NUCLEAR THERMAL ROCKET ELEMENT ENVIRONMENTAL SIMULATOR (NTREES) UPGRADE ACTIVITIES. William J Emrich, Jr., NASA Marshall Space Flight Center, Huntsville, AL, 35812, bill.emrich@nasa.gov

Over the past year the Nuclear Thermal Rocket Element Environmental Simulator (NTREES) has been undergoing a significant upgrade beyond its initial configuration[1]. The NTREES facility is designed to perform realistic non-nuclear testing of nuclear thermal rocket (NTR) fuel elements and fuel materials. Although the NTREES facility cannot mimic the neutron and gamma environment of an operating NTR, it can simulate the thermal hydraulic environment within an NTR fuel element to provide critical information on material performance and compatibility.

The first phase of the upgrade activities which was completed in 2012 in part consisted of an extensive modification to the hydrogen system to permit computer controlled operations outside the building through the use of pneumatically operated variable position valves. This setup also allows the hydrogen flow rate to be increased to over 200 g/sec and reduced the operation complexity of the system.

The second stage of modifications to NTREES which has just been completed expands the capabilities of the facility significantly. In particular, the previous 50 kW induction power supply has been replaced with a 1.2 MW unit which should allow more prototypical fuel element temperatures to be reached. The water cooling system was also upgraded to so as to be capable of removing 100% of the heat generated during. This new setup required that the NTREES vessel be raised onto a platform along with most of its associated gas and vent lines. In this arrangement, the induction heater and water systems are now located underneath the platform. In this new configuration, the 1.2 MW NTREES induction heater will be capable of testing fuel elements and fuel materials in flowing hydrogen at pressures up to 1000 psi at temperatures up to and beyond 3000 K and at near-prototypic reactor channel power densities. NTREES is also capable of testing potential fuel elements with a variety of propellants, including hydrogen with additives to inhibit corrosion of certain potential NTR fuel forms. Additional diagnostic upgrades included in the present NTREES set up include the addition of a gamma ray spectrometer located near the vent filter to detect uranium fuel particles exiting the fuel element in the propellant exhaust stream to provide additional information any material loss occurring during testing. Figure 1 shows a picture of the new NTREES configuration.

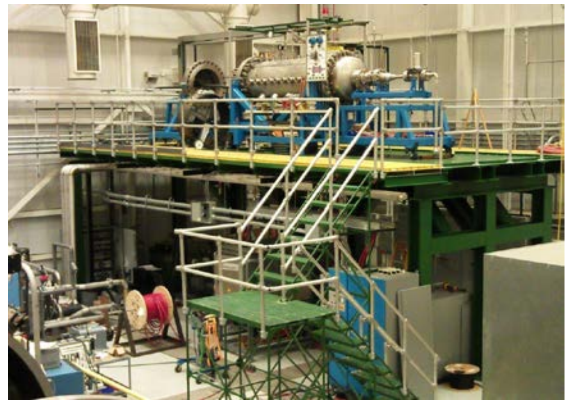

Figure 1. Current NTREES Configuration

Other aspects of the upgrade included reworking NTREES to reduce the operational complexity of the system despite the increased complexity of the induction heating system. To this end, many of the controls were consolidated on fewer panels. As part of this upgrade activity, the Safety Assessment (SA) and the Standard Operating Procedures (SOPs) for NTREES were extensively rewritten. The new 1.2 MW induction heater consists of three physical units consisting of a transformer, rectifier, and inverter. This multiunit arrangement facilitated increasing the flexibility of the induction heater by more easily allowing variable frequency operation. Frequency ranges between 20 and 60 kHz can be accommodated in the new induction heater allowing more representative power distributions to be generated within the test elements. Figure 2 illustrates the current layout of NTREES.

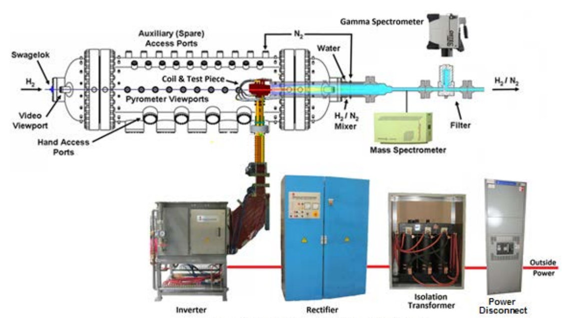

Figure 2. NTREES Power and Flow Arrangement

The NTREES facility is also now equipped with some additional hardware for instrumentation, control, and data acquisition. The hardware is distributed around the test chamber and support equipment, but integrated and controlled from one piece of software running on one computer located in the control room. This new suite of sensors includes:

- Pressure sensors for GH_2 and GN_2
- Temperature sensors for GH_2 and GN_2
- Flow sensors for GH_2 and GN_2
- Thermocouples for general temperature measurements
- Hydrogen detection for the test chamber and room 101
- Pyrometers for temperature measurement of test pieces
- Mass spectrometer to measure gas composition
- Gamma ray spectrometer to detect uranium loss
- Motion detector to sense possible fuel failure

The NTREES mixer assembly was completely rebuilt for the present setup. Super alloys were used in the fabrication of the mixer along with modifications to the internal coolant flow paths to support higher exhaust temperatures. The mixer assembly is used to support the test articles during testing while they are being heated and exposed to flowing hydrogen. In addition to supporting the test pieces, the mixer assembly dilutes and cools the hot hydrogen as it leaves the NTREES by using large quantities of high pressure, room temperature nitrogen. The nitrogen is injected into the mixer assembly through taps on the outside of the chamber and is distributed within the mixer such that the hot hydrogen is prevented from touching the sides of the mixer until it has been well diluted and cooled by the nitrogen. To provide additional temperature margins, the entire mixer assembly is internally cooled with water.

The mixer assembly is designed to eliminate the need for a high temperature seal at the test article / mixer assembly interface. This is accomplished by keeping the chamber nitrogen pressure slightly above the hydrogen pressure in the test piece. In-leakage of nitrogen through a small gap in the test article support cap mounted on the mixer cools the interface where the cap supports the test piece and prevents significant quantities of hydrogen from escaping into the chamber.

Once the hydrogen/nitrogen effluent leaves the mixer assembly, it is directed into a new high temperature/high flow filter prior to entering the vent piping to prevent any particles which may have eroded off the test article from being discharged to the environment.

Later this spring, it is expected that fuel elements will be available which will more closely resemble, both in material composition and geometry, those which will be used in actual nuclear thermal rockets. NTREES will provide a means to realistically test these fuel elements, even to the point of failure for extremely little cost. Such testing will allow the best fuel designs to quickly move forward to more highly realistic testing in nuclear test facilities with high confidence in their ultimate performance capabilities.

The NTREES facility upgrade and test activities are funded through Science & Technology Office at the Marshall Space Flight Center under the Nuclear Cryogenic Propulsion Stage program. The author greatly appreciates the support, both technical and financial, given by that office.

[1]Emrich, W. J., “Nuclear Thermal Rocket Element Environmental Simulator (NTREES),” *Space Technology and Applications International Forum: 25th Symposium on Space Nuclear Power and Propulsion,* Albuquerque, NM, Ed. Mohamed S. El-Genk, 2008, pp. 541-548.