OECD Halden Reactor Project

ATF experiments overview

4th Meeting of the Expert Group on Accident Tolerant Fuels for LWRs
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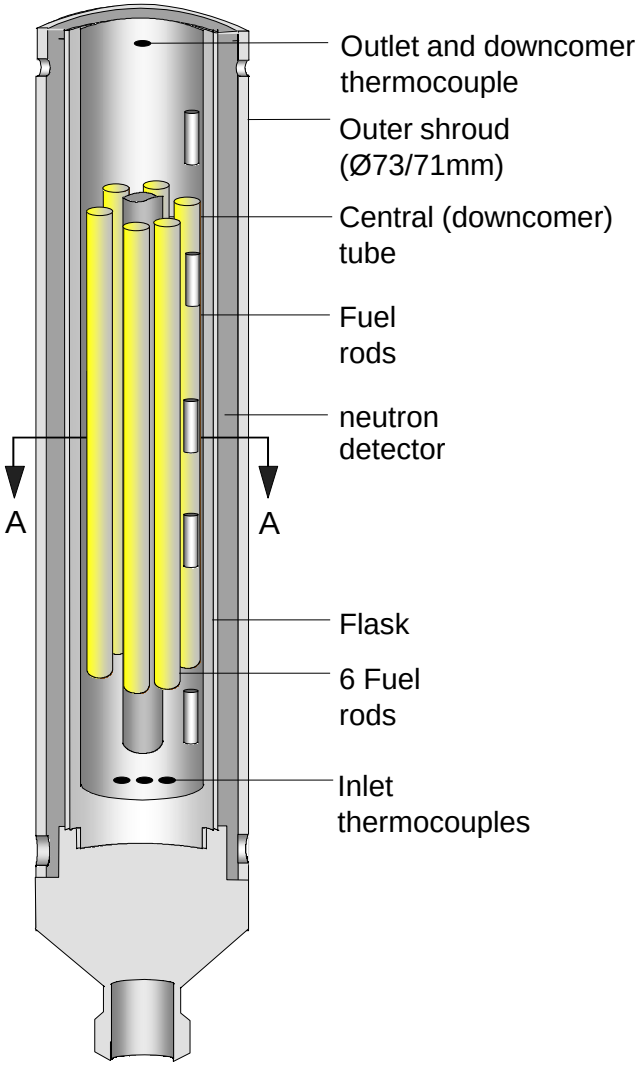
Corrosion, creep and growth behaviour of ATF claddings



- Determine ATF cladding performance under normal PWR operating conditions
- Cladding corrosion determined via interim inspections (visual and eddy current) and PIE
- Cladding dimensional changes determined during interim and PIE (profilometry)
- Limited options for in-pile instrumentation
- Use of segmented rods as in IFA-708/785 to increase size of test matrix
- Option to start with smaller than standard fuel-clad gap to promote early PCMI
- Fuel pellet enrichment (to be made at Kjeller) to produce ALHR ~25-30 kW/m

ATF cladding test – proposed materials

- Candidate claddings proposed by HRP participants so far:
  - CEA
    - low tin Zry-4 with ~5-15 μm chromium coating (optimized PVD process)
    - 2 variants - different coating thickness and microstructure
  - KAERI
    - Zry-4 with ~80 μm chromium coating (3D laser process)
    - Surfaced modified Zry-4 (laser beam irradiation with ODS treatment)
  - IFE
    - Zry-4 with ~2-4 μm CrN coating (PVD – commercially available) as shown in IFA-774
  - ORNL
    - Modern Fe-Cr-Al ferritic alloys
    - 2 alloy composition variants
  - EPRI
    - PVD coated Mo thin-walled tube
    - 4 variants: Mo-LCAC (pure Mo) and Mo-ODS with a coating of Zry or FeCrAl

ATF cladding test - test matrix under discussion

add EC?

Segment	CEA	KAERI	IFE	ORNL	EPRI	REF
	Rod 1	Rod 2	Rod 3	Rod 4	Rod 5	Rod 6
Top*	~5 μm Cr	~80 μm Cr	CrN	FeCrAl-1	Mo-LCAC FeCrAl	Zry-4
Top-mid	~15 μm Cr	ODS	FeCrAl-2		Mo-LCAC Zry	Zry-4
Bot-mid	~5 μm Cr	~80 μm Cr	CrN		Mo-ODS FeCrAl	Zry-4
Bottom*	~15 μm Cr	ODS	FeCrAl-2		Mo-ODS Zry	Zry-4

** possibility to unload and replace segment mid-way for destructive PIE*
NOTE: would require re-fabrication

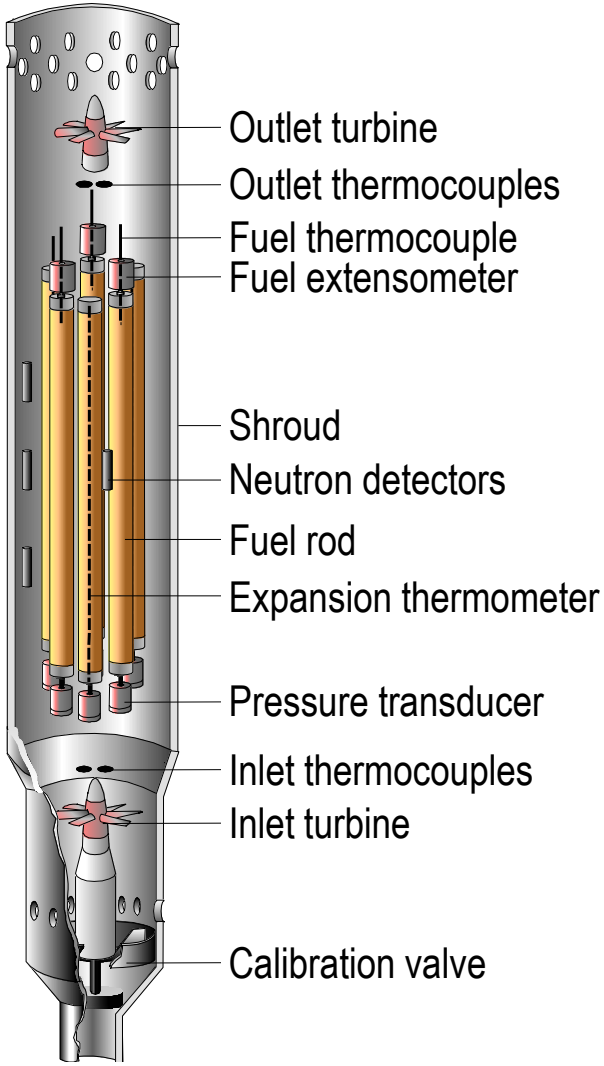
ATF cladding test - test plan

- To be discussed and decided upon by HPG during **2015** with irradiation planned to start **2016**
- Prototypic PWR conditions for ~5 years with target ~45 MWd/kg or 4-5 dpa
- Interim inspections after cycles 1, 3, 5, 7, 9:
  - cladding appearance (visual / photos)
  - oxide thickness and defect detection (where possible with eddy current technique)
  - dimensional changes (profilometry)
- PIE (can also be performed on segments unloaded e.g. mid-way*):
  - oxide thickness and morphology, hydrides (optical metallography and limited SEM)
  - HT oxidation (hot-cell LOCA) testing
  - recommend additional PIE and testing at participant labs (TEM, EPMA, mech. props, RIA ...)
- Specific objectives include:
  - Checking for any coolant-clad/coating interaction issues
  - Effect of irradiation on clad/coating microstructure and remaining HT oxidation resistance
  - Effect of PCMI on clad/coating integrity

** requires disassembly & subsequent re-fabrication with replacement segment*

Long-term irradiation of additive / ATF fuels

- A long-term fuel irradiation experiment is planned to study the thermo-mechanical and FGR behaviour of enhanced performance fuels
- Candidate fuels proposed by HRP participants:
  - Additive fuel aimed at retaining fission gas products in the pellets during transients/accidents and/or imparting higher thermal conductivity (KAERI)
  - UN fuel with USi (SSM/KTH)
  - Fuel as disks (high BU accumulation rate) for future PIE (cooperation with EPRI – NFIR) e.g v.small/v.large GS, USi, UN, AlSi-UO2
- Discussion and decision by HPG during **2015/2016** with irradiation starting **2017**



Long-term irradiation of additive / ATF fuels – test plan

- Plan to use a test rig with 6 fuel rod positions (like IFA-716)
- Irradiation under HBWR conditions for ~5 years from zero to ~45 MWd/kg
- Fuel rods with small BOL fuel-clad gap (PCMI) and 3 instruments per rod
  - **Thermocouple**: fuel centre-line temperature (thermal conductivity)
  - **Pressure bellows**: fuel densification & swelling then FGR
  - **Fuel stack length**: direct fuel densification & swelling
- Specific objectives include:
  - How does micro-cell UO_2 fuel compare to UO_2 for thermo-mechanical and FGR?
  - Does micro-cell UO_2 fuel retain fission products during transients?
  - How does UN/USi compare to UO_2 for PCMI and dimension stability (swelling)?
  - "PIE behaviours" of fuel variants at high burn-up: thermal conductivity, microstructural changes, fission gas, fragmentation ..... (ref: IFA-649)
- Recommendation to plan for extensive PIE and testing also at participant labs

Thanks for your attention!