U-7MO QUALIFICATION AT

BWX TECHNOLOGIES INCORPORATED

Research/Test Reactors and Targets, RTRT

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ABSTRACT

BWX Technologies Incorporated (BWXT) is in the process of qualifying the alloy U-7Mo using low enriched uranium for use in low to high flux research reactors. This is a cooperative effort with the Reduced Enrichment for Research and Test Reactors (RERTR) program and includes Argonne National Laboratory (ANL), The Petten HFR Reactor, the Korean Atomic Energy Research Institute (KAERI), and BWXT. BWXT is responsible for the fabrication of two Petten fuel elements containing LEU U-7Mo with a loading of 6 gU/cc. To date, BWXT has successfully fabricated 6 gU/cc fuel plates using depleted uranium supplied by KAERI. The use of existing equipment and methods worked well for the processing of new atomized U-7Mo fuel. In addition, the processing of atomized fuel appears to be beneficial to production efficiency. This paper will evaluate the successes and challenges encountered and expected during the on-going qualification effort.

INTRODUCTION

In January 2000, BWXT began developing and qualifying fabrication processes for the use of U-7Mo fuel in research & test reactors. Phase One of the qualification included using atomized, depleted fuel provided by KAERI to develop the processing parameters to be used in the LEU fuel plates to be fabricated under Phase Two. The first phase is 90% complete and the results are showing that the fuel responds favorably under standard processing conditions. Phase Two will be the actual fabrication of LEU U-7Mo fuel plates and elements.

Considerable efforts are being expended to provide the necessary Quality Assurance for the U-7Mo fuel plate product. During Phase One, the depleted fuel plates are being tested under varying conditions for homogeneity and bond. Homogeneity quality inspections of the fuel plates are complete and the ultrasonic testing for the fuel core to clad bond is underway. Observation of this process shows that the end core region requires different processing parameters and transducers. Standards are being fabricated to provide satisfactory inspection criteria for the LEU plates. Bonding between the clad and the main fuel section has been verified through standard Ultrasonic Inspection (UT).

U-7Mo FUEL POWDER

The depleted U-7Mo fuel powder is being provided by KAERI. The fuel powder is ANL U-metal atomized by KAERI using a proprietary process. Further details of this process are available in the US Patent document number 5,978,432. BWXT has received the depleted U-7Mo powder and has evaluated the powder using Scanning Electron Microscopy (SEM) and chemical and physical testing at BWXT. The results of the chemical analysis provided by KAERI and the physical test results performed by BWXT are shown in Table One below.

Chemical Analysis (ppm unless otherwise noted)				**Particle Size Distribution**	
Element	**Amount**	**Element**	**Amount**	**Size µm**	**Wt%**
U	91.95 wt%	Cd	10	90 – 150	9.34
Mo	7.05 wt%	Co	10	75 – 90	19.34
Fe	15	Cu	10	53 – 75	28.46
Si	255	Mn	10	45 – 53	9.61
Ni	43	Li	0.5	<45	33
Al	50	C	110		

TABLE ONE

The SEM results reveal that the fuel is generally uniform in appearance with smooth surfaces. The powder was sieved to provide the distribution shown above, however, very little waste was produced. This indicates the capability of the KAERI process to provide a variety of fuel sizes in a reasonable range for fuel plate processing. Figure One shows the general shape (roughly spherical) and proportion of the size distribution. With closer examination, the fuel contained very little surface micro cracking. Evidence of powder processing was found in the flattened edges of fuel particles, which were soft enough to deform upon contact with the atomization containment. This flattening could have only a small but positive effect on fuel distribution by stabilizing fuel movement during compact production.

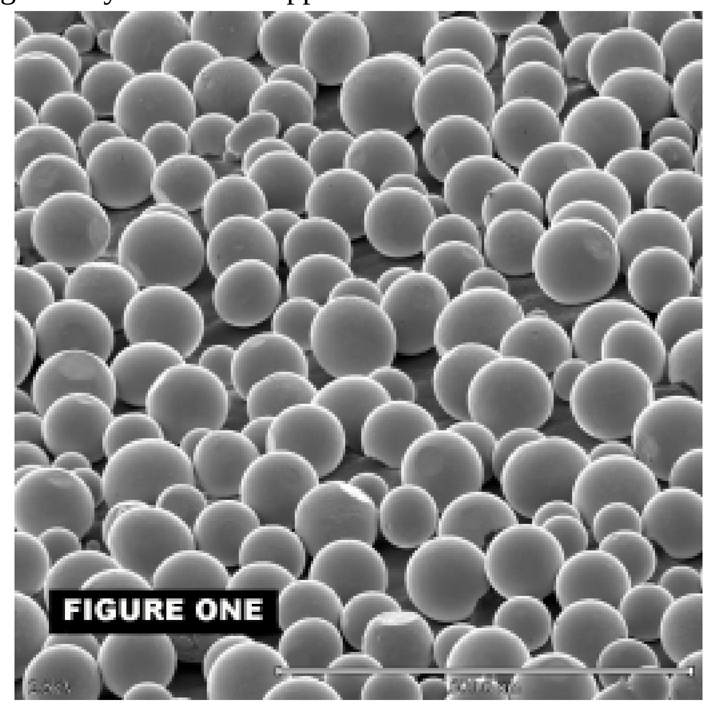
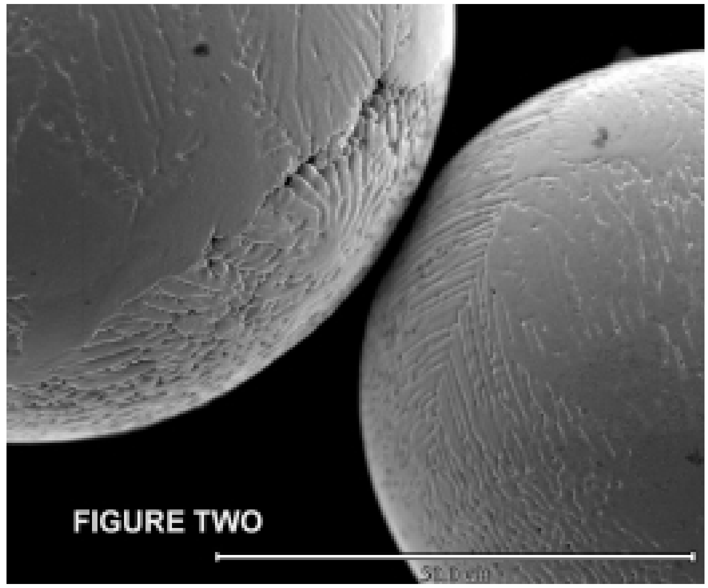


FIGURE ONE

While the fuel particles were generally smooth, evidence of the effect of rapid solidification was found on a high percentage of particles. Many of these particles displayed a dendritic type surface structure similar to that shown on Figure 2. This structure does not negatively impact early plate fabrication attributes. Some fuel particles had bulges or were connected to other particles most likely caused by collisions during cooling.



Specification requirements for LEU U-7Mo to be used in element irradiation differ little from the depleted and similar processing characteristics are expected.

FUEL PLATES

Development fuel plates were manufactured using depleted U-7Mo based on standard RTRT fabrication processes. The fuel powder was mixed with aluminum powder in the precise amounts listed in Table Two and compacted to a density of approximately 90%. After compaction, the compacts were annealed. The compacts were placed into the cladding frames made of 6061 aluminum (ASTM-B209) and hot rolled to a reduction of greater than 6:1, then blister annealed. No blisters were found under visual inspection and after cold rolling to final thickness, the ultrasonic test equipment also indicated no blisters in the fuel or outside of the fuel region. The fuel loading and plate parameters are shown in Table Two below.

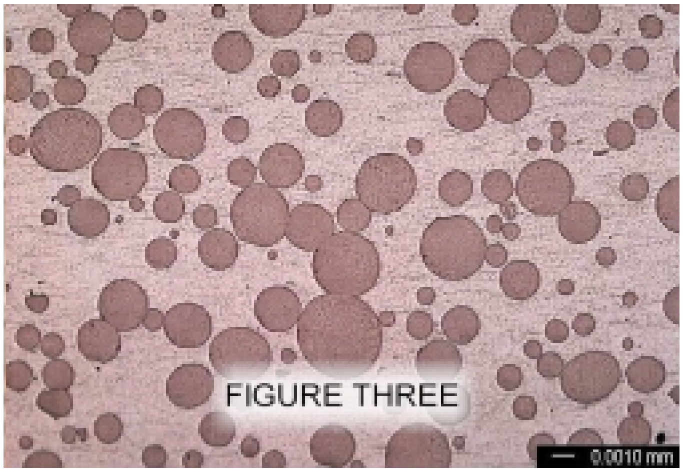
FUEL LOADING ATTRIBUTES		**NOMINAL CORE DIMENSIONS**	
Grams U-7Mo	171.054	L (mm)	600
Grams Al Powder	43.310	W (mm)	63.22
Target Loading	6 gU/cc	Th (mm)	0.695
Approx. Vol %	38	Nominal clad (mm)	0.41

TABLE TWO

Standard mechanical processing was used to provide a suitable size plate for development purposes such that quality control procedures would provide an accurate representation of the fuel plates. Three of the Quality Assurance steps were predominant in determining the success of the development. Homogeneity analysis was performed using x-ray and densitometer measurement techniques. Thirty readings were taken in the main body of the fuel region and the average of those readings was compared with visually high loaded (lighter) areas and lower loaded (darker) areas. The homogeneity was within 12.5% variance from the average and is consistent with other RTRT fuel systems with a reduced loading of 4.8 gU/cc (~43 volume %). In addition, no stray particles (white spots) were found under inspection outside the core region.

Ultrasonic Testing provided much needed information on the current capabilities of the standard equipment. Since no test standards were available, an accurate quality inspection was not possible. One of the plates fabricated is being manufactured into a test standard for a 1.0 mm defect in the core region and a 2.0 mm defect outside the core (clad area). Initial results of the plates using the U_3Si_2 test standards showed that the results of the core end to clad transition should indicate successful bond. This will be further demonstrated when the test standard is available.

Fuel plate destructive evaluation (DE) revealed that the plates conform to the min clad and nominal core thickness requirements listed in Table Two above. The fuel was uniform and had very little oxidation in the end core region. The plates were not seal welded during the pre-hot roll assembly to test the reactive properties of the fuel. An argon blanket, however, was used to help reduce oxidation. It is possible that with the reduced potential towards oxidation, processing could become more efficient than many standard processes. Micrographs of the DE show some deformation of particles that were in contact with each other during hot roll. Figure Three shows the uniform nature of the fuel with little vertical segregation (top to bottom of the clad). The particle to particle contact is also visible.



Void volume testing was not performed on the fuel plates. Void content of greater than 2% is difficult to achieve and more cold working through cold roll may be needed to provide a small increase in void volume. The void content is considered to be approximately 2% by visual evaluation of the destructive evaluation test.

The results from the development indicate that BWXT may proceed with LEU fuel plates using the U-7Mo alloy. Although the Ultrasonic Testing has not been qualified for this fuel, the initial results show that at a fuel loading of 6 gU/cc, production fuel plates will be satisfactory.

ELEMENT FABRICATION

Two Petten fuel elements will be fabricated with U-7Mo LEU fuel under Phase Two of the qualification. Processing of the element will consist of standard machining and assembly practices. Several of the element parameters are shown in Table Three.

ATTRIBUTE	CONSTRAINT
Number and type of plates	20 plates with arc, 18 inner and 2 outer
Coolant channel	2.46 mm
Element Construction	Swaged plates
Element Shape	Rectangular
Bundle Width	76.98
Internal Poison	Cadmium wire imbedded in side plates

TABLE THREE

The elements will be shipped to Petten HFR reactor and irradiated. This will be followed by Post Irradiation Evaluation (PIE) with cooperation of NRG and ANL. PIE results should be available by late 2001.

CONCLUSION

The fabrication of fuel plates consisting of U-7Mo fuel powder can be considered feasible under a moderate loading of 6 gU/cc. Quality inspection of the fuel plates has been successful to the point of instituting the Ultrasonic Testing standards. The remaining work to be completed on the UT test standards and qualification of the test parameters is underway and is expected to be successful.

BWXT has been fabricating research and test reactor fuel elements since the 1960's. The fuels used vary from HEU U_3O_8 and UAl_x to LEU U_3Si_2. BWXT was involved in the testing of fuel elements using U_3Si_2 during the initial push to develop a low enriched alternative in the 1980's. BWXT has consistently provided high quality elements with that fuel since then. The commitment to support the RERTR program in the development of U-7Mo has been made by BWXT. BWXT will be discussing and arranging for fabrication of additional qualification elements as needed by other reactors in 2001.

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