AGR FUEL COMPACT DEVELOPMENT PROGRAM

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Oct 27, 2015

OAK RIDGE NATIONAL LABORATORY

AGR FUEL COMPACT DEVELOPMENT

OVERVIEW OF PRESENTATION

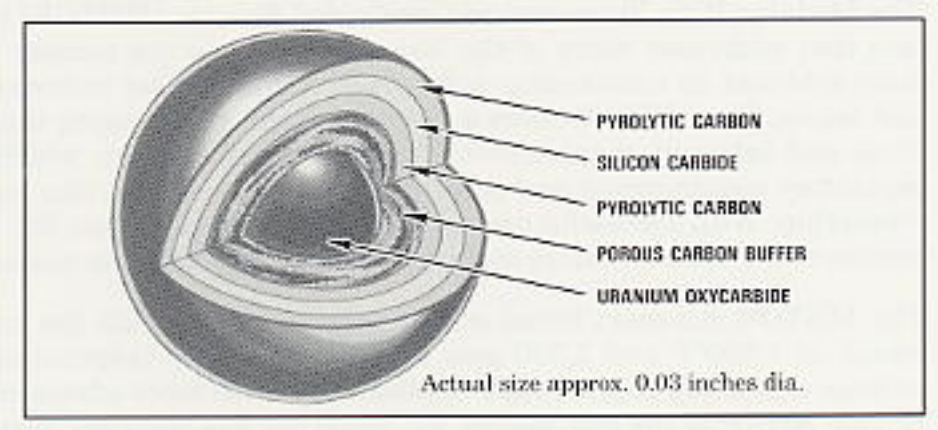
- **BACKGROUND**
  - **FUNCTION OF COMPACT**
  - **METHODS OF MANUFACTURE**
  - **ATTAINABLE FUEL PARTICLE VOLUME FRACTIONS**
  - **NEUTRON IRRADIATION DIMENSIONAL STABILITY**
- **RECOMMENDED APPROACH**
  - **METHOD & MATERIALS**

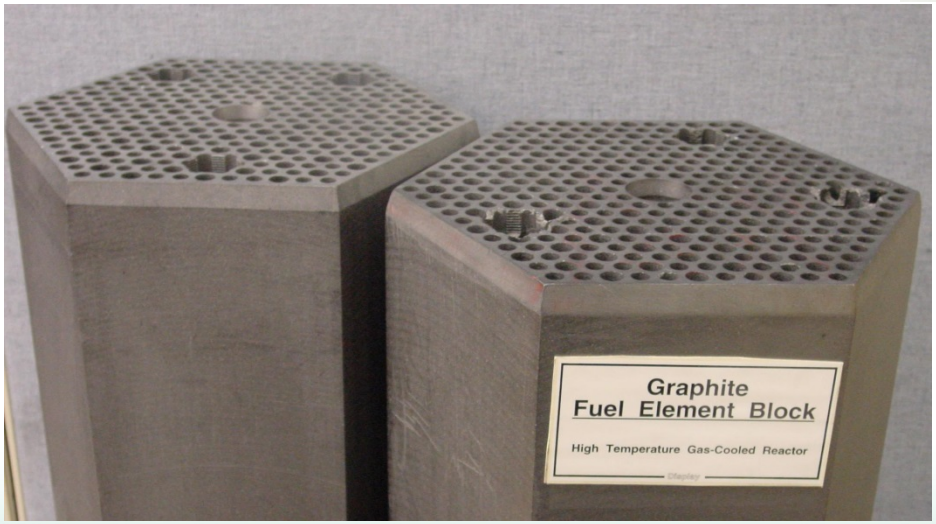
AGR FUEL COMPACT DEVELOPMENT

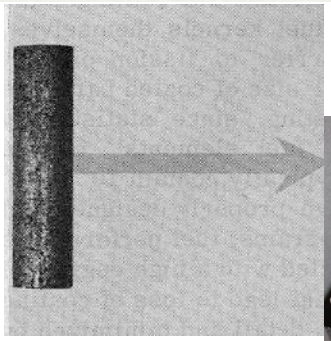
BACKGROUND

THE GAS TURBINE-MODULAR HELIUM REACTOR (GT-MHR) UTILIZES CERAMIC COATED PARTICLE FUEL

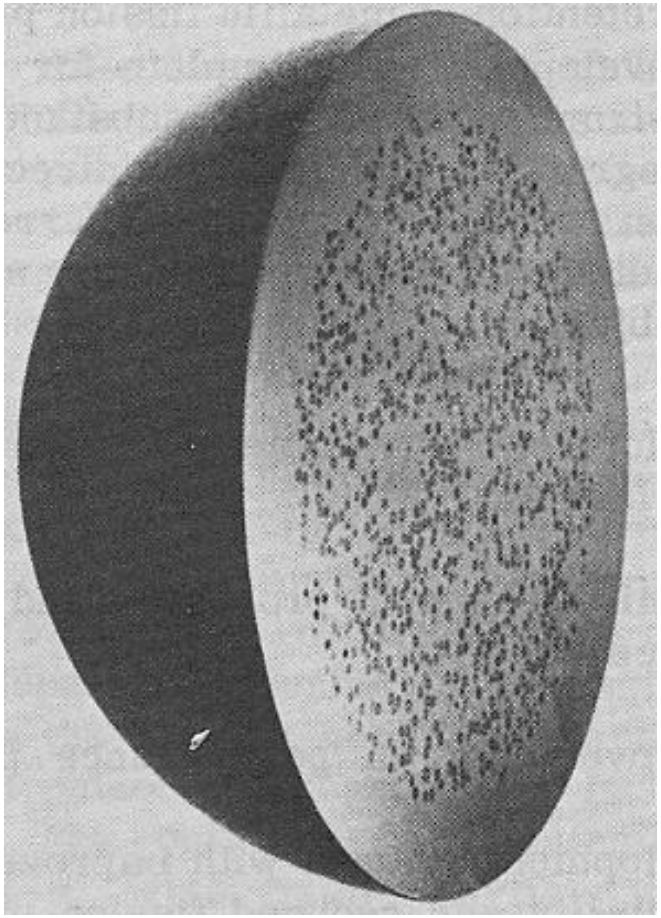
FUEL PARTICLES ARE FORMED INTO 12.5 mm DIAMETER FUEL STICKS AND INSERTED INTO GRAPHITE FUEL BLOCKS



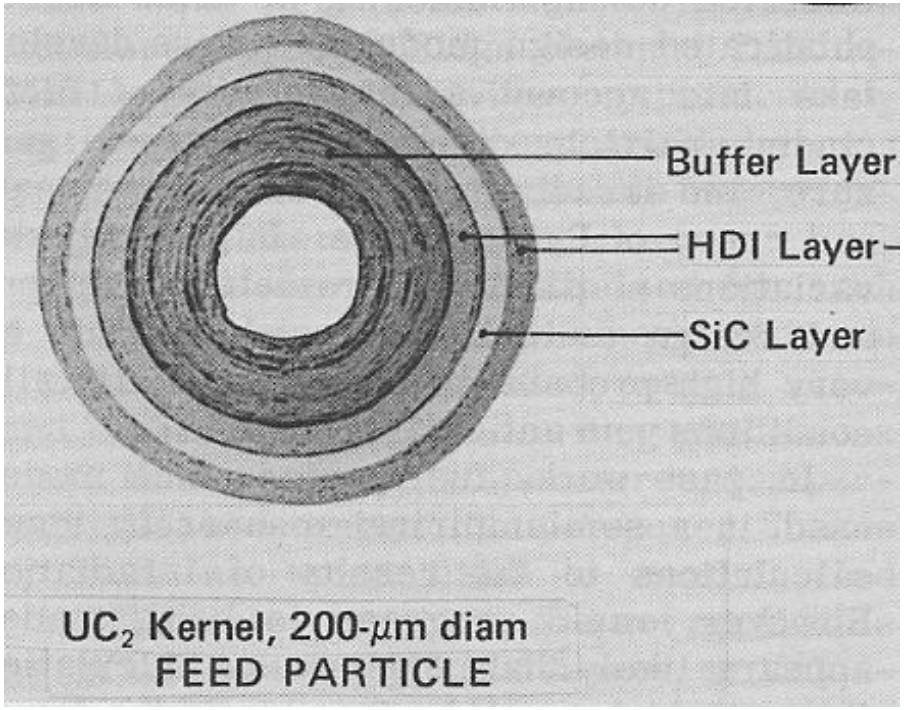




THE PEBBLE BED REACTOR UTILIZES CERAMIC COATED PARTICLE FUEL



THE TRISO FUEL PARTICLES ARE COMBINED INTO A CARBON FUEL BALL (PEBBLE) 6 cm IN DIAMETER



FUEL COMPACT: FUNCTION & TERMINOLOGY

- RENDERS FUEL PARTICLES INTO HANDLEABLE FORM (i.e., COMPACT OR FUEL PEBBLE)
- COMPACT COMPRISES OF FUEL PARTICLES, MATRIX AND GRAPHITE SHIM
- MATRIX CONSISTS OF FILLER (COKE OR GRAPHITE) AND BINDER (PITCH OR RESIN)
- THE MATRIX BINDS TOGETHER THE FUEL PARTICLES AND PROTECTS THEM FROM MECHANICAL DAMAGE BY FAILING PREFERENTIALLY SO AS TO AVIOD DAMAGE TO THE FUEL PARTICLE COATINGS
- ADDITION OF GRAPHITE FILLER TO THE BINDER INCREASES THE THERMAL CONDUCTIVITY OF THE FUEL COMPACT, AND INCREASES DIMENSIONAL STABILITY DURING HEAT-TREATMENT AND NEUTRON IRRADIATION
- AGR COMPACT IS 12.5 mm DIA & 49.3 mm LEN, AND HAS A FUEL PARTICLE VOLUME FRACTION IN THE RANGE 22-33.6%

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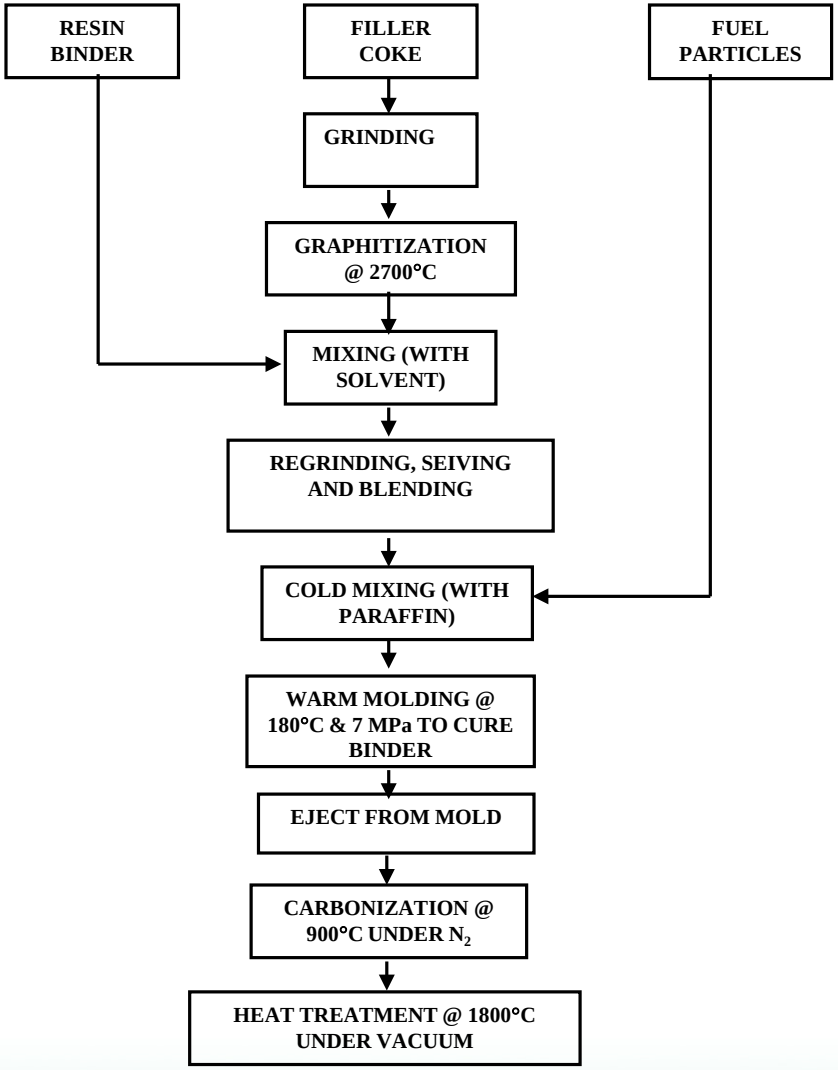
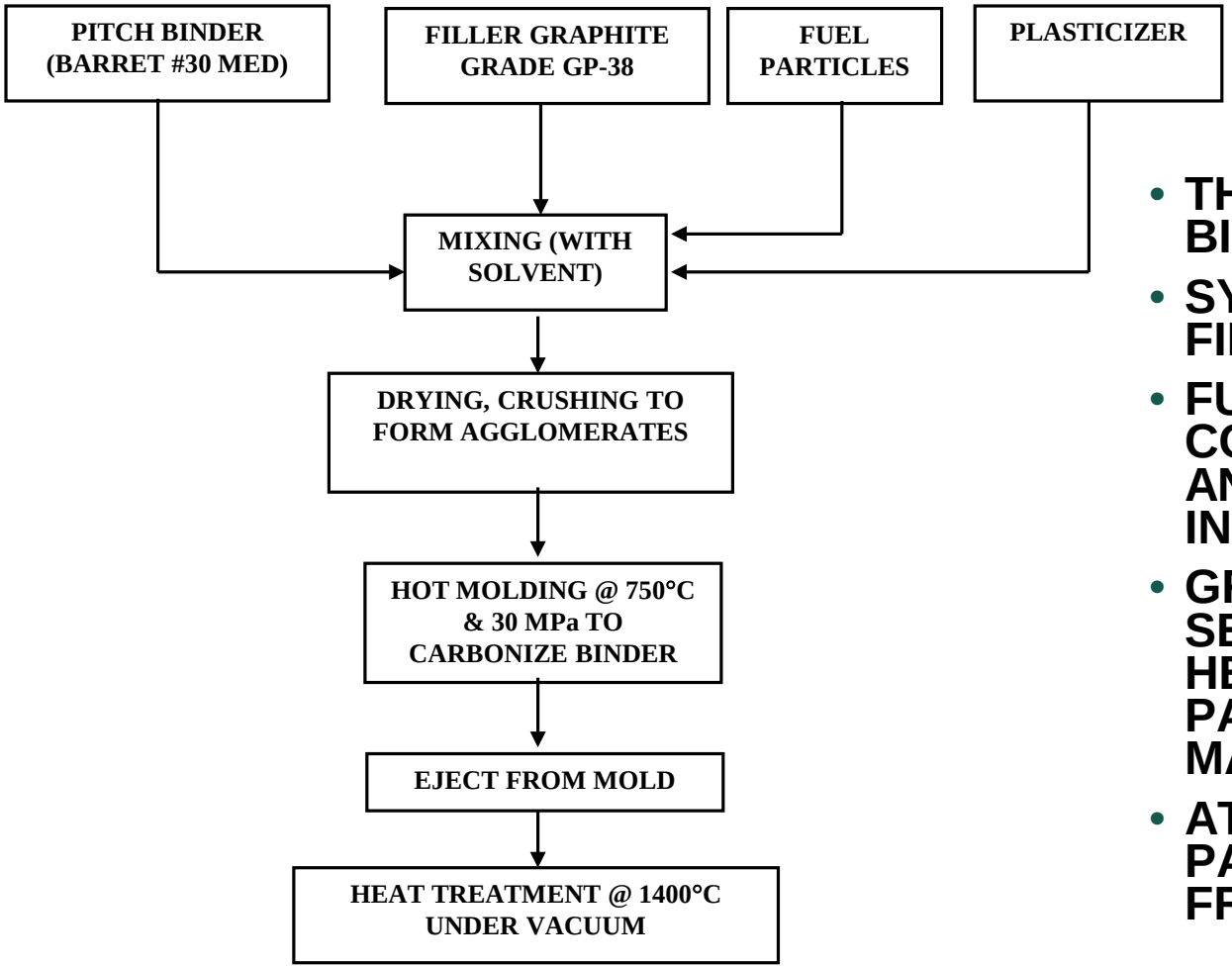
FUEL COMPACT METHODS OF MANUFACTURE

DRAGON PROJECT ADMIX METHOD



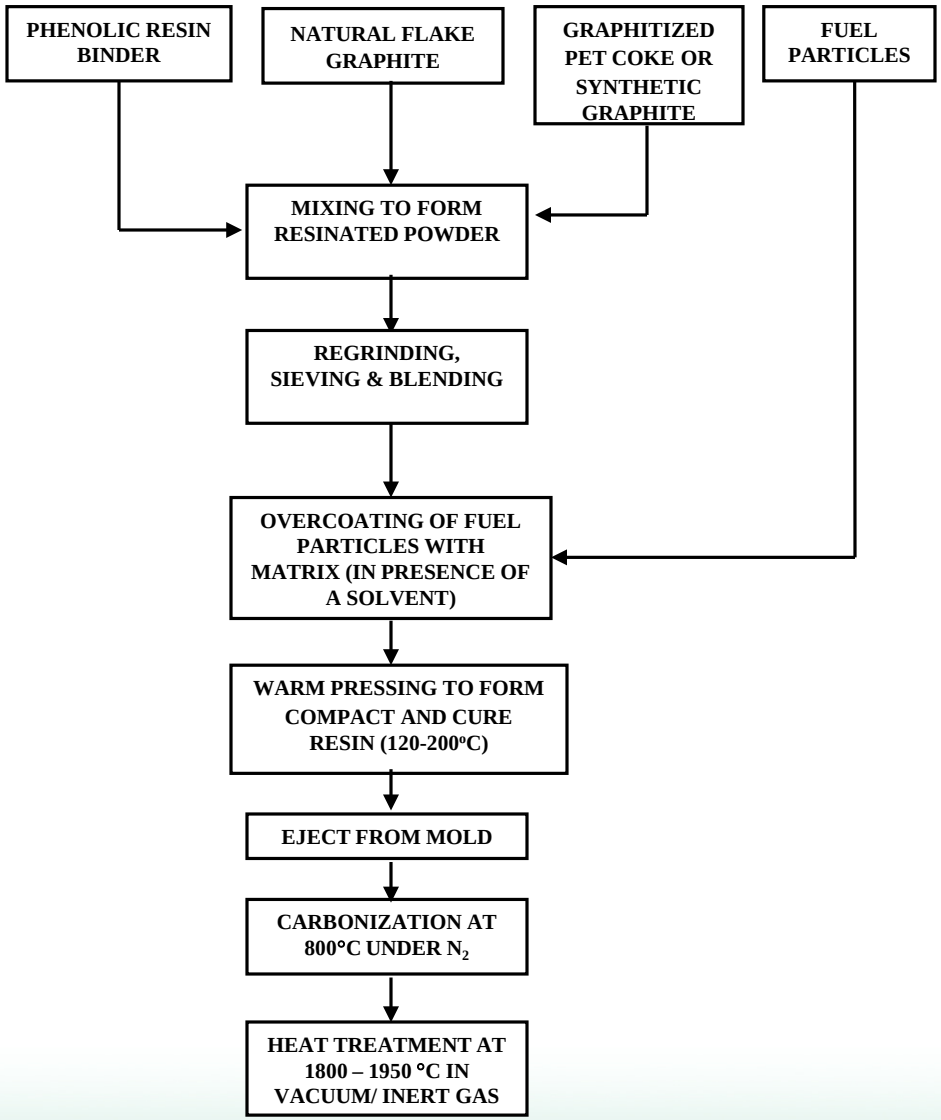
- HIGH CHAR YIELD RESIN (PHENOL FORMALDEHYDE) SOLVATED WITH ALCOHOL
- GRAPHITIZED PETROLEUM COKE (< 50 MICRON SIZE)
- PRODUCE A RESIN COATED GRANULATED POWDER (88% FILLER)
- SIEVED, BLENDED AND MIXED WITH COATED FUEL PARTICLES
- WARM MOLDED TO FORM AND CURE BINDER, & EJECTED FROM MOLD
- CARBONIZED @ 900°C & HEAT TREATED TO 1800°C
- ATTAINABLE FUEL PARTICLE VOLUME FRACTIONS TYPICALLY < 25%

PEACH BOTTOM PROCESS (GENERAL ATOMICS)



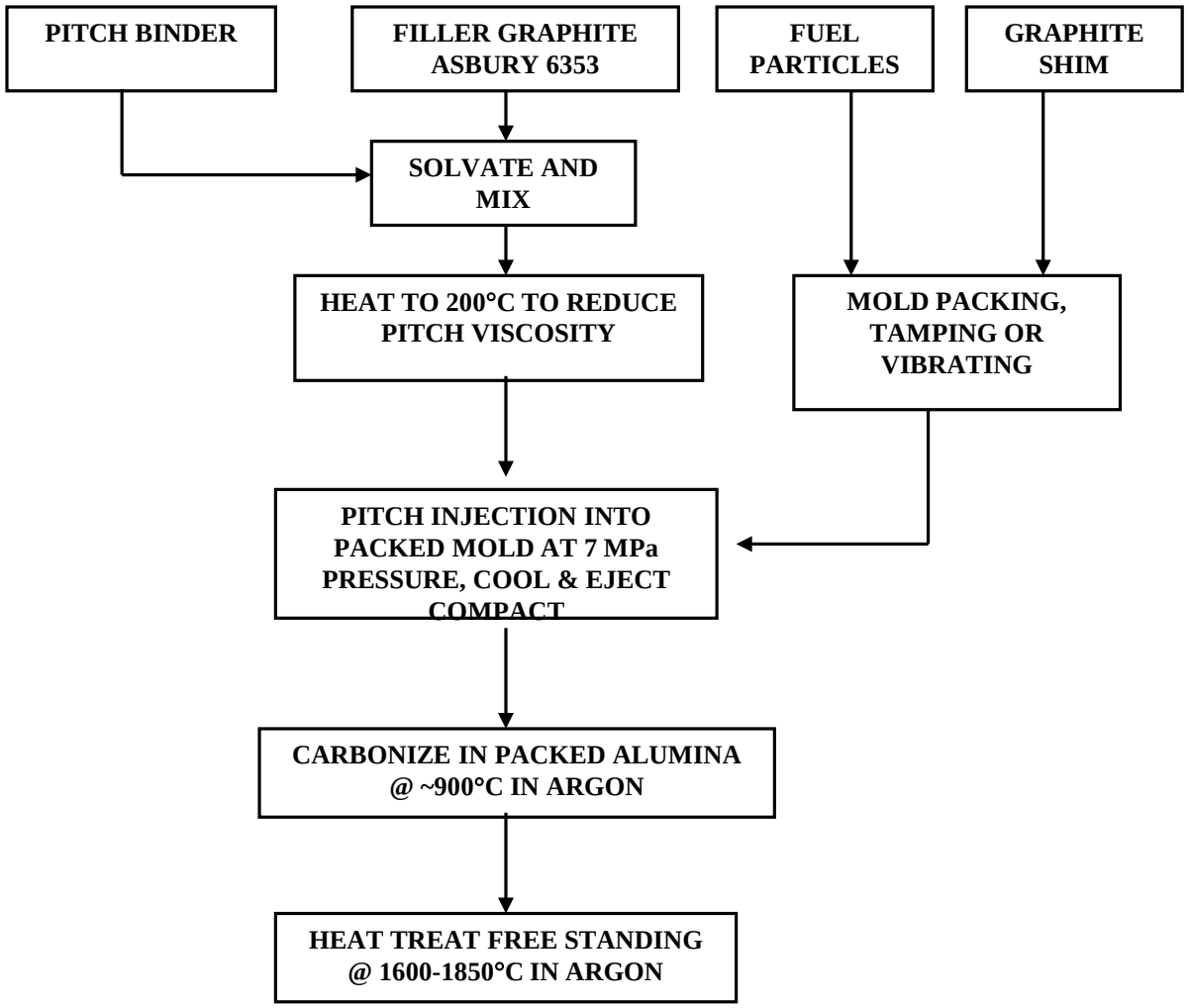
- THERMOPLASTIC (PITCH) BINDER
- SYNTHETIC GRAPHITE FILLER (90% OF MATRIX)
- FUEL AND MATRIX COMPONENTS MIXED AND THEN GRANULATED INTO 3-9 mm PELLETS
- GRANULIZATION AVIODS SEGREGATION OF THE HEAVIER FUEL PARTICLES & LIGHTER MATRIX COMPONENTS
- ATTAINABLE FUEL PARTICLE VOLUME FRACTION 25-35%

PARTICLE OVERCOATING PROCESS



- THERMOSETTING RESIN (PHENOLIC) BINDER
- MATRIX FILLER CONSISTS OF NATURAL FLAKE AND SYNTHETIC GRAPHITE OR GRAPHITIZED PET. COKE
- RESINATED POWDER MATRIX MIX FORMED THE “A3” MATRIX (WITH 80 wt% GRAPHITE FILLER)
- MATRIX MIX FED INTO ROTATING DRUM WITH FUEL PARTICLES AND SOLVENT (METHANOL) TO “OVERCOAT” THE FUEL PARTICLE
- COMPACTS ARE WARM MOLDED TO CURE RESIN
- FINAL HEAT TREATMENT 1800-1950°C
- ATTAINABLE FUEL PARTICLE VOLUME FRACTION 5-50%

GENERAL ATOMICS MATRIX INJECTION PROCESS



- THERMOPLASTIC (PITCH) BINDER
- NATURAL GRAPHITE FILLER (~28 % OF MATRIX)
- CLOSE PACKED BED OF FUEL PARTICLES
- MATRIX HEATED ABOVE ITS SOFTENING POINT AND "INJECTED" INTO PARTICLE BED.
- COMPACT COOLED, EJECTED AND PACKED IN ALUMINA TO SUPPORT COMPACT DURING CARBONIZATION WHEN PITCH SOFTENS PRIOR TO PYROLYSIS
- ATTAINABLE FUEL PARTICLE VOLUME FRACTION < 60%

SUMMARY OF THE FUEL PARTICLE VOLUME FRACTIONS ATTINED FROM THE VARIOUS COMPACTING PROCESSES

FUEL COMPACTING PROCESS	FUEL PARTICLE VOLUME FRACTION (%)
ADMIX (DRAGON REACTOR)	< 25
ADMIX/AGGLOMERATE (PBR)	25-35
PARTICLE OVERCOATING (DRAGON, AVR, THTR, HTTR, HTR-10)	5-50
PITCH INJECTION (FSV)	< 60

AGR COMPACT FUEL PARTICLE VOL. FRACTION TARGET IS 22-33.6%

NEUTRON IRRADIATION DIMENSIONAL STABILITY OF COMPACTS

- THE FUEL COMPACT MATRIX MATERIAL SUSTAINS A SIGNIFICANT AMOUNT OF NEUTRON INDUCED DISPLACEMENT DAMAGE
- IRRADIATION BEHAVIOR OF CARBONS & GRAPHITES MARKEDLY AFFECETED BY THE DEGREE OF CRYSTALINITY OF THE MATERIAL
- AGR COMPACTS WILL HAVE A HIGH MATRIX CONTENT SO THE IRRADIATION BEHAVIOR OF THE MATRIX IS CRITICAL
- IT HAS BEEN ARGUED THAT PITCH PRECURSERS ARE MORE SUITED FOR BINDERS SINCE FOR A GIVEN FINAL HTT THEY ARE MORE CRYSTALINE THAN RESIN CHARS, ALTHOUGH PITCH IS A MAJOR SOURCE OF CHEMICAL CONTAMINATION
- LOADING THE THERMOSETTING RESIN (GLASSY CARBON) WITH A LARGE FRACTION OF HIGHLY GRAPHITIC FILLER MARKEDLY IMPROVES THE MATRIX IRRADIATIOIN BEHAVIOR, REDUCES THERMAL SHRINKAGE ON PYROLYSIS, AND INCREASES MATRIX THERMAL CONDUCTIVITY

AGR FUEL COMPACT DEVELOPMENT

RECOMMENDED APPROACH

THE FOLLOWING FACTORS MUST BE CONSIDERED IN RECOMMENDING AN APPROACH

1. A thermosetting resin binder has been selected for the production of AGR fuel compacts
2. The required fuel particle volume fraction for the AGR compacts is very modest (22-33.6%) and is within the attainable range of the admix/agglomerate, the overcoating, or injection processes.
3. The most stable matrix is one with a large fraction of graphite filler.
4. Highly filled (>40 vol.%) pitch or resin matrix materials cannot be injected into packed particle beds.
5. Injectable low graphite filler content thermosetting resin binder formulations with additions of low char yield (fugitive) resin (e.g., polystyrene) were developed, but were never adopted for the manufacture of large quantities of fuel compacts.
6. The overcoating method with resin binder was used for the manufacture of fuel compacts for the Dragon and HTTR, and for fuel pebbles for the AVR, THTR and HTR-10.

AGR FUEL COMPACT DEVELOPMENT

BASED UPON THE FORGOING DISCUSSION IT IS RECOMMENDED THAT THE PARTICLE OVERCOATING PROCESS BE ADOPTED AS THE REFERENCE METHOD FOR THE FABRICATION OF AGR FUEL COMPACTS