Contract No:

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy (DOE) Office of Environmental Management (EM).

SR19036 – TRP Cutter Head Improvement

Facility Need

The current Target Rod Preparation (TRP) Cutter Head suffers from overheating problems during TPBAR breaching operations. The overheating leads to work stoppage due to the periodic need to allow the TRP Cutter Head motor to cool. This work stoppage and allowance for cooldown of the motor leads to a very inefficient TPBAR breaching process. Due to the increased need for Tritium gas, the system must be improved to increase the efficiency of the TPBAR breaching process.

Potential Benefits

☑ Cost Reduction	☐ Defect Reduction	☑ Error Reduction	☐ Mission Diversification
☐ Mission Viability	☑ Obsolescence Solution	☑ Process Optimization	☐ Safety

Project Summary

The project would include the following major steps:

- Determine likely causes of overheating of the TRP cutter head motor.
- Identify and research methods for cooling currently installed motor.
- Identify and research alternate motors for TRP cutter head.
- Procure a new motor for testing.
- Perform TPBAR breaching mockup testing with new motor.
- Write report on results and recommendations on potential path forward.

SR19036

Status

Started: Beginning FY19, Completed: TBD

Technology Readiness Level

Start of FY19:	4
End-of-FY19 Forecast:	6
End-of-FY19 Actual:	6

Financial

FY19 Project Cost:	$77,000
Cumulative Total Project Cost:	$77,000
FY19 Authorized Amount:	$77,000

Credits

Principal Investigators:	William Housley Joshua Slice Andrew McNight Nicole Drey Alan Busby
Facility Engineering Co-Lead:	Michael Harber Brian Black Gary Aaronson

Milestones/Findings/Accomplishments

Project Milestone	Expected End	Actual End
Research and Identify Alternate Motor(s) for the TRP Cutter	3/28/19	4/1/19
Procure New Motor for Testing	8/19/19	8/26/19
Perform TPBAR Breaching Mockup Testing with New Motor	9/10/19	9/20/19
Submit Year-End Report/Project Summary	9/18/19	9/27/19

Research and Identify Alternate Motor(s) for the TRP Cutter

The TRP Cutter System was originally designed and fabricated with an Empire Magnetics Radiation Hardened stepper motor and Gemini GT-6 controller. The motor was specified by the Original Equipment Manufacturer (OEM) to adequately handle the high percentage duty cycle associated with breaching a TPBAR. However, during production-level TPBAR breaching operations the motor suffered from overheating issues, the cause of which is purely speculative. Regardless of the cause, it was determined that a replacement motor could potentially solve the overheating problem in a cost-effective manner.

Criteria were established in order to select a motor that would be a best-fit for the TRP cutter system. It was determined that a motor capable of mating directly to the TRP module mechanical and electrical systems was very desirable in that making changes to the TRP systems and/or TRP hot cell would not be cost effective. A radiation hardened motor would be required due to the proximity of the motor to the high radiation field produced by a full basket of TPBARs. It was also determined that the replacement motor should be of the "stepper" type in order to provide very precise positioning data to the controller during the breaching process. Most importantly, the replacement motor would be able to adequately handle the high percentage duty cycle required by the TRP cutter module without overheating. These were the driving criteria for selection of the prospective replacement motor.

Many stepper motor manufacturers were researched and contacted; however, most motor manufacturers do not fabricate radiation hardened motors. In nearly all cases, the motors that were radiation hardened did not easily integrate with the GT-6 controllers and mechanical systems of the TRP cutter module.

Additional analysis of methods by which the motor could be cooled, or duty cycled reduced, were analyzed. This was due to the limited pool of prospective motors that would readily mate to the electrical and mechanical systems of the TRP cutter.

A convective cooling module that contained a small fan to provide forced convection over the surface of the motor was analyzed. This method would have required additional electrical power to be run into the cell, which would have been quite costly. Battery powered fans were also analyzed, but this would require frequent changeout of the battery and would generate mixed hazardous waste. In addition, no radiation hardened fans were available; as such, the lifespan of a non-rad hardened electrically powered fan would be rather short due to the radiation field in the TRP cell during operation.

A dual motor concept was also considered. One motor would run the TRP cutter head until it began to overheat. The electrical power to the first motor would be switched to the second motor and the mechanical connection between the motor output shaft and TRP cutter head input shaft would be changed as well. How this process would be executed was not explored as the dual motor system would not physically fit due to the volume in which the TRP motor currently sits. These two concepts were not chosen due to the aforementioned challenges and time constraints.

It was determined that a larger motor with a different gear ratio would be purchased from Empire Magnetics. This motor would readily mate with the TRP cutter head electronic and mechanical connections. The current motor responsible for driving the TRP cutter system is an Empire Magnetics Radiation Hardened U33 Stepper motor of frame size 34 with a 40:1 gearbox. This means the motor must turn 40 times in order to obtain one output rotation. The motor that was chosen as a replacement was an Empire Magnetics Radiation Hardened Stepper motor of frame size 42 with a 22:1 gearbox. The gear ratio and amount of current drawn to produce torque equivalent to the smaller motor would reduce the overall heat produced by the motor, leading to a longer duty cycle.

Procure New Motor for Testing

The motor selected for testing was a standard motor manufactured by Empire Magnetics; however, these motors are not "off-the-shelf" in the sense that there is a stockpile. The motors are custom built when they are ordered. The motor was ordered on May 13th, 2019 with a 14-week lead time. An expedited fabrication and delivery were requested of the vendor but could not be fulfilled. The motor arrived on site on August 26th and was received by R&DE on August 28th.

Perform Benchmark TPBAR Breaching Mockup Testing with U33 Stepper Motor

The TRP cutter test stand was acquired from the Tritium Extraction Facility (TEF) to provide the necessary equipment to accurately perform mock-up testing. The test stand was relocated to the mechanical lab located in building 723-A. Tritium personnel provided guidance and applicable procedures to set up and operate the TRP test stand. Pictures of the test stand are shown in Figures 1 and 2.

Figure 1. TRP Test Stand

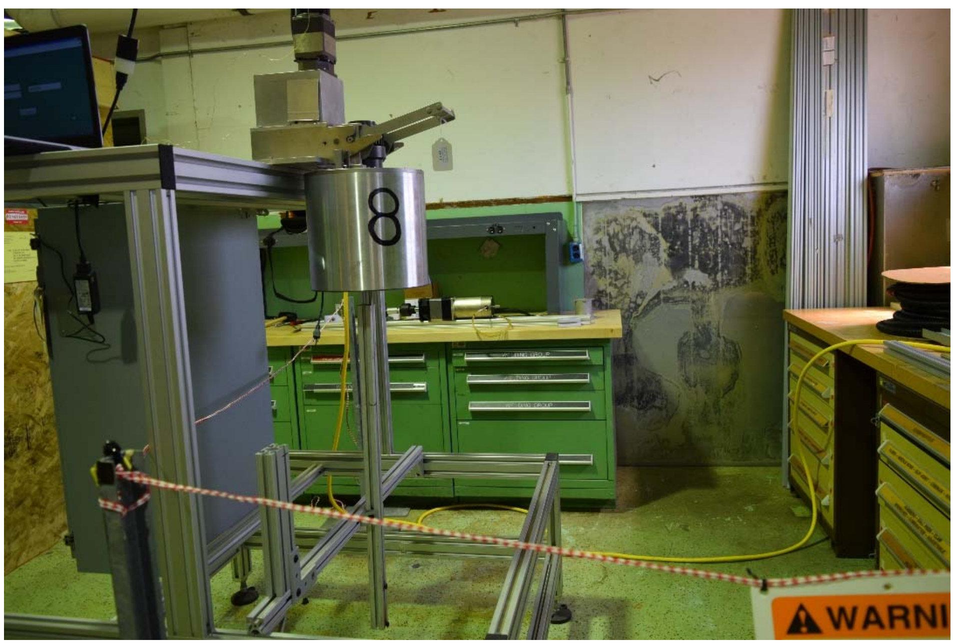

Figure 2. TRP Test Stand

Prior to testing the new motor, an initial set of benchmarking tests were conducted to determine the uptime of the U33 Stepper motor currently installed on the test stand. These benchmarking tests consisted of three over-heat cycles. Each over-heat cycle involved running the motor until the four calibrated thermocouples attached to the external surface of the motor read mean temperatures in excess of 100ºC. The layout of the thermocouples can be seen in Figure 3.

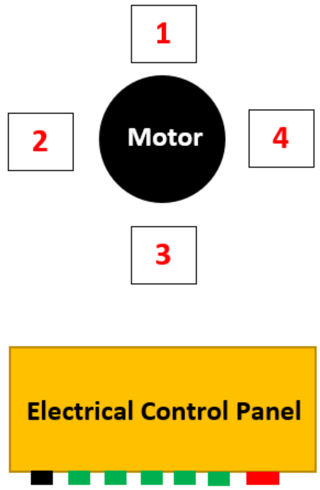

Figure 3. Thermocouple Layout

The data collected by the thermocouples indicates that the motor currently installed on the test stand can cut approximately 7 rods before reaching 100 ºC. The results of these tests suggested that the motor installed on the test stand can run a similar number of cycles as the radiation hardened motor installed in the TEF; based on information provided by TEF personnel. Graphs showing the temperature data are shown below in Figures 4-6. Red circles indicate the end of each cutting cycle after the cutter head is reset to the "Insert/Seek Rod" step in the procedure.

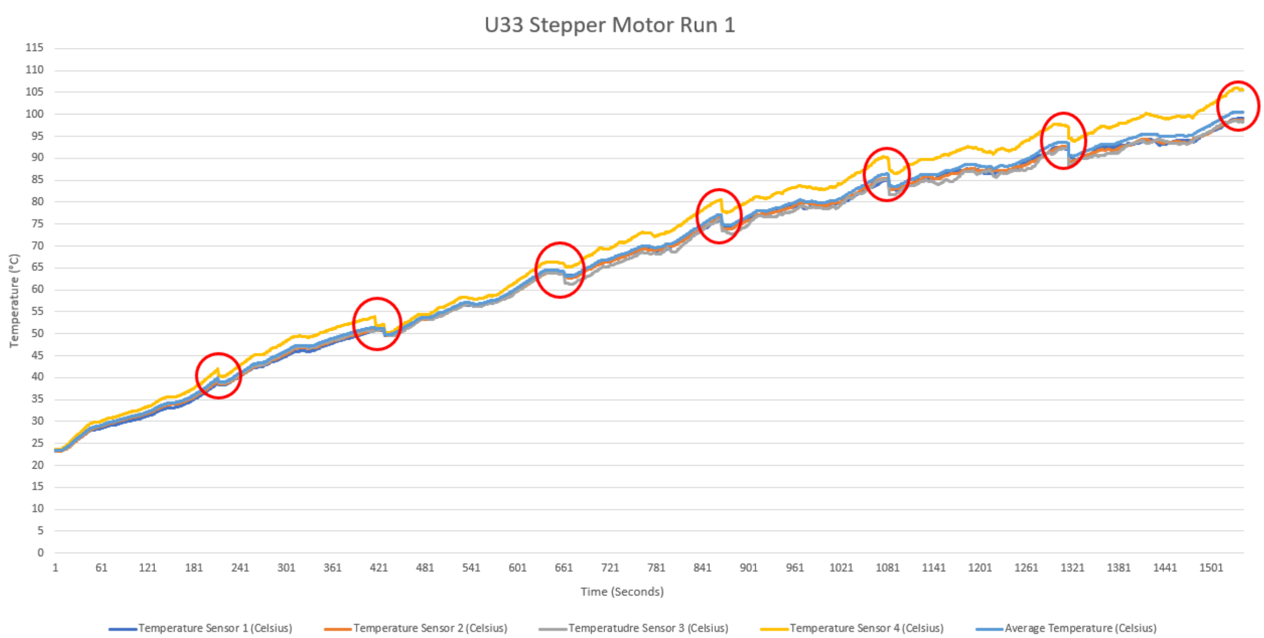

Figure 4. U33 Stepper Motor Run 1

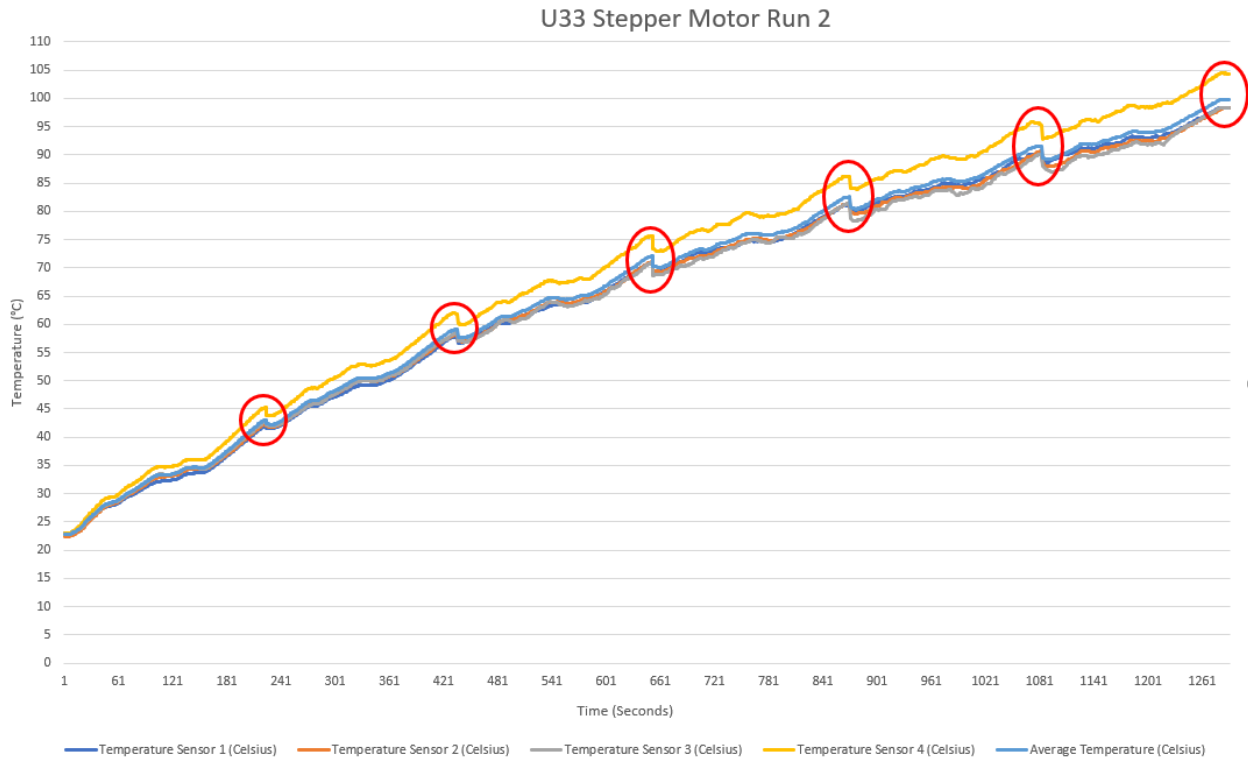

Figure 5. U33 Stepper Motor Run 2

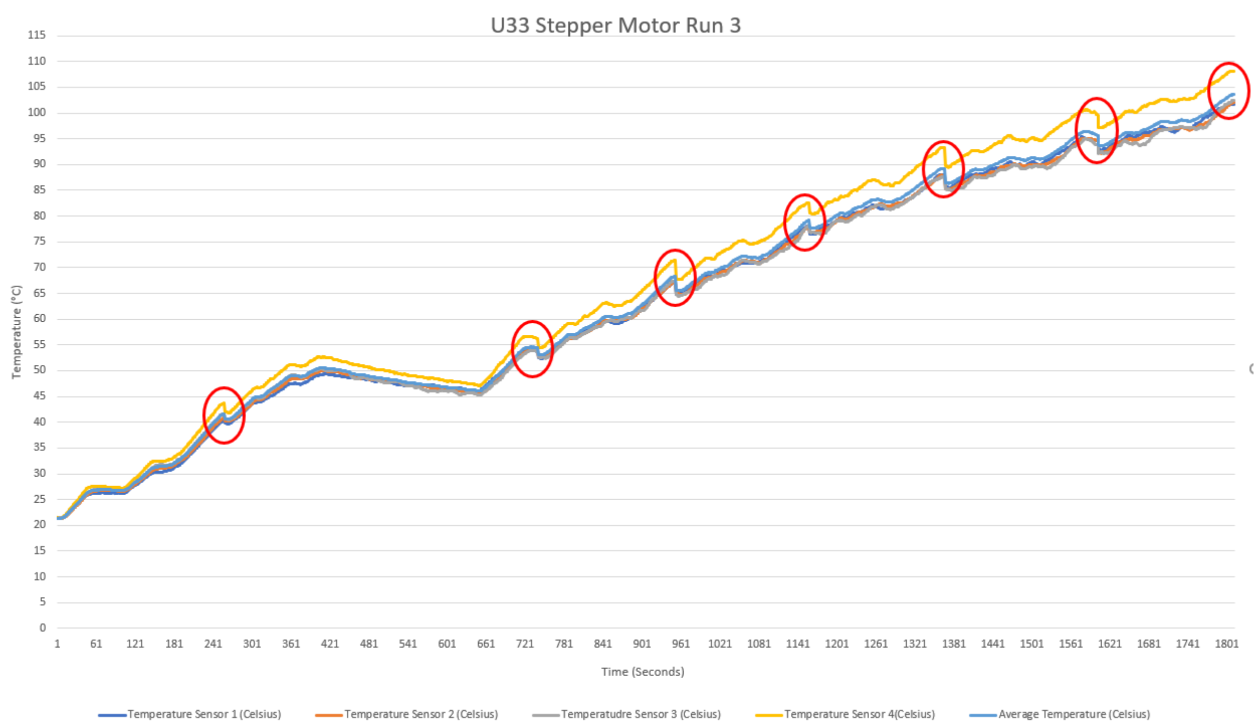

Figure 6. U33 Stepper Motor Run 3

Each graph displays similar trends regarding temperature increase. Run 3 shows a long decline in temperature between 400 and 660 seconds. This decrease was due to the failure of a heel to fully exit the cutter head. The emergency stop button was pressed and the situation was analyzed. The heel was visibly stuck and could be easily removed but operations had to be stopped in order to do so. The heel was safely removed, and the cutter head was allowed to finish the current run. The pause in operations to address the trapped heel led to the decrease in temperature, as the motor was not running during this time.

Runs 1 and 3 successfully reached 7 cutting cycles, while Run 2 only completed 6 before reaching the 100 °C temperature limit. It is believed that the lower number of cutting cycles was a result of starting Run 2 with an initial motor temperature higher than Runs 1 and 3. Since 2 out of 3 runs went through 7 cutting cycles it is safe to assume that the test set-up accurately mimicked the overheat cycles that are experience at TEF.

Perform Torque Testing on New Motor

Concerns were expressed about the torque output of a larger motor and the possibility of damaging the internals of the TRP cutter; therefore, a small test module was constructed to quantify the torque outputs of the new larger motor. The larger motor could be outfitted with electrical and/or mechanical interlocks that would prevent the output shaft of the larger motor from reaching a torque value higher than the currently installed motor. The electrical controls would be implemented in the programming that controls the motor. Further research is required to determine exactly how to achieve this form of limitation. A mechanical torque limiter was purchased and installed downstream from the motor's output shaft during testing. This mechanical torque limiter was set such that the torque being applied to the TRP cutter would not exceed the torque value produced by the currently installed motor. The inner workings of the torque limiter are shown in Figure 7.

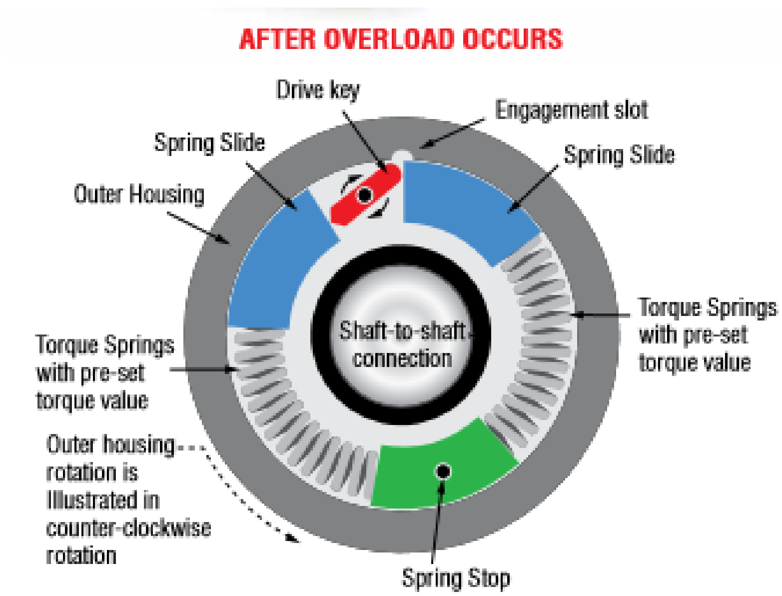

Figure 7. Mechanical Torque Limiter

Using the test module set up shown below in Figure 8, data was collected using a Futek shaft-to-shaft rotary torque sensor. The collected data is shown in Figures 9-11. Each test lasted for approximately 2 minutes with the data acquisition unit sampling at a rate of 4.5 Hz. A total of 3 tests were conducted to capture any trends produced by the torque limiter.

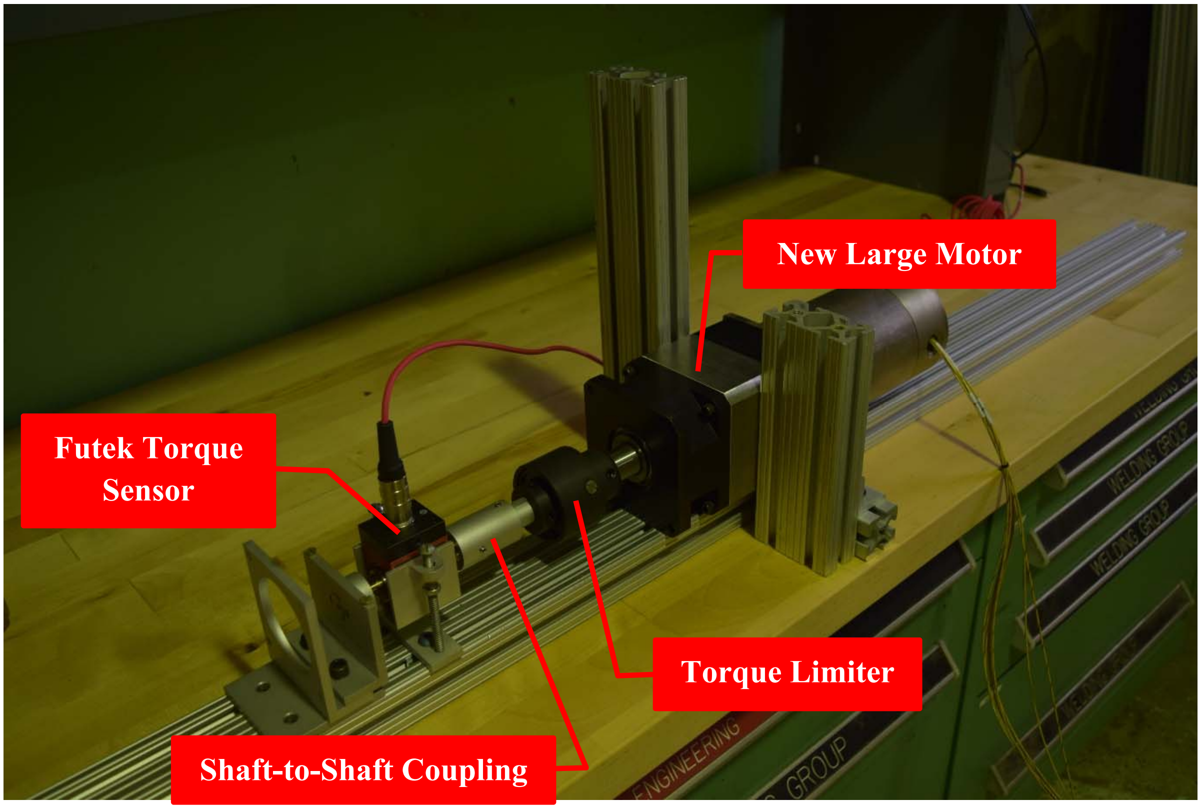

Figure 8. Torque Test Set-Up

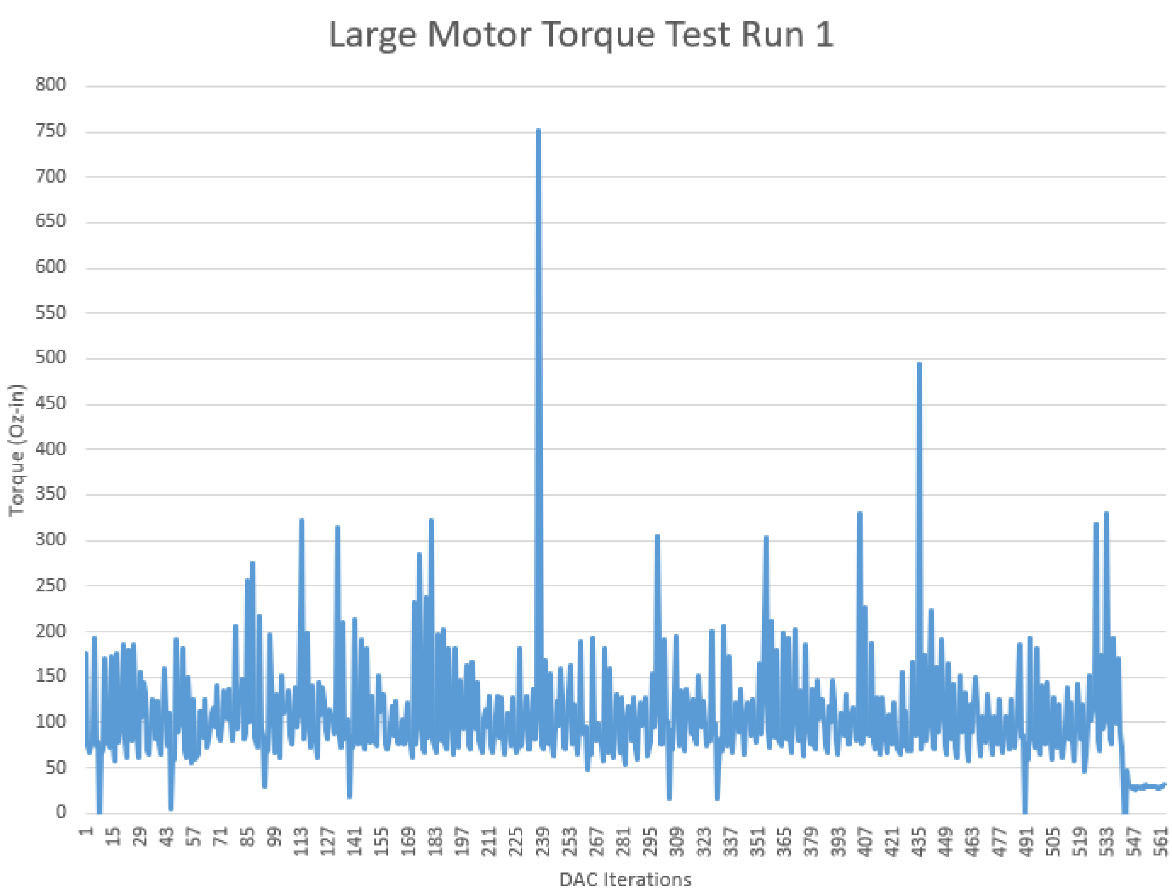

Figure 9. Torque Test Run 1

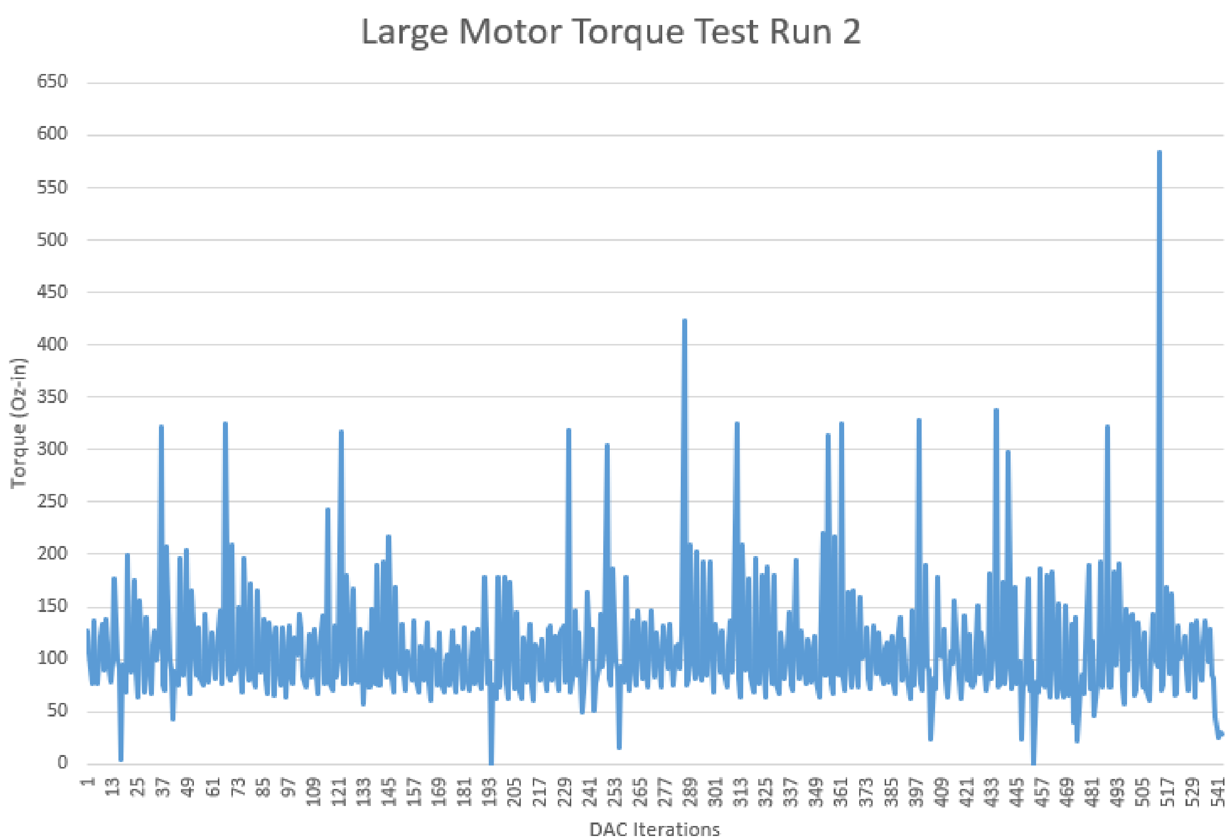

Figure 10. Torque Test Run 2

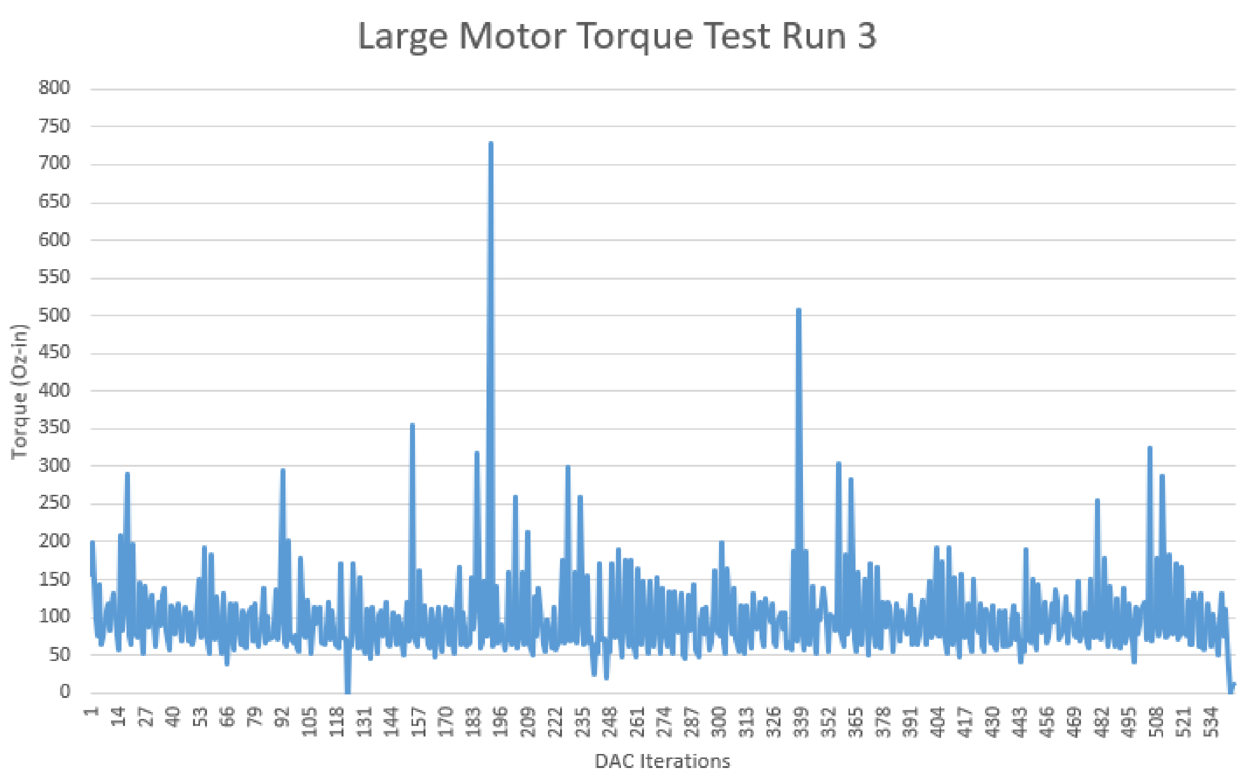

Figure 11. Torque Test Run 3

All three runs provided trends that were expected due to the design of the torque limiter. There were peaks in the torque value as the internal springs were compressed, followed by a resolution period for the springs to decompress. Based on the Empire Magnetics torque curves for the U33 stepper motor currently installed in TEF, the maximum torque value that was assumed to be acceptable was 350 oz-in. Most of the peak cycles captured by the torque sensor contained values that were at or less than 350 oz-in. This was the desired result as to replicate the performance of the motor currently installed in the field. However, each run experienced 2-3 peaks where the torque value exceeded 350 oz-in. This raised concern about potential damage being done to the cutter head due to over-torqueing of the system. Because of this, the larger motor was not installed on the TRP test stand to perform cuts. More torque senor testing will be performed utilizing both the mechanical torque limiter and electrical parameter adjustments to achieve the desired confidence in the large motor system before installing it on the test stand.

Future Work

- Perform successful cut of TPBAR using larger motor
- Analyze various heat loads within TRP cell and study impacts on motor operation
- Research and develop alternative methods for breaching TPBARs