The Manufacture of W-UO_2 Fuel Elements for Nuclear Thermal Propulsion Using the Hot Isostatic Pressing Consolidation Process. J. W. Broadway, R. R. Hickman and O. R. Mireles, NASA Marshall Space Flight Center, email:jeramie.w.broadway@nasa.gov.

Introduction: On the critical path to developing a nuclear thermal rocket (NTR), is the design, development, testing and qualification of a reactor fuel material. Under the Advanced In-space Propulsion (AISP) project Marshall Space Flight Center (MSFC) focused on the development of the Hot Isostatic Press (HIP) manufacturing process to fabricate CERMET fuel materials. Currently, Marshall Space Flight Center (MSFC) along with the Department of Energy is working to develop NTP fuel forms for the Nuclear Cryogenic Propulsion Stage (NCPS) Project. MSFC's focus of the NCPS project is to develop an optimized tungsten uranium dioxide, W-UO_2, CERMET fuel element using the HIP process.

Hot Isostatic Press: The use of refractory metals in CERMET fuels is advantageous due to their high melting temperatures and hydrogen compatibility. However, the hardness and brittle nature of these materials make traditional machining processes difficult. HIP is a powder metallurgy manufacturing process that provides numerous advantages for producing CERMET fuel materials. The HIP process produces net shape or near-net shape components, meaning there is little post processing required once a part is HIPed. HIPing provides the ability to produce internal geometries with the use of mandrels. The only post HIP processing required for CERMET fuels fabrication is HIP can removal and etching of the internal mandrels. The HIP process also produces high density parts, greater than 99% theoretical density. High density integral claddings are also possible with the HIP process. The ability to produce uniform thickness, integral claddings on the external surfaces of a fuel element eliminates the need for additional post HIP processing, which can be difficult.

CERMET Material Development: MSFC's focus under the AISP project was to demonstrate the ability to fabricate CERMET materials using the HIP process. MSFC successfully fabricated a six inch long tungsten hafnium nitride, W-HfN, CERMET replicating the 19 channel configuration of the Rover/NERVA element design. MSFC was also able to fabricate a 12 inch long sample of the same configuration demonstrating the HIP process is scalable.

To demonstrate the ability to HIP a more complex geometry, MSFC demonstrated a 331 channel hexagonal shaped element configuration replicating the Argonne National Laboratory (ANL) fuel element design. The six inch element replicated the 0.067" diameter cooling channels and 0.102" pitch from the ANL design.

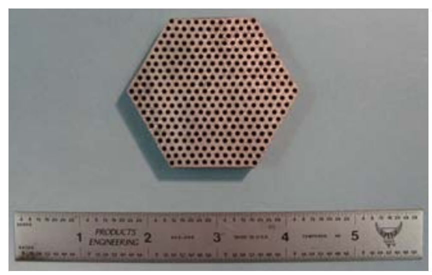

Figure 2. 331 channel hexagonal demonstration fabricated by MSFC using the HIP process.

Under the NCPS project, MSFC will continue the development of W-UO_2 CERMET fuel materials using HIP. The development approach is to optimize the HIP process first using a surrogate material in place of the UO_2. A packing density study will be conducted using a blend of tungsten cerium dioxide, CeO_2, powders. The study will include using fine, medium and coarse powder particle sizes to achieve an optimum packing density, greater than 60 volume percent. The particle sizes being investigated range from 10 to 100 microns. Once an optimized particle size blend is achieved, a HIP processing study will take place to optimize the HIP cycle time and temperature variables. This study will evaluate the HIP processing effects on pre versus post particle geometry as well as the impacts of particle size and HIP processing on mechanical properties.

Once the HIP process is characterized and understood for W-CeO_2, the development of the W-UO_2

CERMET material will begin. A more detailed understanding of the processing effects on grain size and structure will be conducted. Material testing will be done to determine mechanical and thermal properties of the fuel material. Hot hydrogen testing will be performed to understand material compatibility and fission product retention capability in prototypic conditions.