DESIGN OF A URANIUM-DIOXIDE PLASMA SPHEROIDIZATION SYSTEM. D. P. Cavender[1], O. R. Mireles, and J. W. Broadway[2], [1]University of Alabama-Huntsville (301 Sparkman Dr. Huntsville AL 35899), [2]NASA Marshall Space Flight Center (ER24 MSFC AL 35812).

Introduction: NASA is adapting modern commercial manufacturing processes for the development of Nuclear Thermal Rocket (NTR) engine technology. UO2 Plasma Spheroidization System (PSS) is the first major process in the development of the solid core in a NTR engine. Processed powders show significant improvement in mechanical properties such as crack and void elimination, packing density, and preferred surface morphology for eventual CVD coating. Consolidation of the UO2 particles in to spheroids improves the overall mechanical integrity of the W-UO2 fuel cermet system. UO2 fuel loss during prototypic environmental testing occurs in part to mechanical failure of the cladding caused by formation of UH3 at high temperatures resulting in large volumetric expansion [2,5]. Surface modification and powder purification will improve fuel retention [2,5].

Problem Statement and Objective: Unprocessed "raw" UO2 particles have poor surface morphology that requires improvement before cladding by chemical vapor deposition (CVD). Additionally, the UO2 compound has a melting temperature above the expected operating temperature of a NTR engine (approximately 3000°C) [5]. Thermal plasma processing is the most economic method for improving the powders [1]. However, the handling of UO2 requires special procedures, controls, and licenses that drive costs to an estimated $80,000/kg. Purchasing commercially spheroidized UO2 powder is beyond the budget allowance for the project. Additionally, NTR development does not require large quantities of spheroidized UO2. Therefore, a PSS is being developed at MSFC to produce lab-scale quantities.

Apparatus and Procedure: NASA MSFC has a developmental history in Vacuum Plasma Spray (VPS) systems. PSS and VPS systems have a similar technology base. As a result, PSS development costs have been kept low. Power supplies, powder feeders, vacuum pumps, water chillers, and control consoles were repurposed or shared. Much of the material needed to fabricate the system was available for the project. The chamber and platform were manufactured at MSFC.

PSS Developmental Approach. The PSS design team reviewed plasma spherodization publications and consulted with subject matter experts to understand the physical requirements and theoretical operation of PSS. Additionally, the PSS design team worked closely with other NTR development teams to capture product and process requirements. The PSS design team considered features and scenarios for system safety, operation, maintenance, and evolution.

PAS System Design. The free standing unit has a planform of 0.6m squared and a height of 5m. The 0.3m ID double-walled, water cooled, stainless steel chamber (Figure 1) is supported inside of a rigid frame (Figure 2). The chamber is segmented for maintenance and cleaning. The plasma torch can mount internally or externally on the top plate (Figure 4). UO2 transfer canisters attach at the bottom of the chamber. Chilled water is pumped into the chamber walls, top plate, and plasma torch. Auxiliary cooling hookups exist for system growth. A vacuum pump pulls gas and aerosolized UO2 particles through an assembly of parallel 0.5 μm filters.

Figure 1: PSS Segments

Figure 2: PSS Frame

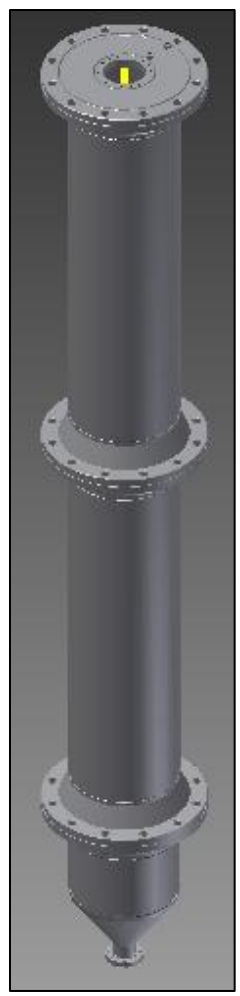

Figure 3: PSS Chamber CAD Model

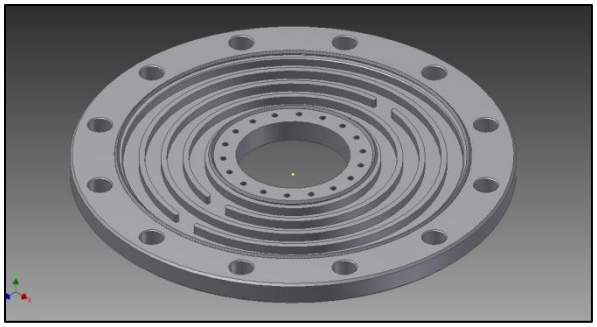

Figure 4: PSS Top Plate with cooling channels (cover plate removed) and 6”CF for plasma torch mounting plate

PAS Process. Powders are first classified by size. Plasma temperature (on the order of 10,000°C to 20,000°C) varies proportionally with the power input to the torch. The power level must be matched for the target particle size to maximize the percent yield of spheroidized powder. Particles above the target size may not fully spheroidize. Particles below the target size may be fully vaporized or form even smaller particles [1,3,4]. Gas flow rate and chamber vacuum pressure effect the residence time of the particles in the plasma [1,3,4]. Classified particles are passed through the plasma flame and melt. The molten particles spheroidize due to surface tension effect. A large thermal gradient exists between the plasma and the chilled chamber walls. After falling through the flame, the molten spherical particles are essentially quenched and solidify [1]. The particles settle at the bottom of a conical reducer where they flow into a removable transfer canister. Once the powder batch is processed, the transfer canister is disconnected from the PSS system, and transported to an inert glove box. The powders are further classified by size before CVD processing.

Results: Expected results include a target particle size distribution (-100 μm course and medium grains with +5 μm fines) to maximize bulk packing density, corresponding power, gas flow rates, and feed stock rates, and percent yield of spheroidized UO2.

Conclusions: Optimization of DC power, plasma gas flow rates, and chamber vacuum pressure parameters is necessary for a variety of target spherical UO2 particle sizes.

Recommendations: Determining target particles sizes and calculating the theoretical input parameters of the PSS are the focus of the near future work. The chamber design is universal allowing for evolution of the system. Experimental results and conclusions will drive refinement of the PSS. Surrogate powder will be used during the iterative phase of process parameter refinement. Processed powders will be analyzed to determine percent yield of spheroidized powder, density, phase composition, and purity [3].

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