DEVELOPMENT OF FUEL COMPACTS FOR GRAPHITE MODERATED REACTORS

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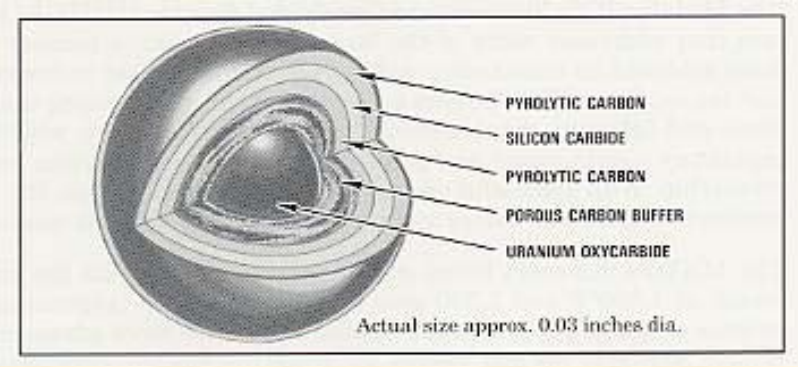
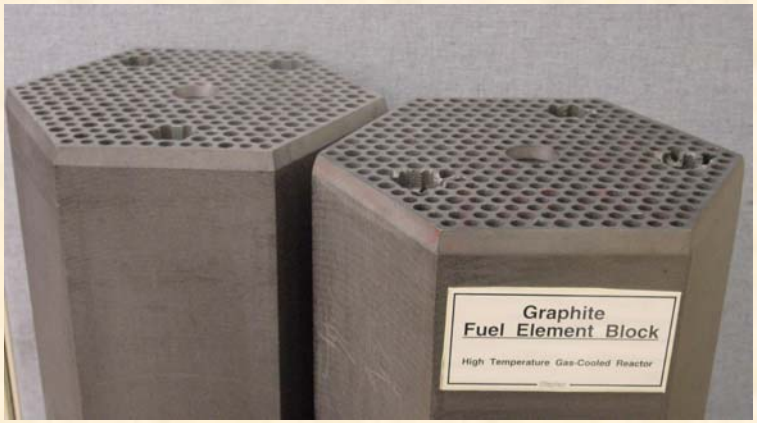
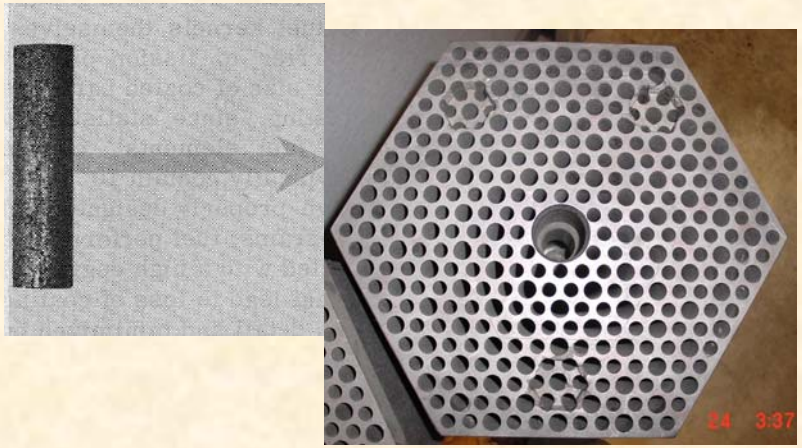
FUEL COMPACTS AND MODULAR GRAPHITE CORES

Fuel particles are formed into 12 mm diameter fuel sticks and inserted into graphite fuel blocks







Prismatic core for VHTR?

THE OVERCOATING METHOD FOR PRODUCING FUEL COMPACTS

- Dragon Reactor (U.K.) developed the admix process: graphitized petroleum coke filler (88%), high char yield resin binder (12%)
- Filler and binder were mixed in denatured alcohol, dried, and then re-ground to produce a resin-coated graphite powder
- Coated fuel particles were then mixed with the graphite powder
- The "overcoated" fuel particles were then warm pressed in a mold, carbonized, and heat-treated

THE A3 MATRIX FOR OVERCOATING PARTICLES

- The German Pebble Bed reactor fuel pebbles were made by a derivative of the Dragon overcoating process
- The coke filler was replaced by natural and synthetic graphite, and a higher percentage of thermosetting resin binder was used
- The ratio of natural graphite, synthetic graphite, and binder was 64:16:20, now called the A3 matrix
- The A3 matrix was produced in one mixing step, dried, re-ground, and used to overcoat particles dampened with a solvent
- The overcoated particles were then re-mixed with additional A3 matrix and isostatically pressed into spherical fuel pebbles

SLUG INJECTION PROCESS FOR PRODUCING FUEL COMPACTS

- General Atomics designed and produced the fuel compacting process for the Fort St. Vrain reactor in the US
- A prismatic core was used, and the compacts were made by the slug injection process in order to achieve ~60% fuel loadings
- Slug injection involved mixing of the dry ingredients in a packed mold and injecting molten pitch subsequently
- Problems with impurities from the pitch and fuel particle integrity were identified

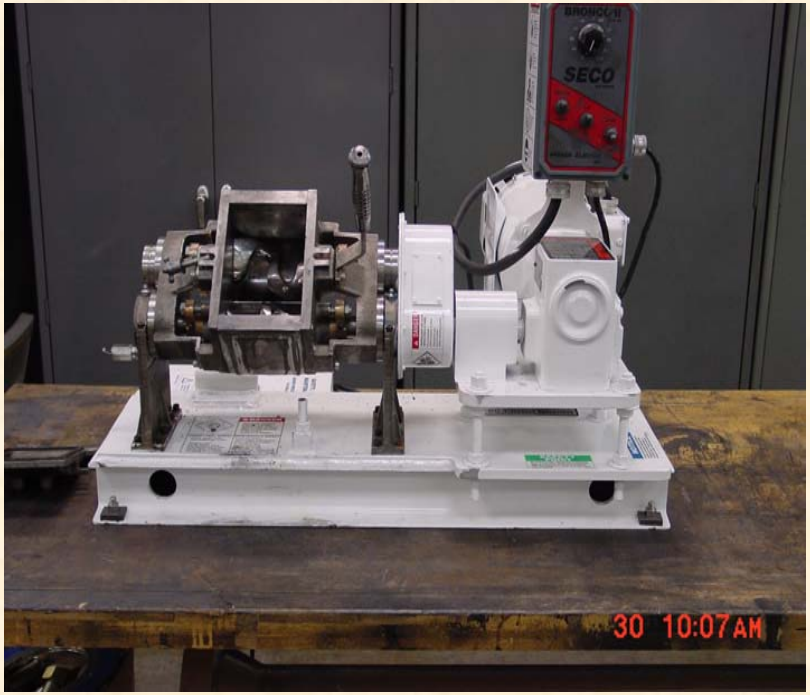
RECOMMENDED APPROACH FOR FUEL COMPACTS IN VHTR

- The recommended approach is to use the A3 matrix to overcoat particles, and press them into a cylindrical shape
- Essentially, the fuel compacts are identical in size to those from FSV, but produced by a different method
- This work is ongoing in the Carbon Materials Technology (CMT) group at ORNL

OVERVIEW OF THE KEY STEPS IN THE PRODUCTION OF A FUEL COMPACT

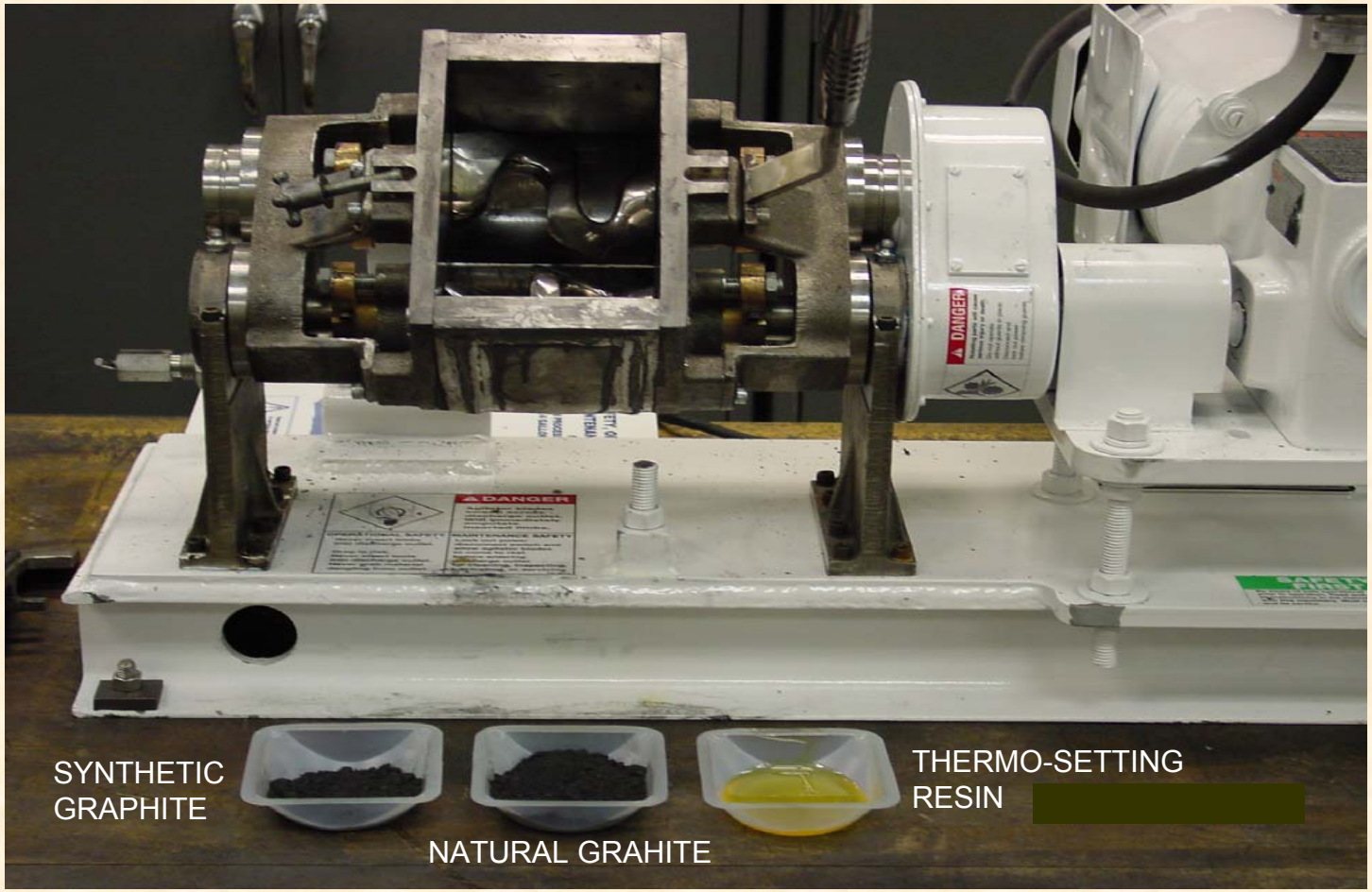
- The powder resination step—natural and synthetic graphites are combined with a thermo-setting resin
- Grinding of the resinated powder—the resinated powder is re-ground into a fine powder
- Overcoating—fuel particles are overcoated with the resinated powder
- Compaction—the overcoated fuel particles are pressed in a heated mold
- Carbonization—the green fuel compact is carbonized to 800°C
- Final heat treatment—the carbonized fuel compact is heat treated to ~1800°C

MIXING GRAPHITE POWDERS WITH A THERMO-SETTING RESIN



- The powder resination step is performed in a sigma blade mixer
- A 64:16:20 ratio of natural graphite, synthetic graphite, and thermo-setting resin is combined

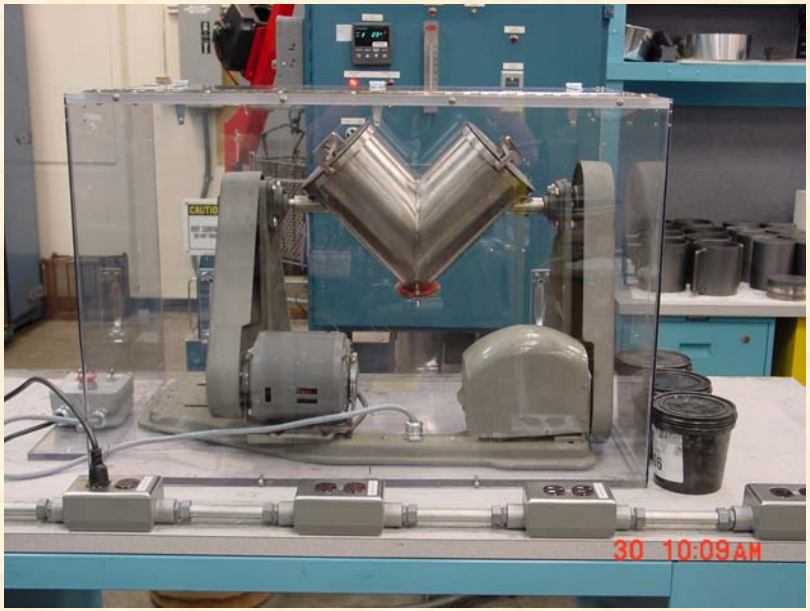
THE SIGMA BLADE MIXER WITH CONTENTS READY FOR COMBINATION



RESINATED POWDER IS RE-GROUND

- The resinated powder is re-ground using a jet mill
- Other mill types are currently being tested as well
- It may not be necessary to re-grind the powder, success with ro-taps

OVERCOATING OF THE FUEL PARTICLES



- A V-blender is used to overcoat the fuel particles
- The interior agitator in this blender was removed so as not to damage the fuel particles
- Other shaped blenders are currently being tested

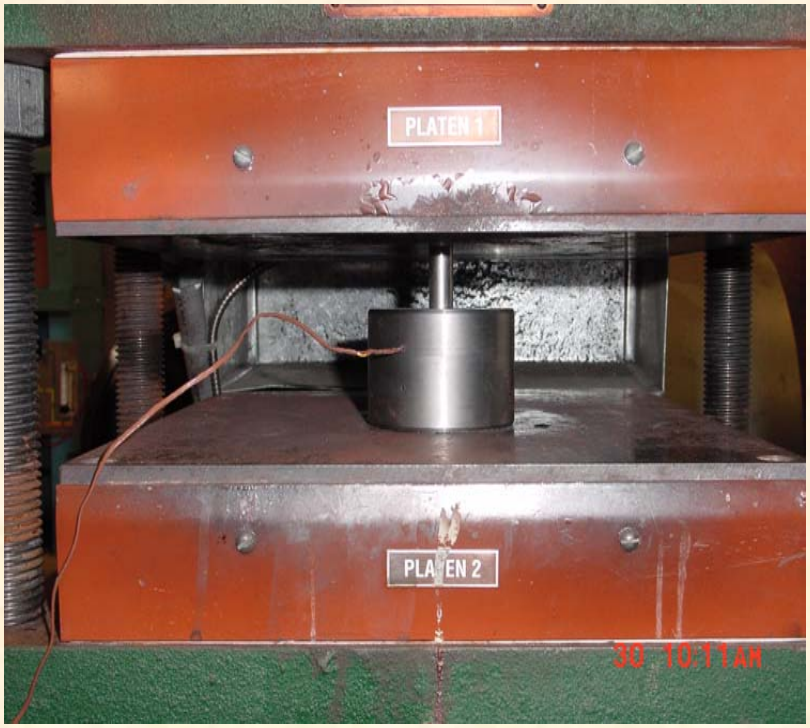
V-BLENDER WITH CONTENTS READY FOR OVERCOATING

INTERNAL AGITATOR REMOVED

Resinated power

Fuel particles (ZrO_2)

OVERCOATED FUEL PARTICLES ARE PRESSED INTO A FUEL COMPACT



- A hot press is used to form the overcoated fuel particles into a fuel compact
- The temperature of the mold is held at approximately 150°C
- Appropriate pressure still being determined

THE FUEL COMPACT IS CARBONIZED IN A TUBE FURNACE

- Carbonization temperature is ~800°C for one hour
- A flowing helium inert atmosphere is used, and other gases are also being tested

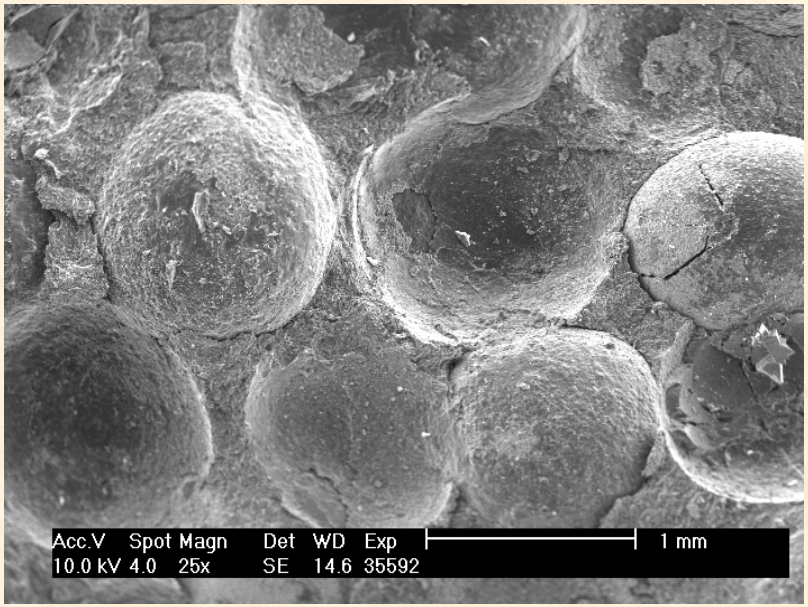
THE FUEL COMPACT UNDERGOES A FINAL HEAT TREATMENT

- A vacuum Astro furnace is used for the final heat treatment
- The final heat treatment temperature is not to exceed 2000°C

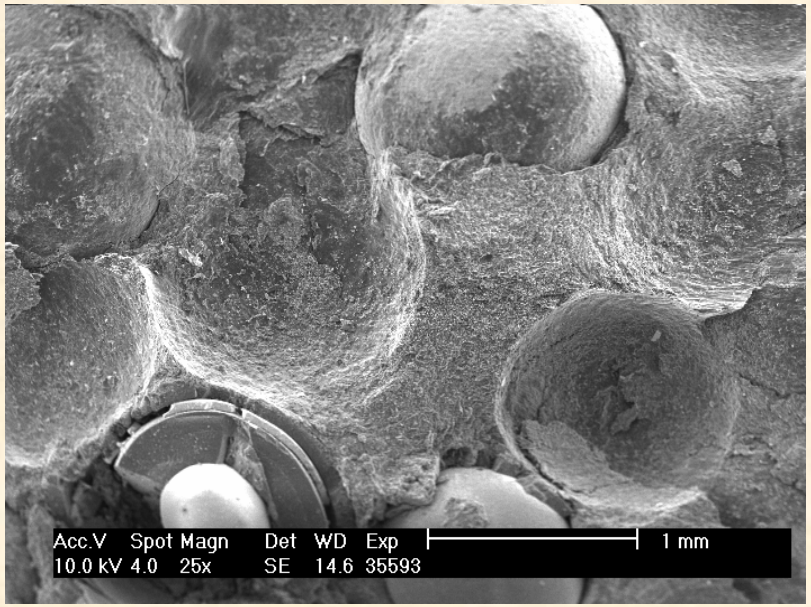
COMPACT CHARACTERIZATION

- Cracking of fuel particle layers, especially SiC, must be avoided
- Testing procedures include leach-burn-leach or burn-leach, density, crush strength, and TC measurements
- Optical and scanning EM are used to examine the layers of the particles in the compact
- Hg or methylene idodide intrusion is used to check the integrity of the SiC layer

SEM IMAGES OF PRELIMINARY TEST COMPACTS



SEM image of broken fuel compact



SEM image showing exposed ZrO_2 core

SUMMARY

- The method of making right circular cylinder compacts by the overcoating A3 matrix approach is currently being optimized in the CMT group of ORNL
- This work is being funded by US DOE for the eventual production of the VHTR reactor
- All of the process parameters are being investigated, but compacts have been made and it appears that the A3 matrix approach can be successfully translated to the production of a compact as well as a pebble
- This process allows for flexibility in the fuel particle loading fraction and fuel compact shape