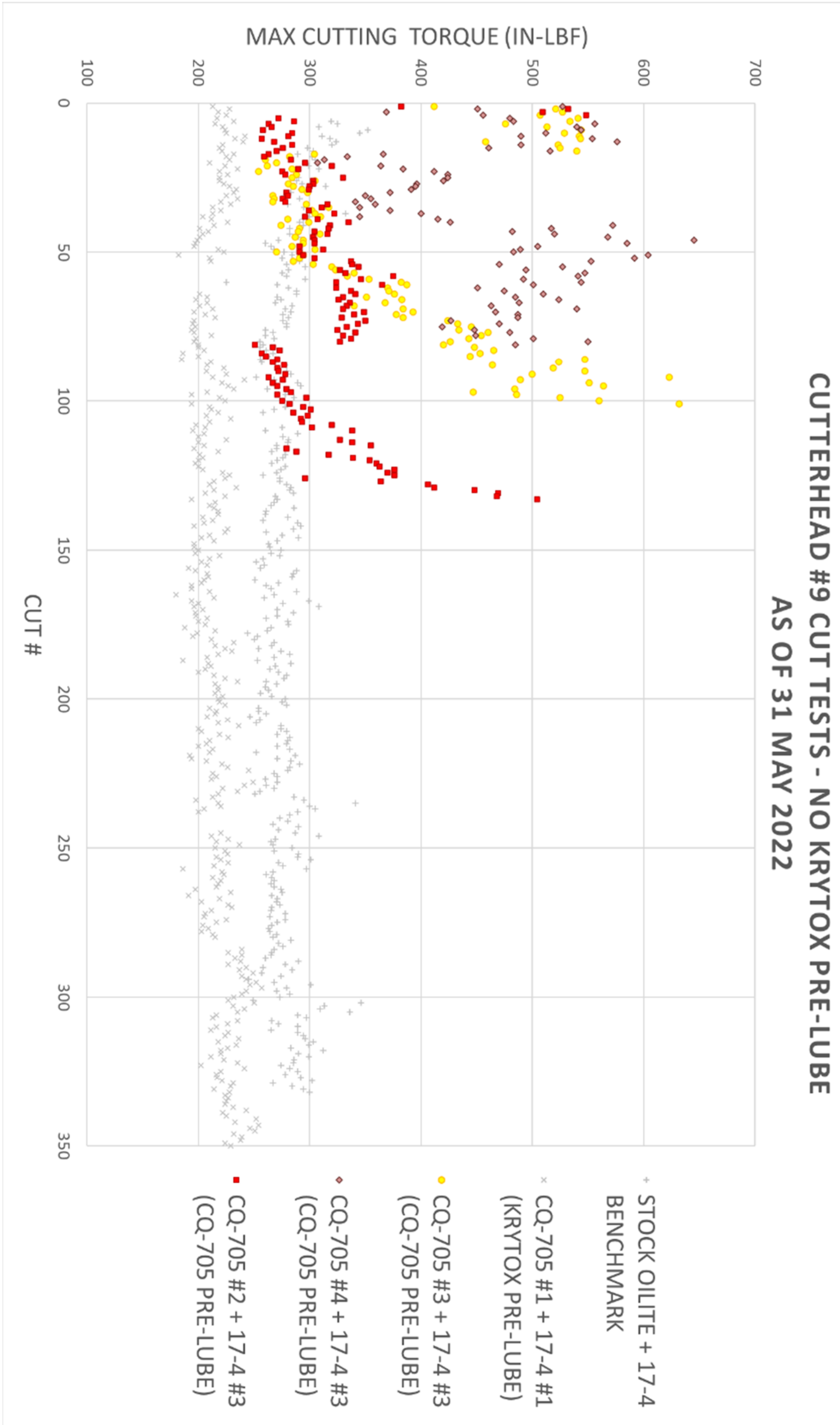

Figure A-2. TEF Cutterhead No-Krytox Tests

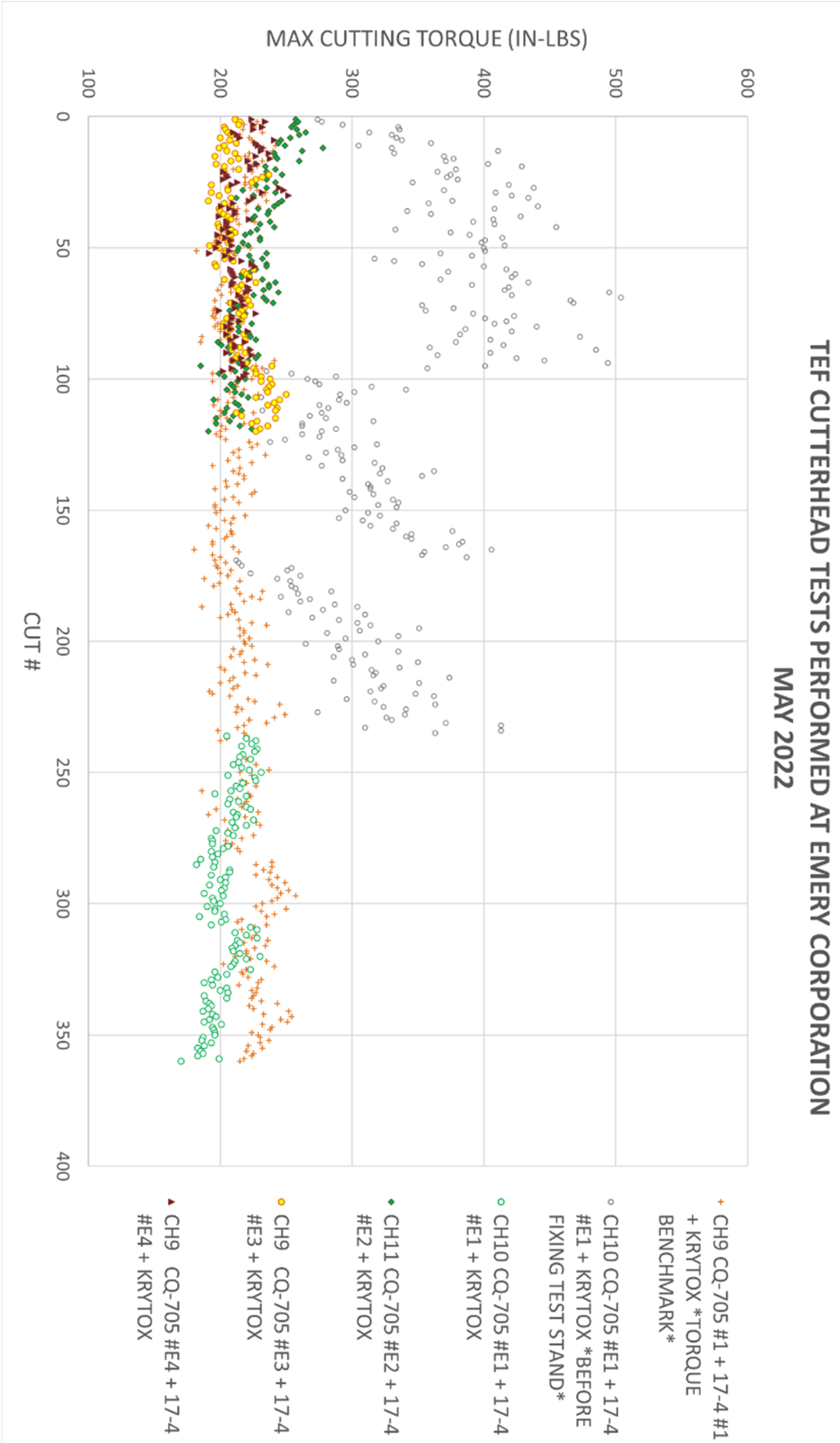

Figure A-3. Cutterhead Tests Performed at Toner Machining Technologies

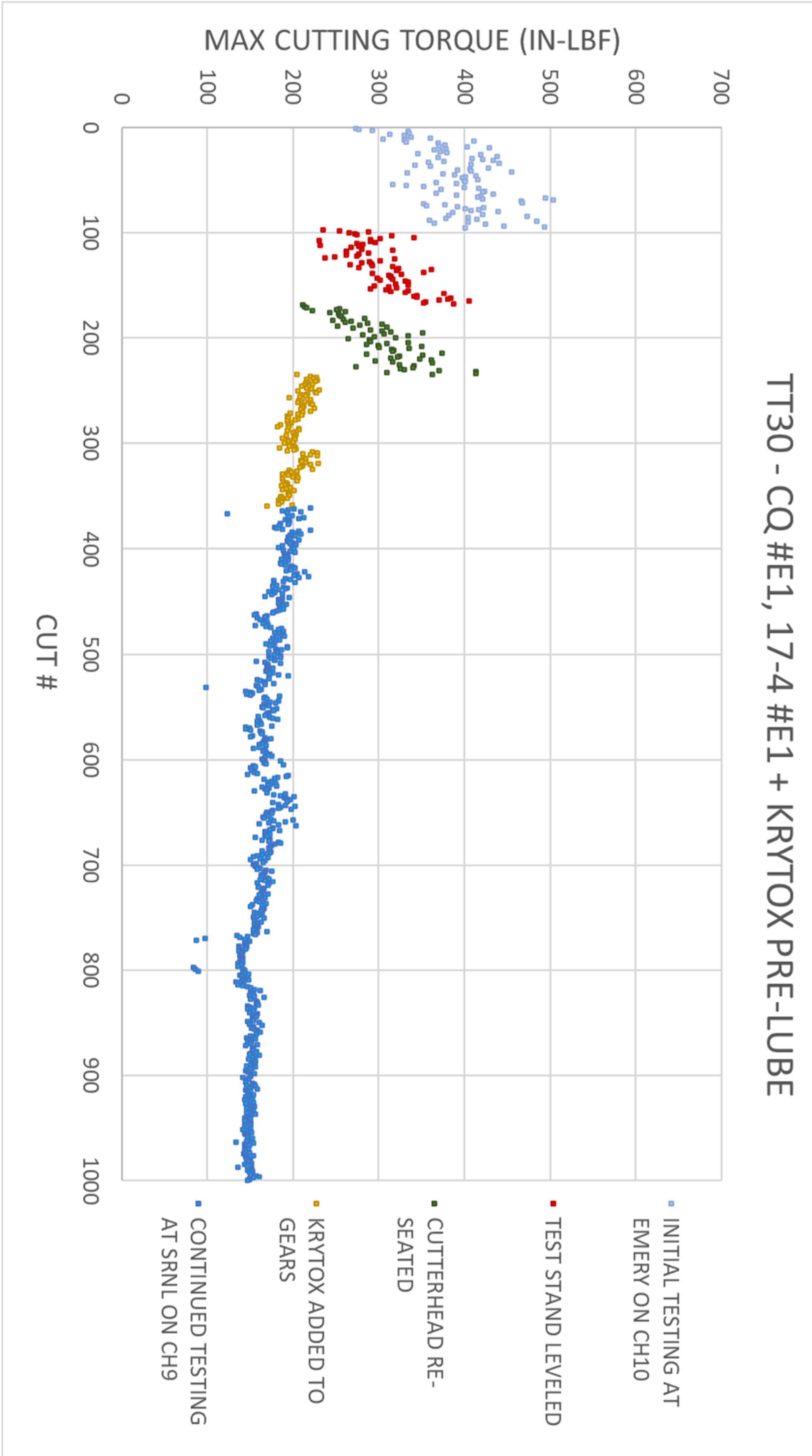

Figure A-4. Thread Test 30-One Thousand Cycles Test

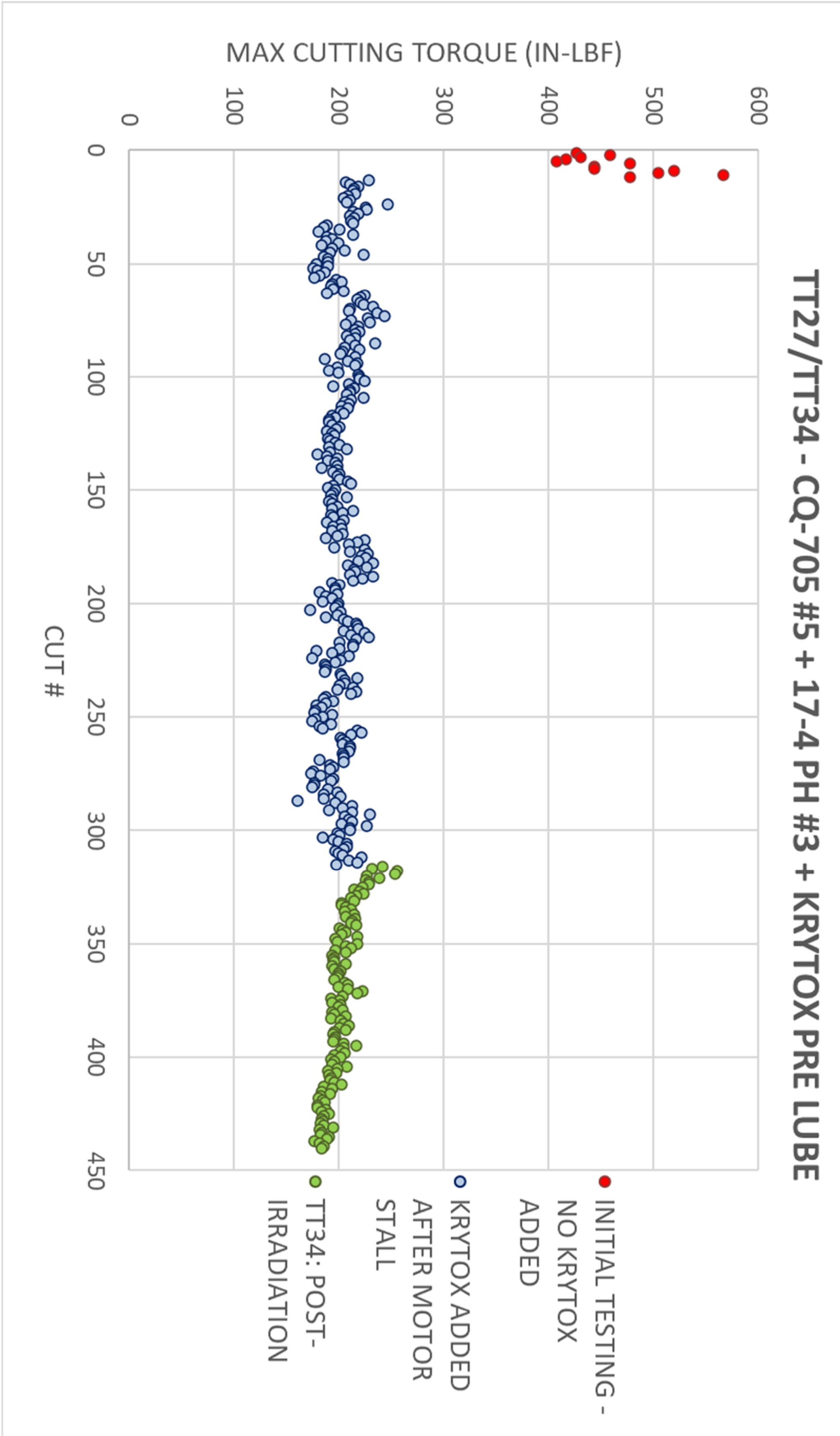

Figure A-5. Thread Tests 27 and 34—Before and After Irradiation