



Pebble Bed Modular Reactor High Temperature Materials

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October 2001

I-15

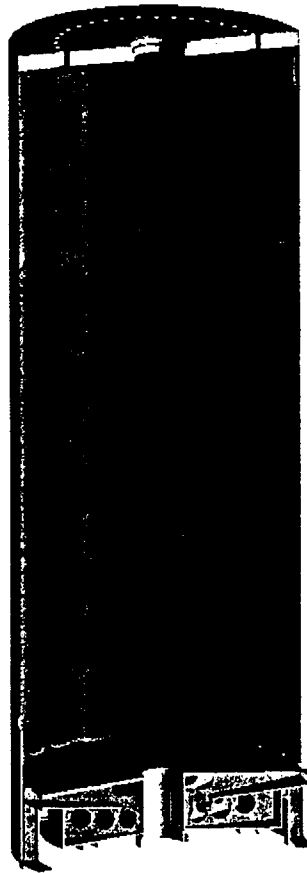


High Temperature Materials

- Core Barrel
- Control Rods
 - Chain
 - Segments
 - Secondary Shock Absorber
- Carbon-Carbon Composites

CORE BARREL AND SUPPORT STRUCTURE

Material: Type 316 Stainless Steel

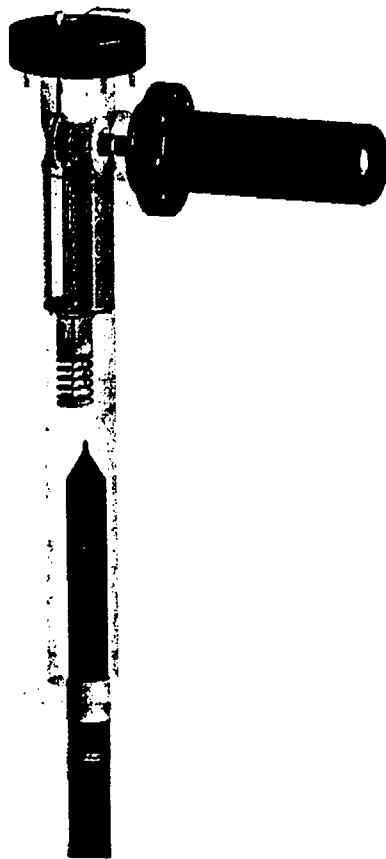


- Operating Temperature: ~490°C
- Abnormal Temperatures:
 - PLOFC, 590°C max
 - DLOFC, 711°C max
- Fast Fluence ($E > 0.1 \text{ MeV}$):
 $1 \times 10^{19} \text{ n/cm}^2$.
- Design Code: ASME III, Subsection NG and ASME Code Case N-201.
- This material is qualified for use in accordance with ASME III, Subsection NG (Core Support Structures) at service temperatures up to 429°C and for service temperatures between 429°C and 816°C by ASME Code Case N-201 for a design life up to 300 000hrs.



REACTOR CONTROL RODS

Material: Incoloy 800H



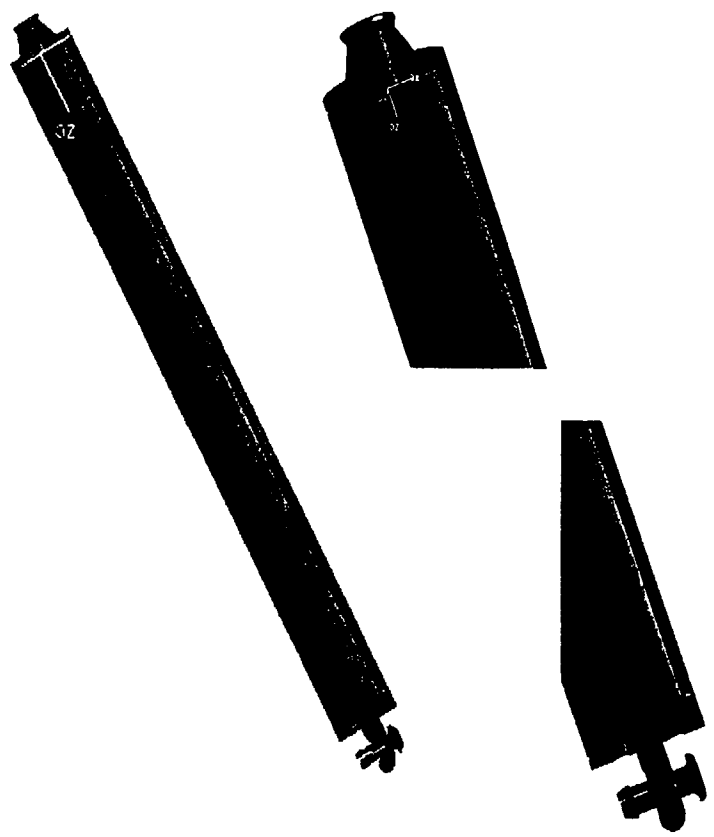
Chain

- Operating Temperature: ~330°C
- Abnormal Temperatures: PLOFC, 870°C max:
DLOFC, 900°C max
- Fluence (Thermal): $<5 \times 10^{21} \text{n/cm}^2$
- ASME III, subsection NH (Class 1 Components in Elevated Temperature Service) has qualified the use of Incoloy 800H to temperatures of up to 760°C, for service periods of up to 300 000hrs.
- Design data for temperatures up to 900°C and service periods of 300 000hrs as well as data for temperatures up to 1100°C and service periods of 100 000hrs have been provided in the guideline KTA 3221- Metallic HTR Components (in draft).
- The material's response to irradiation effects have been characterized in the German HTR development program. The test results envelop the following conditions:

Hot tensile testing (at temperatures between 400°C and 900°C) of samples irradiated at 400-600°C, to a fluence of $3 \times 10^{21} \text{n/cm}^2$ (thermal and fast).



REACTOR CONTROL RODS 1

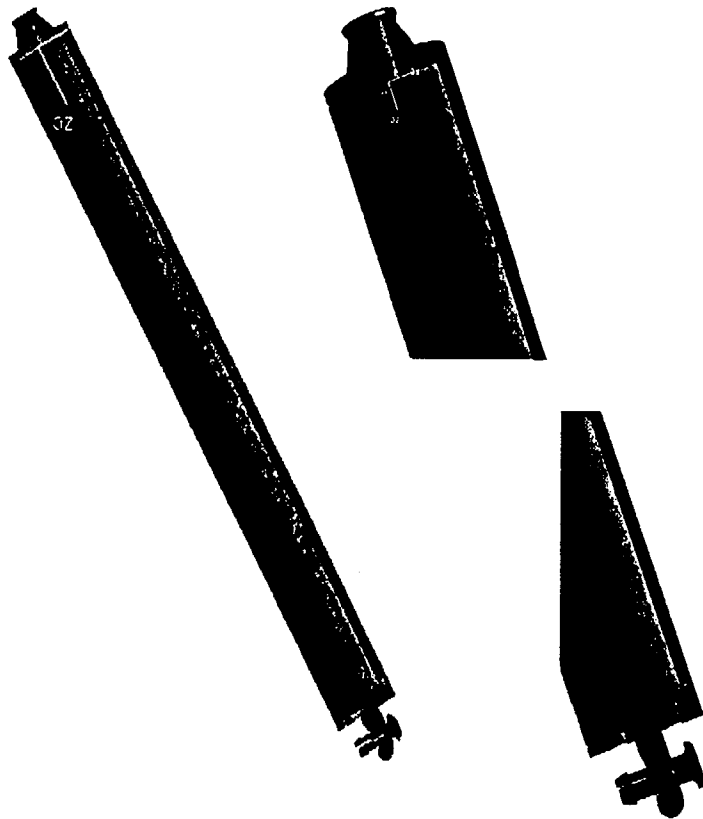


Segments

Material: Incoloy 800H

- Operating Temperature: ~650°C
- Abnormal Temperatures:
 PLOFC, 926°C max
 DLOFC, 1100°C max
- Fluence (Thermal):
 $5 \times 10^{21} \text{ n/cm}^2$

REACTOR CONTROL RODS 2



Segments

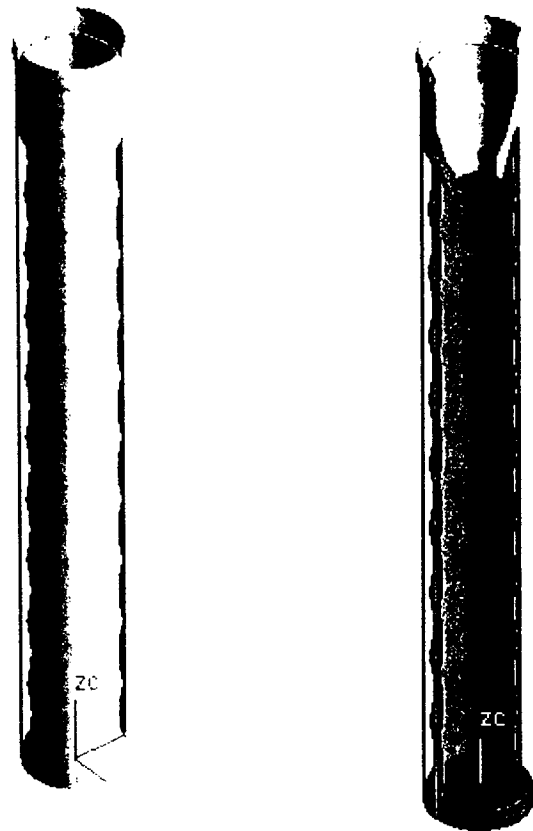
Material: B_4C

- Operating Environment: as above
- Density: 2.51 g/cm^3
- Melting Point: around $2,450^\circ\text{C}$
- Thermal expansion coefficient: $5 \times 10^{-4} \text{ }^\circ\text{C}^{-1}$
- High resistance to chemical attack
- High thermal neutron absorption cross section $\sim 4,000$ barns.
- Crystal structure: Rhombohedral
- Very high hardness: It is third hardest material next to diamond and cubic boron nitride (cBN).



REACTOR CONTROL RODS

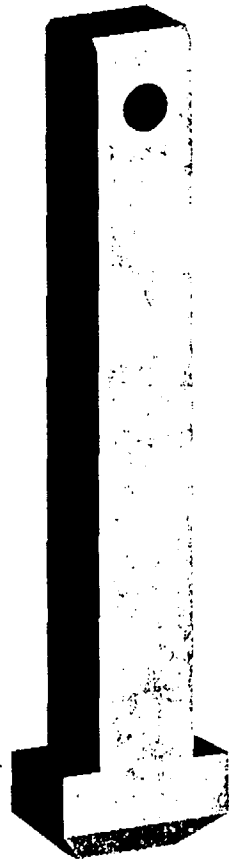
Material: Incoloy 800H



Secondary Shock Absorber

- Operating Temperature: ~900°C
- Abnormal Temperatures:
PLOFC, 1100°C max
DLOFC, 1100°C max
- Fluence (Thermal):
 $5 \times 10^{21} \text{ n/cm}^2$

Carbon-Carbon Composites



Carbon Composites

- Top Reflector Tie rods
 - Required safety factor >20
 - Fast neutron dose to base of rod = 1.56×10^{20} n/cm² EDN
 - Graphite Temperature = 1200 °C
- Restraints
 - Graphite Temperature = 1000 °C