DUAL FUEL GRADIENT DEVELOPMENT UPDATE*

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ABSTRACT

Development with fuel gradients in Uranium Silicide plates has continued through the past year at Babcock and Wilcox. In that time, dual gradient plates with loadings ranging from 1.3 gU/cc through 4.8 gU/cc have been manufactured. The results from these development fuel plates have been analyzed showing that the dual fuel gradient is possible in fuel loadings up through 4.8 gU/cc. The development will continue with work in maintaining the dual gradient while centering the fuel core within the cladding.

INTRODUCTION

Babcock and Wilcox (B&W) has done extensive work in cooperation with Oak Ridge National Laboratory (ORNL) to achieve a controllable bidirectional fuel gradient in uranium silicide (U_3Si_2) plates. The effort has been focused for the purpose of the Advanced Neutron Source (ANS) which was scheduled to be built at ORNL.

The goals of the development were to create a dual gradient in U_3Si_2 fuel plates to vary the effective fuel loading both down the length of the plate and across the width. To achieve the dual gradients, alternative manufacturing and fuel processing methods have been evaluated.

To date, 40 development plates have been manufactured with dual fuel gradients with varying degrees of success. The fuel loadings of these plates vary from 1.3 gU/cc to 4.8 gU/cc and depleted uranium was used throughout. A fair degree of success was achieved in each lot of plates with the exception of only one of the early lots which did not display the desired fuel gradients. B&W is currently preparing to complete another phase of the fuel gradient development, the results of which should be available this summer.

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DUAL GRADIENT FUEL CORES

The fuel gradient which has been chosen for development can be best described by a comparison of the compacts used in the development to the typical HFIR compact profile shown in Figure 1. The HFIR gradient is asymmetrical across the width with no gradient down the length of the plate. The original dual gradient plates used a similar gradient across the width as shown in the width view on Figure 2. The length gradient was designed to be symmetrical from one end to the other.

As in the case of the HFIR compact, the development gradient across the width was swept using a tapered die surface. A flat layer of aluminum powder was swept over the fuel and then compressed. The bottom of the compact, where the lengthwise gradient is located, was addressed in the early stages of development when different methods of ensuring the gradient were tested. Using an aluminum powder filler was one of the original ideas of how to fill the void area left by the length gradient. However, 3 separate powder sweeps were involved and the die tended to gall due to aluminum powder buildup. Other methods tried were machining a contour in the associated cover plate and the use of wedge shaped inserts during packing. Both of these methods proved satisfactory and the wedge method was used for the remainder of the development due to its simplicity.

After the methods for achieving the dual gradients were determined, the loadings were varied to evaluate the response of the gradient under different conditions. In each case the gradients were predictable and in line with the original objectives.

Gradient Specific Effects

The manufacturing of the different gradients produced conditions not normally found in standard fuel plates. Two conditions displaying the most interesting results are fuel smear along the edges and thin edge homogeneity consistency.

Fuel smear occurs after the fuel powder is swept into the die cavity and then is adjusted to accommodate the aluminum powder filler. Friction between the die block and powder pulls small quantities of the powder up against the aluminum powder cap. During hot rolling, the smear is stretched along the length edge such that it does not produce any appreciable change in local homogeneity in the effected areas.

One of the primary concerns of this development has been to understand how the homogeneity in the thin edges and corners will be effected by overall homogeneity effects and by particle size. To further evaluate this area, a comparison of the DE data from the plate center (maximum core region) to the plate ends was made. The study was done using data from the 3.0 gU/cc loaded plates by enlarging photos of the DE section involved and measuring the length of the fuel particles at the intersections of a traverse through the plate from the top to the bottom as shown in Figure 3. The data was converted into a unitized gU/cc loading for each section and up to 10 traverses were used across each section spaced at approximately 0.16mm (scaled) apart. Therefore, the loading was an average across each section up to 1.6mm in width. This study does not give any real information about the true homogeneity of the plate but does allow a microscopic look at the end characteristics

HFIR OUTER COMPACT DESIGN

Single Gradient Contour

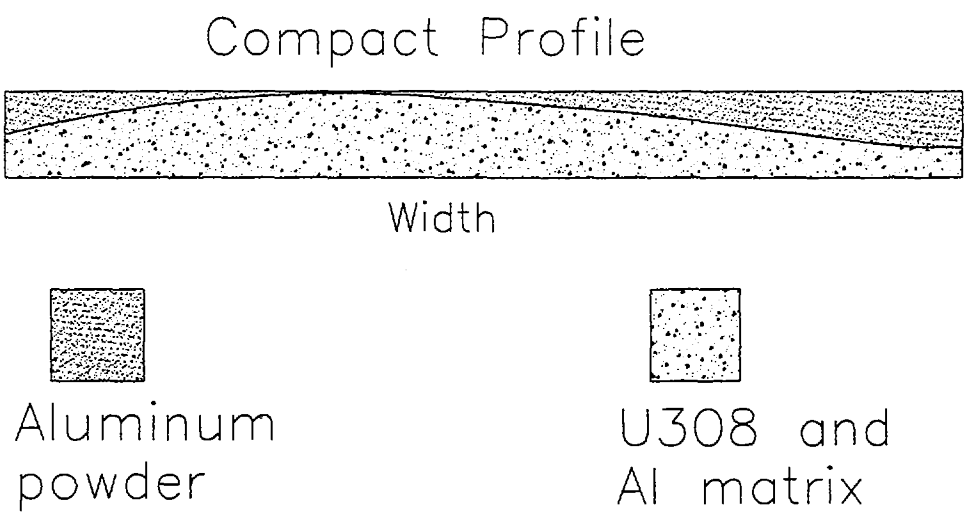


Figure 1

RECENT ANS DEVELOPMENT
COMPACT DESIGN

Dual Gradient Contour

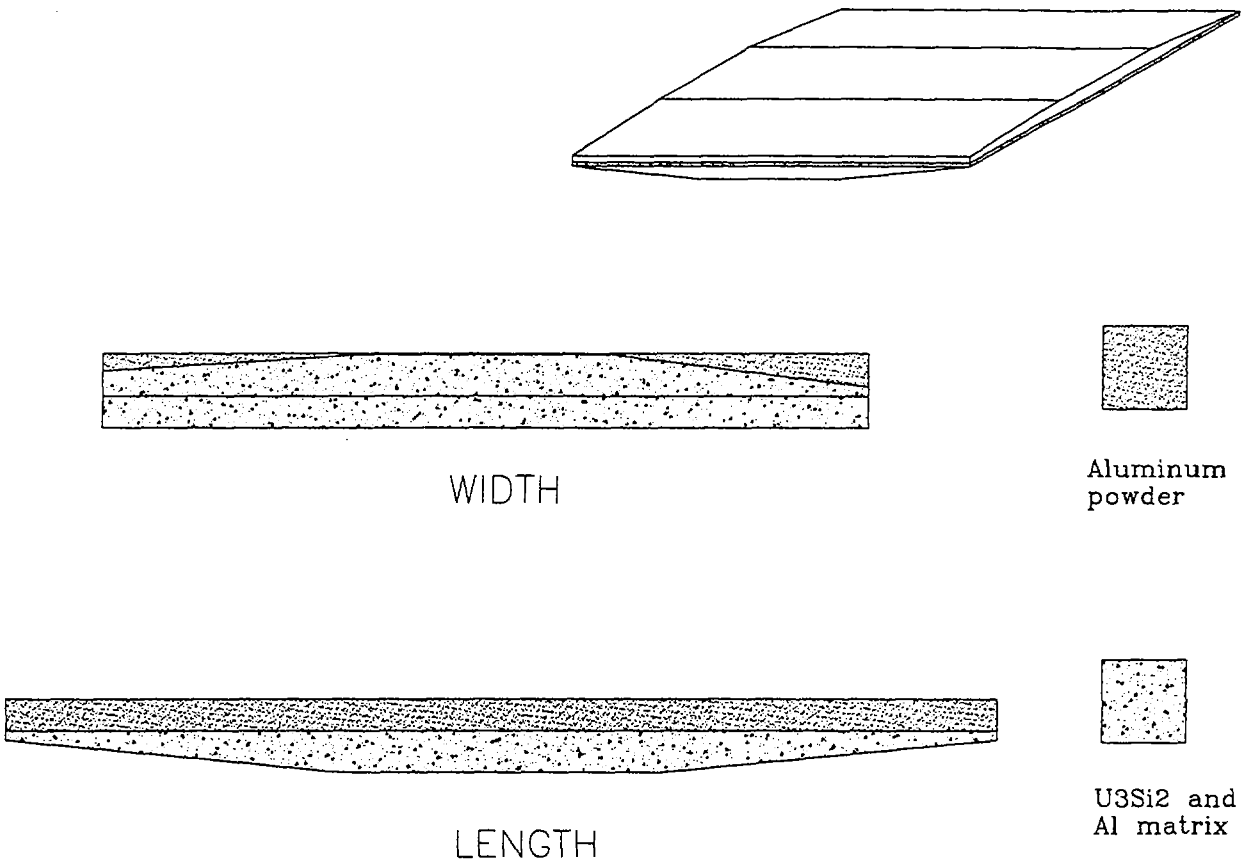
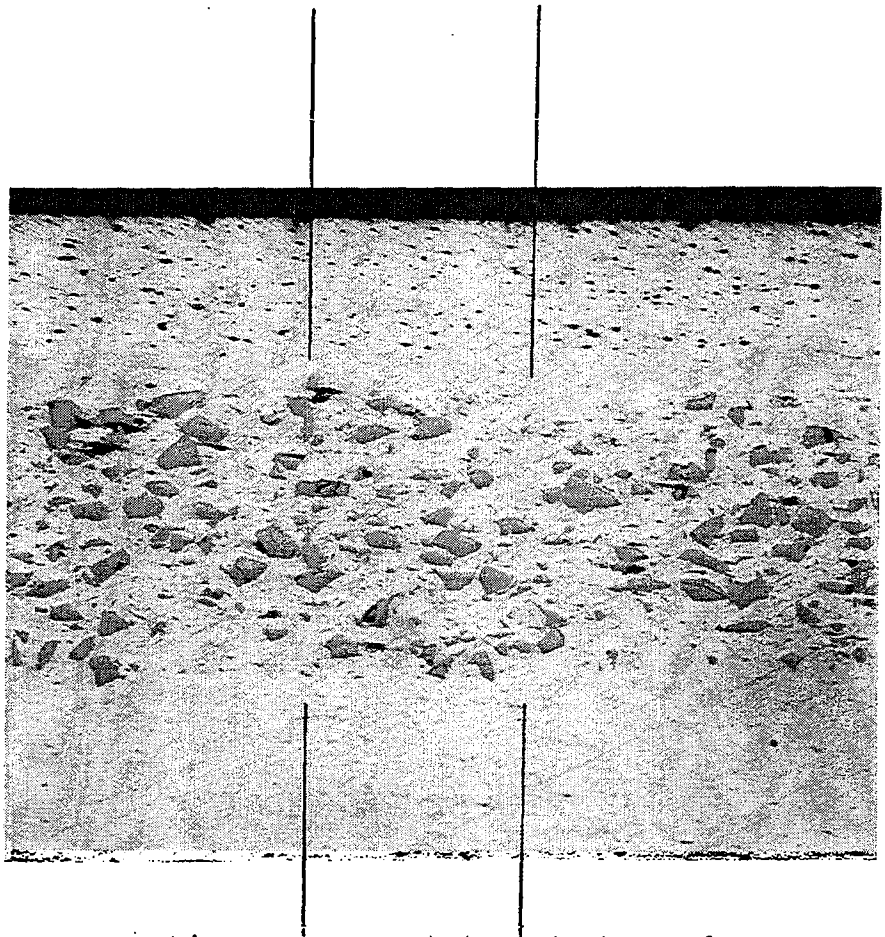


Figure 2

FUEL PLATE SECTION



Lines normal to clad surface

Linear fuel densities measure along transverse (top to bottom) sections located approximately 0.16mm apart.

Figure 3

Gradient Specific Effects Continued

compared to the center. The average loading in each spot was 3.16 gU/cc in the center and 3.14 gU/cc on the end. The standard deviation in the data was 0.6 gU/cc for the center and 1.2 gU/cc for the edge. By observing the fuel particle section sizes one can estimate that the higher variability of the fuel on the edge of the plate is due to the fact that there are fewer particles and an increased incidence of drawing a line normal to the fuel core which may not intersect any sizeable fuel particles. No homogeneity conditions involving quality issues were found and this study will continue to determine the overall magnitude of the effect on the thin fuel edge.

Homogeneity

One of the most useful tools in evaluating the overall homogeneity of the fuel plates is a digital homogeneity scanner. The most recent higher loaded development plates were all evaluated using this equipment showing that the dual gradient concept is feasible over a range of fuel loadings through 4.8 gU/cc. Data for one of the highest loaded plates, 4.8 gU/cc, is shown graphically in Figure 4. The gradients of all plates were very similar among plates with like loadings showing that the process was repeatable.

Research and testing of the digital homogeneity scanner has been ongoing since the system came online in 1992. As part of the latest fuel development, the sensitivity of the scanner has been tested using different diameters of tungsten wire. The results of these test are currently being evaluated.

NEW FUEL DEVELOPMENT

Dual Gradients

The next step in the development of dual gradients is to center the fuel within the cladding at all locations in the plate. The gradient chosen for further development was a redesign of the previous compact to be symmetrical in all aspects as shown on Figure 5. The compact will not have any aluminum powder filler and no wedges will be used to fill the void areas. Instead, the compact will fit inside two dished cover plates with a very thin frame between them to maintain proper fit up. With this configuration, any fuel smear or core end buildup will be removed and homogeneity should be similar to prior development. The plate loadings will be 2.8, 3.0, and 3.5 gU/cc and the quantities will be 4, 4, and 6 respectively.

Spherical U_3Si_2

Through ORNL and in association with Argonne National Laboratory and the Korean Atomic Energy Research Institute (KAERI), B&W will endeavor to manufacture

HOMOGENEITY OF HIGH LOADED

DUAL FUEL GRADIENT U3Si2 PLATE

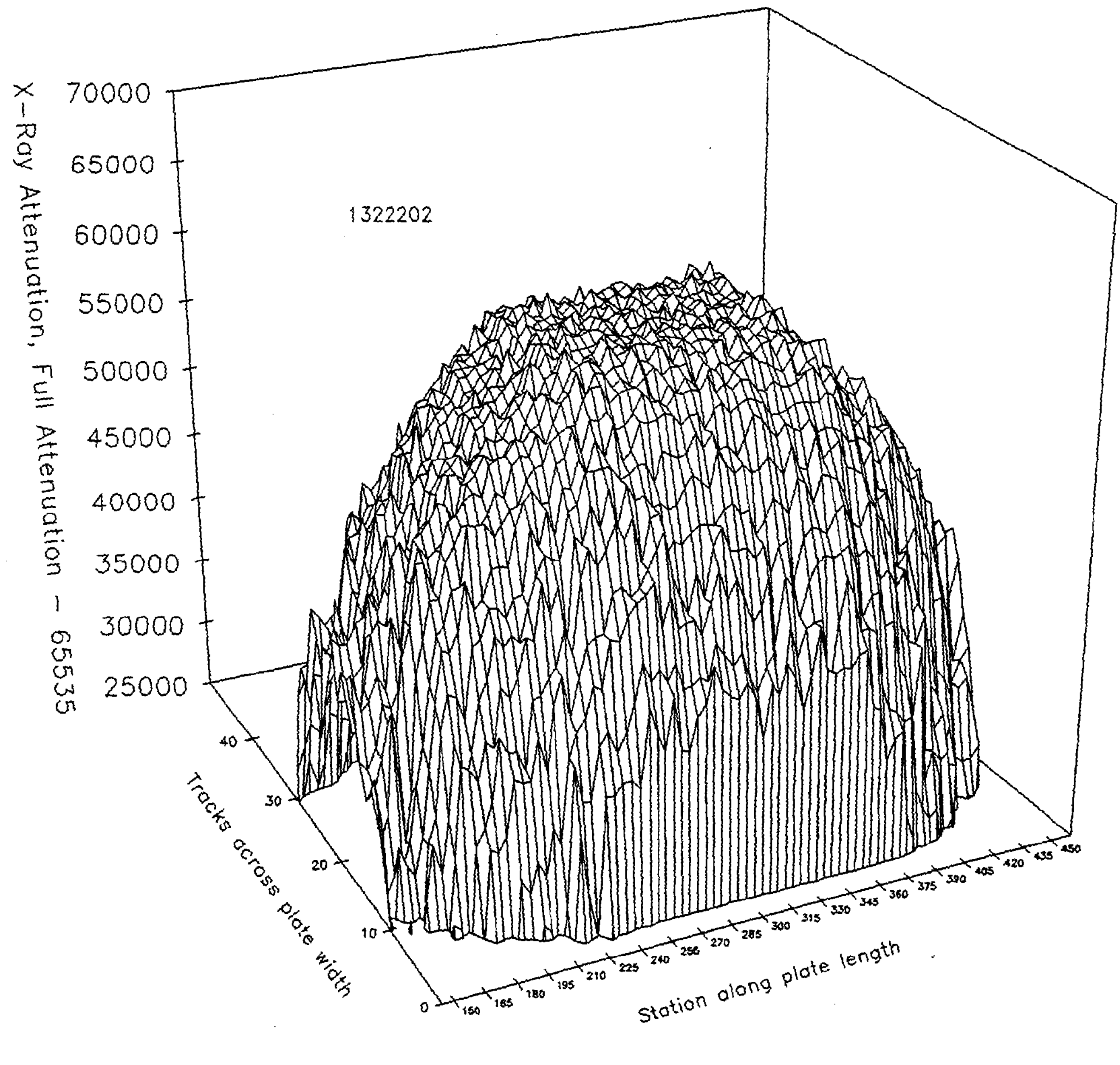


Figure 4

NEW ANS DEVELOPMENT
COMPACT DESIGN

Centered Dual Gradient Contour

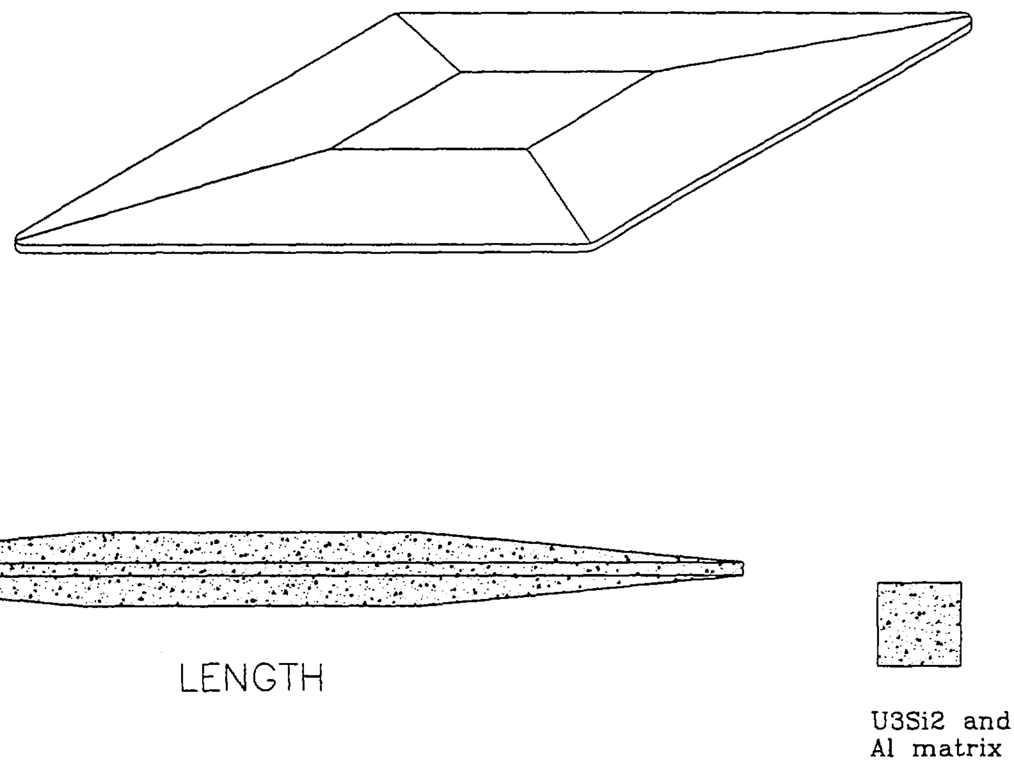


FIGURE 5

fuel plates using spherical fuel manufactured by KAERI. Two sets of three plates each will be manufactured with the original fuel gradient used in development. One set of plates will be loaded at 3.0 gU/cc and the other will be 4.8 gU/cc.

CONCLUSION

The development with dual gradients in U_3Si_2 fuel plates over the last year has increased the understanding of fuel characteristics which will benefit all uranium silicide work at B&W. The ability to produce dual gradients in uranium silicide plates has been proven successful and repeatable without significantly increasing the effort required to produce plates. The fuel core centering development will be an excellent way to finish the development with dual gradients. A final report on all gradient development at B&W will be written in conjunction with ORNL.