FUEL PLATE FABRICATION USING ATOMIZED U_3Si_2

October 1998

Written by: Brett W. Pace, BWX Technologies Inc.

Presented at the 1998 International Meeting on
Reduced Enrichment for Research and Test Reactors

October 18 - 23, 1998
Sao Paulo, Brazil

BWX TECHNOLOGIES INCORPORATED

RESEARCH & TEST REACTOR FUEL ELEMENTS (RTRFE)

October 1998

Written by: Brett W. Pace, BWX Technologies Inc.

FUEL PLATE FABRICATION USING ATOMIZED U_3Si_2

ABSTRACT

BWX Technologies Inc. (BWXT) is dedicated to attaining the most efficient and productive processes possible for the production of research fuel elements. With the ability to maintain high yields in homogeneity for high loaded (4.8 gU/cc) fuel plates, BWXT strives to lower costs on all types of fuels. To prepare for the next generation of fuels for research reactors, BWXT has entered into development to evaluate the fabrication potential of Low Enriched Atomized U3Si2 fuel powder. Atomization may be the optimum powder form for high density fuels. The basis for acceptance Of this type of fuel for the purposes of this development is the homogeneity Of the fuel and the core characteristics during fabrication. The development consisted of three phases. The first phase was a separate benchmark study and production of three mini plates with Uranium loading of 4.8 gU/cc for in reactor testing. Afterwards, two phases of full size plate fabrication were completed for production studies using two separate loadings of 4.8 gU/cc and 5.5 gU/cc. Results at completion of the first full size plate fabrication have shown that the fuel performs satisfactorily using normal fabrication practices. Complete results from 5.5 gU/cc plates are not presently available. BWXT projects that atomized fuel will be a viable alternative form Of U3Si2 for research reactor fuel with reference to ease and efficiency of manufacturing.

OVERVIEW OF RTRFE

BWXT has a long history of providing quality fuel elements to research and test reactors throughout the world. Many varieties of fuel are manufactured every day in the Lynchburg Virginia, USA manufacturing facility. Current contracts in RTRFE range from Universities in the United States to many of the National Laboratories. BWXT currently maintains fuel production for both JMTR and JRR4 reactors and has qualified as a fuel provider for other, reactors in Europe. Fuel types include both high and low enriched uranium in the forms of U_30_8, UAl_x, and U_3Si_2 (LEU only).

SUMMARY

BWXT has begun development of atomized U3Si2 fuel in cooperation with Argonne National Laboratory (ANQ and the Korean Atomic Energy Research Institute (KAERI) for fabrication studies of 4.8 gU/cc and above. The initial results showed that homogeneity would not be a significant problem in fuel production and the fabrication parameters are similar to those of standard comminuted U_3Si_2. BWXT intends to improve the results by customizing the processing parameters to accommodate the subtle differences of atomized fuel and thereby improve the quality of the fuel plates made with this fuel.

DEVELOPMENT BASIS

The development has been divided into three phases. The first phase was a separate production run of three low enriched mini plates (fuel less than 1 gram of U^{235}) of loading 4.8 gU/cc to be used for in pile testing in the HANARO reactor in Korea in cooperation with ANL and KAERI. BWXT first experimented with atomized fuel during development of the ANS reactor so this endeavor was not totally new. The fuel plates were manufactured without any changes from the normal production parameters of mini plates. Phase two was designed to evaluate the loading potential under normal processing for both 4.8 gU/cc and 5.5 gU/cc (50 volume percent) loadings using depleted uranium. During Phase Three, the process parameters were adjusted to improve the results provided from phase two and used a loading to best fit Phase Two development results.

Maintaining the homogeneity Of U_3Si_2 fuel in fuel plates is difficult primarily because of the large difference in density between the U_3Si_2 (12 g/cc) and aluminum powder (2.7 g/cc). Due to this condition, other parameters in compact production become more sensitive to changes. The determining parameters are:

1 Fuel particle size, shape, and distribution
2 Blend time and type of blender
3 Transfer technique to die for compaction
4 Matrix type (aluminum powder) and condition

DEVELOPMENT BASIS cont

In this development, all parameters were maintained with two exceptions. The fuel is atomized (somewhat spherical) and the quantity of fine particles (-325 mesh, < 45 μm) was approximately 30%. BWXT varies the percentage of fines to meet the customers requirements normally between 20% and 35%. The blender used is an off-axis rotating drum which is standard for normal production. The transfer technique is the sweep that BWXT has developed for use with U_3Si_2 fuels.

Two additional qualitative parameters were also used to evaluate the potential of the fuel. The flow characteristics of the fuel are of considerable importance to the success of this type of fuel. The almost spherical nature of the atomized fuel particles causes a difference in flow during hot rolling of the plates. With a typical comminuted fuel, the irregularities prevent extreme flow of the fuel particles with respect to the other fuel particles in the fuel core. The results of excessive flow can manifest in the core ends after the early passes through the hot roll mill. This can cause excessive localized thickness in the fuel core ends and a subsequent reduction in cladding thickness in that region.

The propensity for the fuel type to cause excessive stray particles in the cladding area (white spots as observed in radiography) is the last qualitative parameter of concern to this development. Atomized fuel has few if any, irregular surfaces to create a mechanical bond with the aluminum powder matrix. On the other hand, comminuted fuel has the irregular surface necessary to bind with the matrix, maintaining the fuel in place during the processes of loading the compacts into the frames and hot rolling.

RESULTS

Phase One production of mini plates resulted in a low yield due to stray particles. This has been a characteristic of mini plates and the small size of the fuel core and plate is the predominant cause of the losses. Handling of the compacts during loading into the frames becomes a greater factor as compact size is reduced. As expected, BWXT did not experience any major problems with accumulation of fuel in the core ends. Through ultrasonic testing the fuel plates were evaluated for unbonds. Destructive evaluation was used to evaluate the core and clad dimensions. In both qualitative analyses, the fuel performed well. The homogeneity of the fuel was excellent in almost all cases. Several of the fuel plates displayed patterns of low loaded areas (<15%) at the fuel comers. This condition, however, is consistent with the small compacts because of difficulties in distributing fuel in the comers of the compact. Based on BWXT's previous experience with mini plates, this does not indicate problems for full size production components.

RESULTS cont

Figure 1 shows a longitudinal cross section area of one of the mini plates. Point A shows particles which have been forced together during processing and have created fissures in the particles themselves. Since several indications are present, the characteristics in these plates are very similar to those of comminuted fuel. Point B indicates a large accumulation of particles that have built up in front of the four vertical particles. The particle just beneath the arrow shows the particle moving around the accumulation of broken particles. This condition may have some small impact on homogeneity but the effect did not produce a high loading in the actual results.

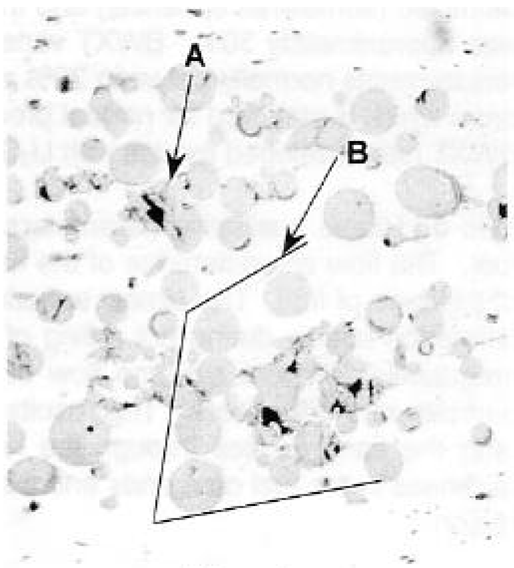

Figure 1

The first phase of development demonstrates that atomized fuel is reasonably similar to comminuted with respect to normal processing parameters. After the mini plates have been tested, ANL and KAERI will study the behavior of the fuel under irradiation.

Phase Two of the development provided excellent details in the fabrication of fuel plates using atomized fuel. The fuel performed very well under the normal fabrication processes for full size fuel plates. The homogeneity of the fuel was within 12.5 % for the 4.8 gU/cc fuel plates. Figure 2 below shows the homogeneity of the fuel plate. This is typical of all the development fuel plates as well as comminuted fuel plates.

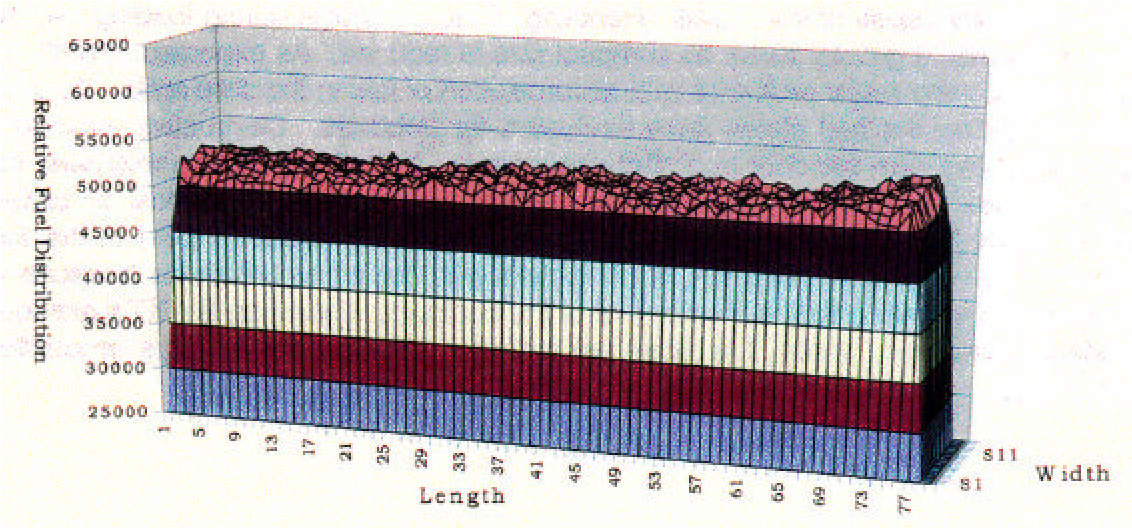

Figure 2

RESULTS cont

The yield for comminuted fuel attributed to homogeneity is in excess of 95%. The 5.5 gU/cc fuel plates are being evaluated and will provide more information for the overall homogeneity yield potential of atomized fuel. Preliminary results indicate that the higher density fuel did not perform as well and a small yield penalty is expected to be incurred if used during production. The results of the qualitative evaluation for bonding and stray particles were excellent. Stray particles increased with the higher loaded plates but the 4.8 gU/cc plates did not show a significant difference from comparable comminuted fuel.

DEVELOPMENT SUMMARY

The process for manufacturing fuel plates using atomized U3S6 is a feasible alternative to comminuted fuel. Pending satisfactory in-reactor testing, this fuel type may be considered for future use in reactors. The atomized fuel process produces more uniform fuel powder at a comparable cost without requiring tremendous amounts of development or process alteration.

PHASE THREE AND FUTURE DEVELOPMENT

BWXT is pleased with the results of the development and is considering other alternatives to the original plans for a production evaluation development. Answers to the following questions are still important to understand the worth of the atomized process.

- Does atomized fuel inhibit fuel oxidation during processing of the fuel, thereby increasing process margin?
- Will homogeneity be a considerable factor with a higher density fuel compound?
- What will be the overall impact to manufacturing process?
- How will this impact cost to the customer?

The potential for using the atomized technique for production of alternative high density fuels may provide justification for pursuing other avenues in evaluation of the atomized fuel. Working to meet all of our customers needs both present and future is of utmost importance at BWXT. Input and discussion with present and potential clients is desired.