July 14, 2022 – Session 3

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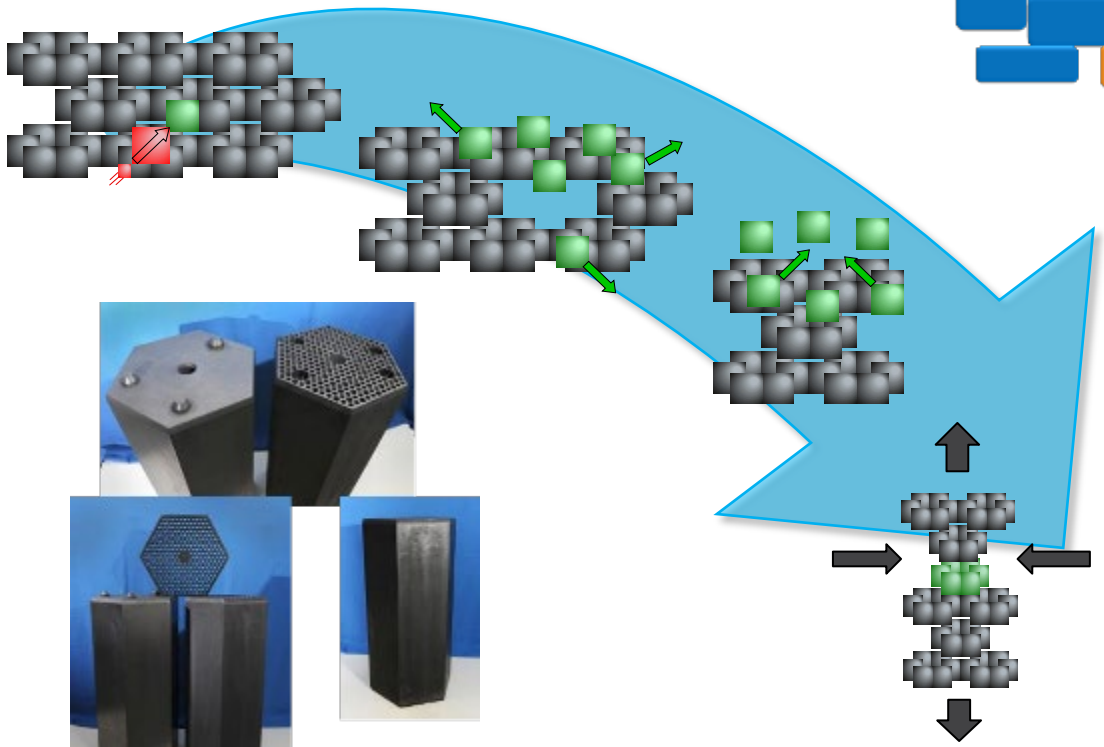
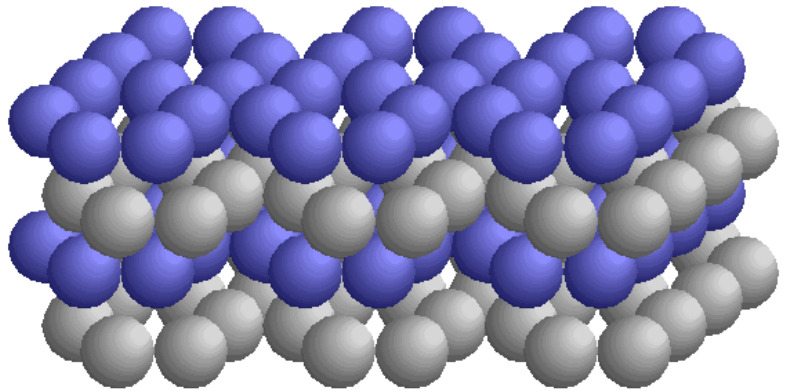
ART Advance Graphite Creep (AGC) Irradiation Experiment

ART
Advanced Reactor Technologies

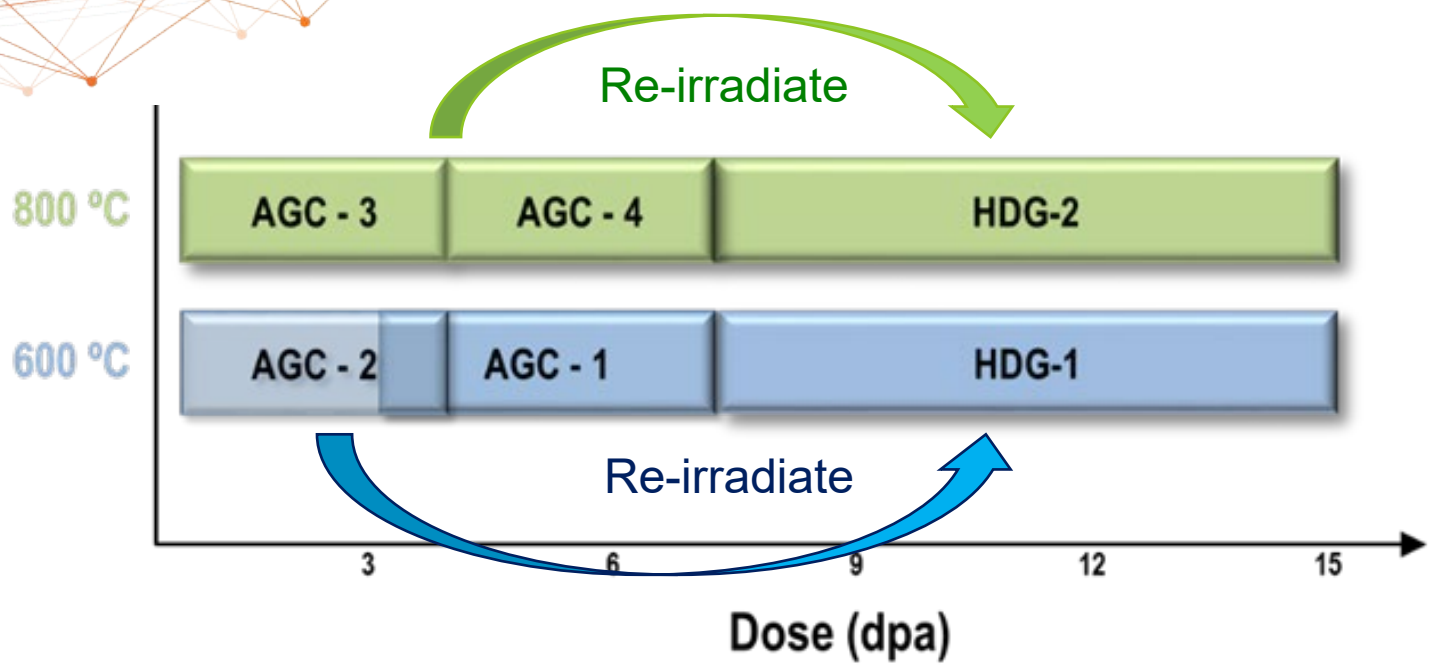
Topics of discussion

1. Schedule
   - ***Effects of COVID and CIC***
2. AGC Experiment Update
3. AGC-4 Status
   - ***Disassembly and Decon***
   - ***Initial PIE***
4. Anticipated areas data will be used
   - ***ASME code rules for irradiated graphite data***
   - ***Support of HTR designs***
   - ***Collaborations (Commercial vendors, NRC, GIF, IAEA)***
5. New vendor specific irradiation capsule
   - ***Why? Please not another AGC experiment***
   - ***How does it fits with new ASME code rules***





AGC Irradiation Experiment: A review



Graphite material property database

- Irradiation creep
- Thermal changes
- Mechanical changes
- Physical changes

Initial 600°C and 800°C irradiations

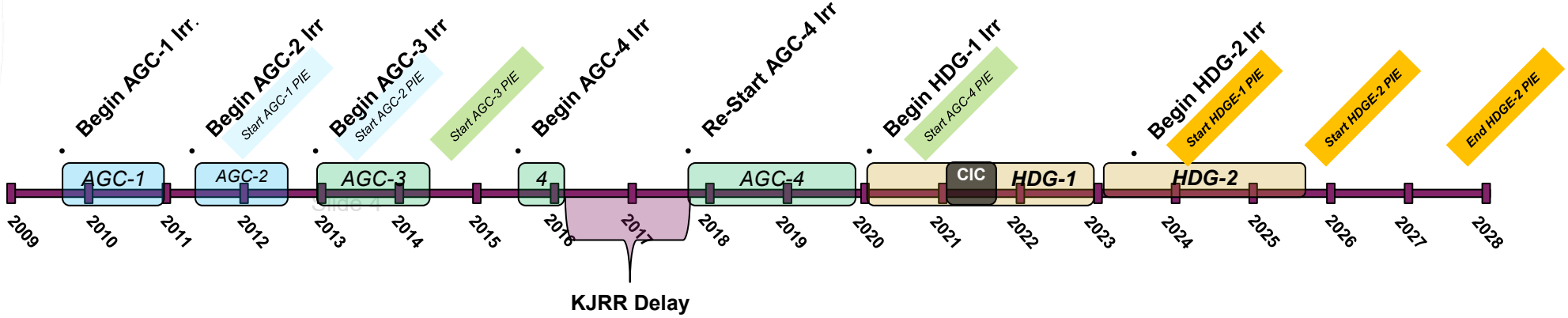
- AGC-1 and AGC-2 (600°C irradiation)
- AGC-3 and AGC-4 (800°C irradiation)
- Dose range ~ 1 to 8 dpa (for both temperatures)
- **Creep data!**

High Dose Graphite (HDG) capsules

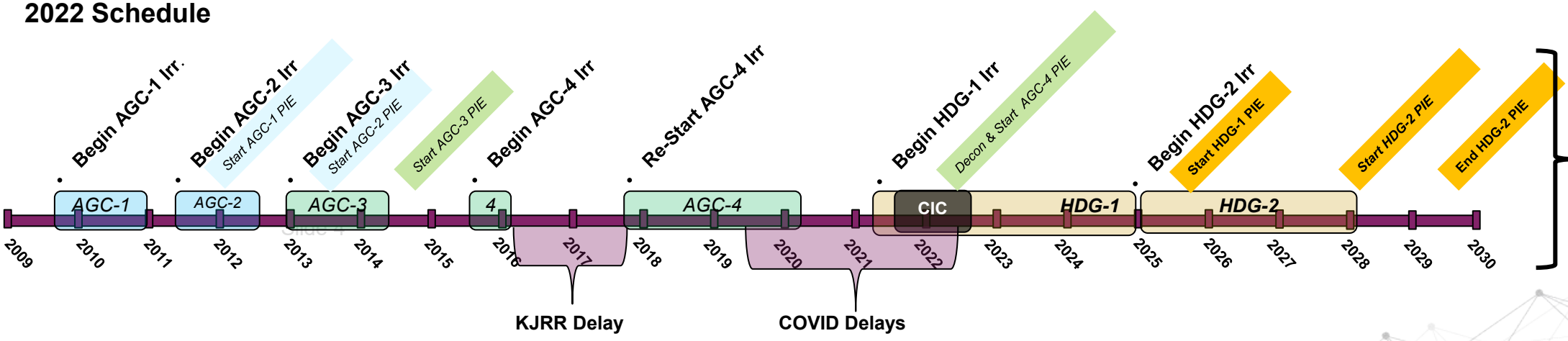
- Re-irradiate previous AGC specimens
- Higher max dose (15 dpa)
- Same Temperatures (600 – 800°C)
- **Higher dose creep data!**

AGC Experiment Status

2018 Schedule



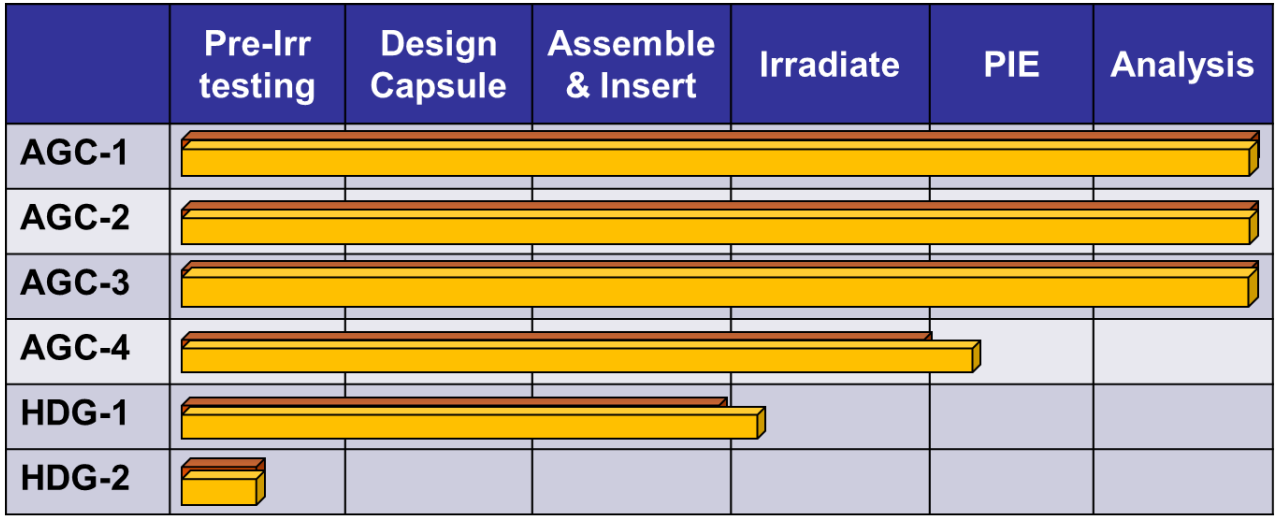
2022 Schedule



COVID & CIC added about 18 months to AGC schedule

Irradiation material properties (AGC Experiment)

- **AGC-1 & AGC-2 :** 600°C (0.5 to 7 dpa)
  - Initial irradiation, PIE, and analysis is complete
- **AGC-3 :** 800°C (0.5 to 3.5 dpa)
  - Initial irradiation, PIE, and analysis is complete
- **AGC-4 :** 800°C (3 to 8.5 dpa)
  - Irradiation complete (February 2020)
  - ***Specimen disassembly complete***
  - We have some specimen with high rad levels
  - PIE (2022 – 2023)
- **HDG-1 :** 600°C (7 to 15 dpa)
  - Back in ATR – ready for irr: 2 more years to max. 15 dpa
  - **Re-irradiation of AGC-2 specimens**
    - *Added super-fine grain sized grades => of interest for MSR designs*
- **HDG-2 :** 800°C (7 to 15 dpa)
  - Irradiation begins 2023
  - Re-irradiation of AGC-3 & -4 specimens to max. 15 dpa



Pertinent Irradiated Graphite Reports
ECAR-5345, As-Run Physics Analysis for the AGC-4 Experiment Irradiated in the ATR, January 2021
ECAR-5414, As-Run Thermal Analysis for the AGC-4 Experiment Irradiated in the ATR, April 2021
INL/EXT-21-63591, AGC-4 Disassembly Report, July 2021

AGC-4 Disassembly

Extraction of AGC-4 samples has been difficult

- Approximately 4-5 samples were clearly crushed
- Center stack region needed to be machined out
- ***But … disassembly completed late FY21***

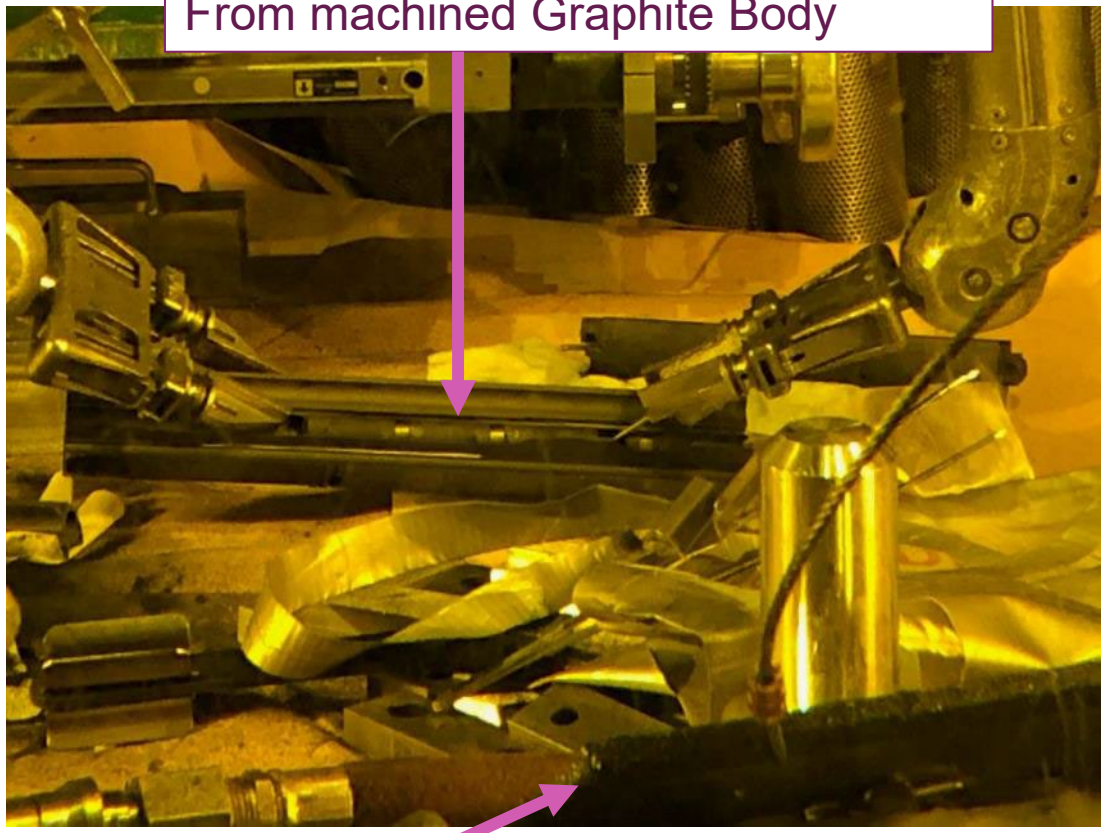
High activity levels detected

- Appears that several specimens have high rad levels
- Special decon glovebox set-up
- Decontamination of all specimens
  - *Activity levels measured for individual specimens*
- Early indications indicate more than simple contamination resulting from disassembly
  - *Preliminary results point to Nickel in graphite*

PIE options based on activity levels

- AGC-4 PIE has begun on low rad level specimens
  - ***Initial shipment = 3 samples. 20+ in June 2023***
  - ***Will be shipping piecemeal. Ship as available***
- If activity levels are too high ➔ Limited PIE on the desert
  - Want to avoid this if at all possible

Extracting piggyback samples
From machined Graphite Body



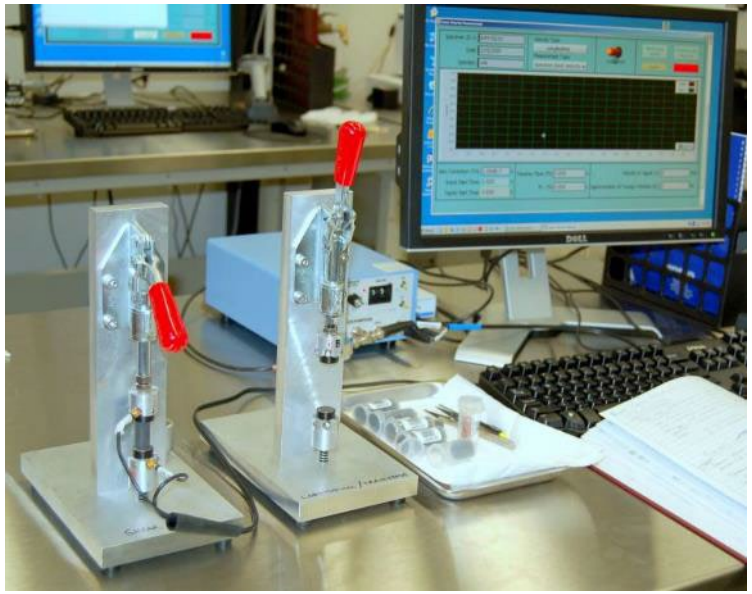
Broken half of graphite body

AGC-4 PIE Status

New Split-Disk Strength

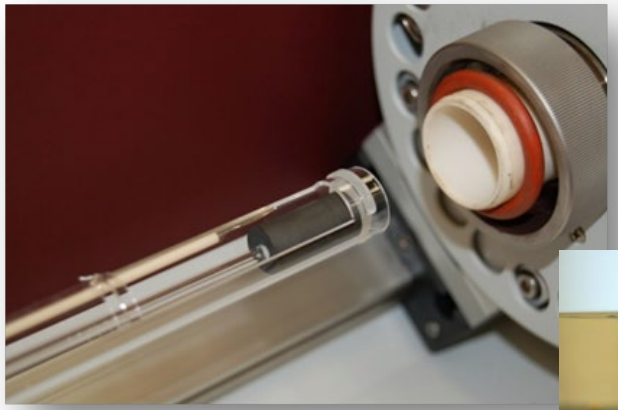
ASTM D8982

Stiffness modulus

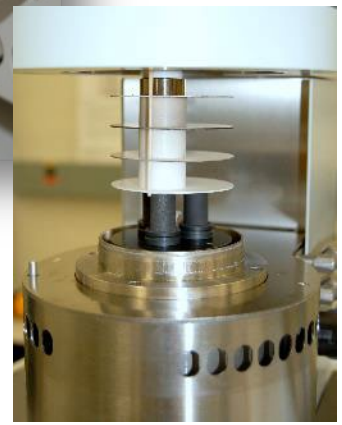


ASTM C 769

CTE



ASTM E 228-06



Physical & Thermal Properties Testing

- *Density*
- *Coefficient of Thermal Expansion*
- *Thermal Conductivity*
- *Resistivity*
- *Resonant Frequency (E_{DYN})*
- *Torsional Frequency (G_{DYN})*
- *Sonic Velocity*
- *Fracture Character**

**Not a non-destructive evaluation*

Tested 3 specimens so far …

- Current batch of specimens being tested

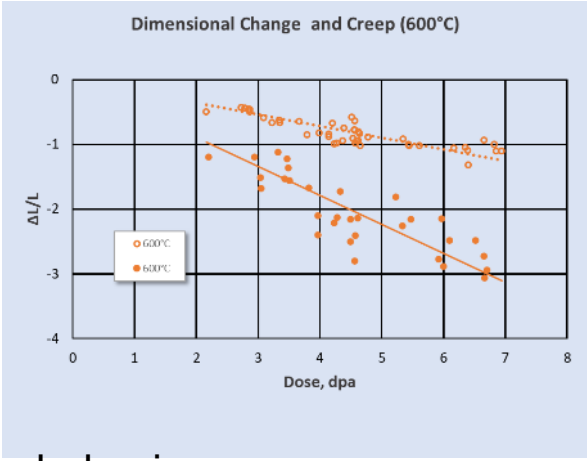
Due to decontamination expect small batches

- Several small batches of specimens
- Much longer time to test

Who/What will use the data?

Commercial reactor design (Direct)

- Any design using the same parameters of AGC Experiment can use the data directly
  - *Same graphite grade, T_{Irr} range : 500 – 850C, dose range : 1 to 8 dpa (15 dpa after HDG)*
- Irradiation dimensional change, creep rate, and material property changes

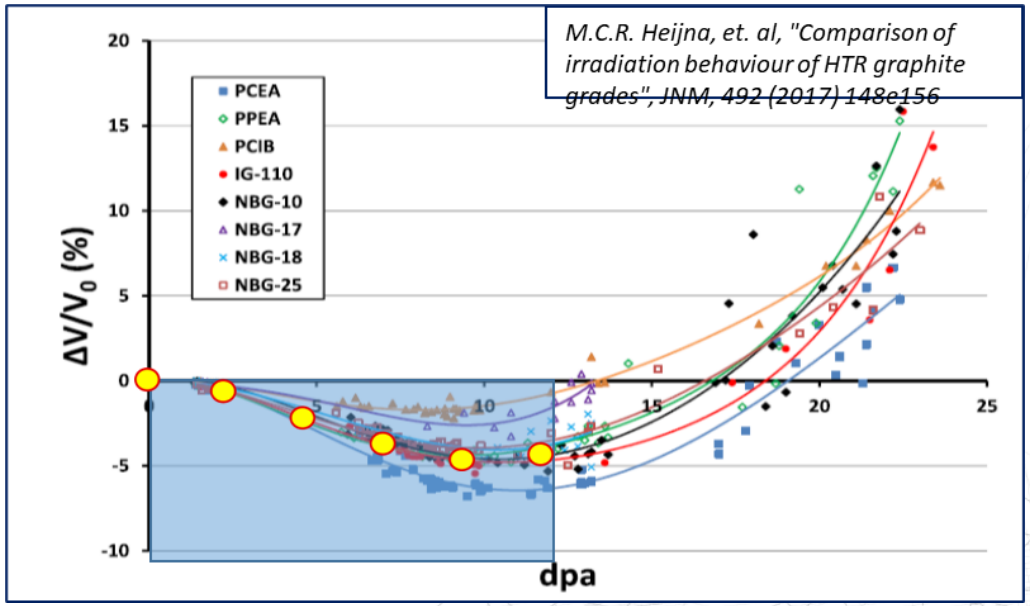


Commercial reactor design (Indirect)

- Other HTR designs can indirectly use the AGC irradiation behavior and creep data
- Combined with the ASME code methodology the data can be used to demonstrate similar behavior
  - *Will need to justify how the graphite is similar*

ASME code development *(Steve Johns)*

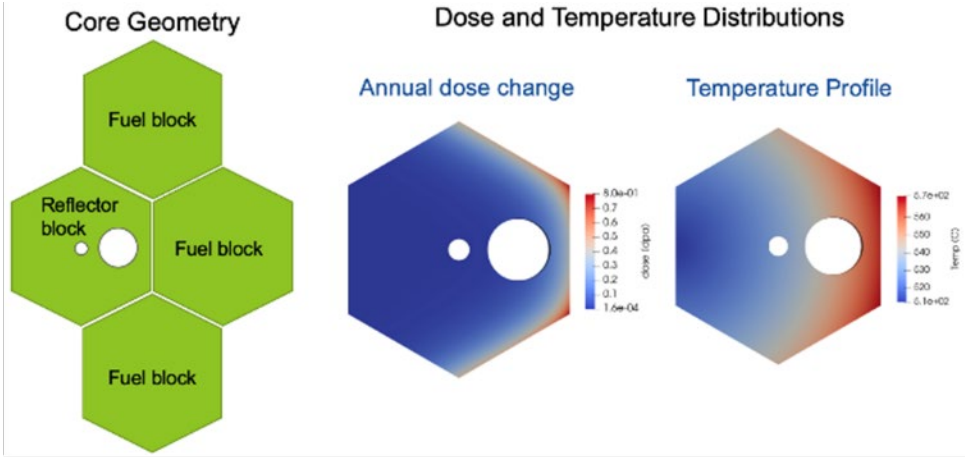
- Used to justify universal graphite response **up to turnaround**
  - *Up to turnaround: All grades behave similarly*
  - *Past turnaround dose: Grades are **not** similar*
  - *So long as your graphite grade is within the data "cloud"*
- Similar methodology for creep response/rate



Who/What will use the data?

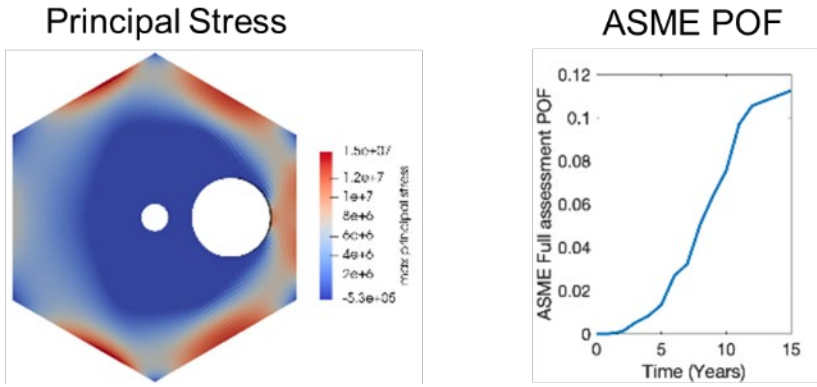
- **NRC/Licensing questions on irradiation behavior**
  - Training, general questions, topical reports, etc.
  - Assistance with acceptance of ASME code rules

Setup

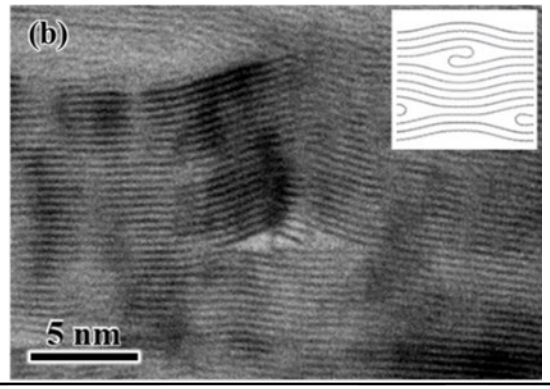


- **Behavior model development** (Joe Bass)
  - Irradiation induced stress build-up (failure determination)
  - Irradiated material property changes
  - Combination of degradation (no empirical data possible)
    - *Irradiation + oxidation + Molten Salt*
- **Other Collaborations**
  - GIF, IAEA, International and National Fundamental Studies

Results



Fundamental studies are designed to explain the empirically measured results



Evidence of a "Buckle, ruck and tuck" defect proposed as possible underlying defect for irradiation creep

Commercial HTR irradiation capsule

Determining interest in a new graphite irradiation capsule

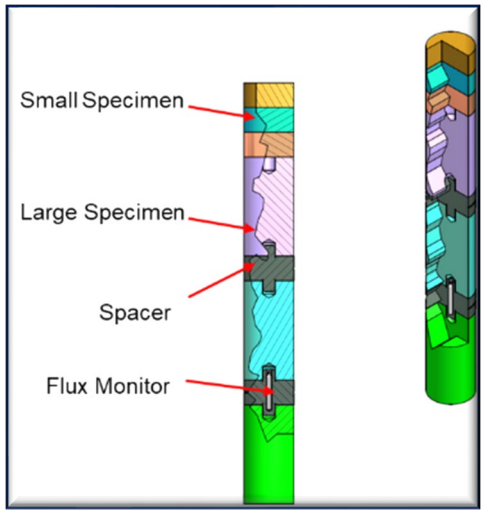
- DOE would provide initial capsule design for use by as many commercial vendors as possible
- DOE would assist determining MTR availability and irradiation positions (ATR and HFIR)
- DOE provides material irradiation experience

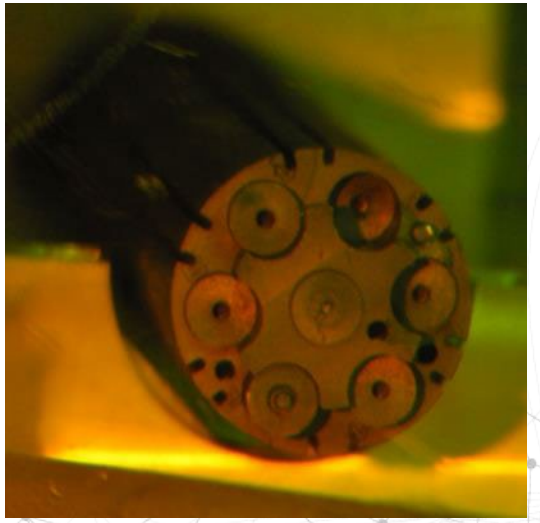
Commercial HTR designers

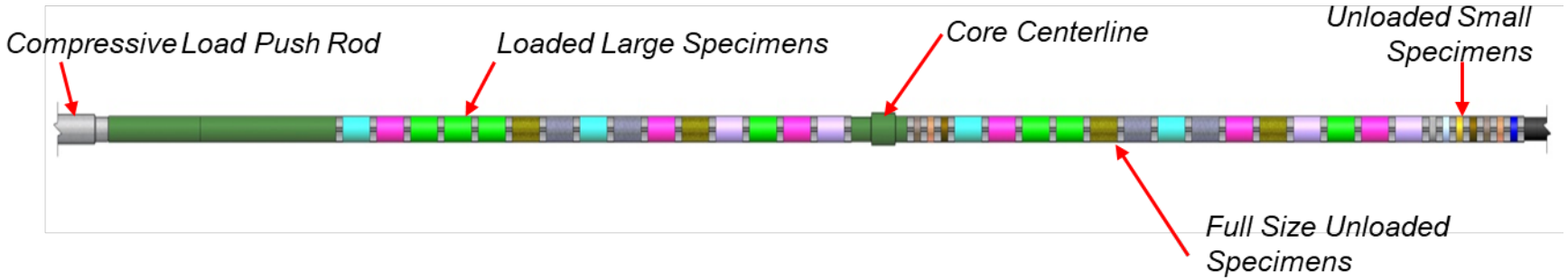
- Designers must determine if they require new or additional graphite irradiation data
- Designers pay for completion of capsule design, assembly, and specimen PIE
  - *Specimen size, testing, irradiation dose, temperature, creep, etc.*
- Capsule intended to be shared by multiple vendors – ***cost share***

Provides limited data needed for ASME's "before turnaround" rules

- This capsule will provide the dozen or so data points as explained previously
- **Saves time, schedule, and cost**







Idaho National Laboratory