Nermeen

$\boxed{83}$

① $T = 650\,K$ $t = 300$ days $\delta = 300\ \mu m$

ⓐ

$t^* = 6.62 \times 10^{-7} \exp\left(\frac{11949}{650}\right) = 63.8$ days ✓

$t > t^*$ we are in the linear oxidation rate

14/14

$\delta^* = 5.1 \exp\left(\frac{-550}{T}\right) = 2.19\ \mu m$ ✓

↳ critical thickness of the transition

linear oxidation rate

$K_L = 7.48 \times 10^6 \exp\left(\frac{-12500}{T}\right) = 0.033\ \frac{\mu m}{d}$ ✓

oxidation thickness

$\delta = \delta^* + K_L (t - t^*)$ ✓

$= 2.19 + .033 (300 - 63.8)$

$= \boxed{9.9846\ \mu m}$ ✓

ⓑ

off by a factor of 10

$C_H = \frac{2 \times f \times \rho_{oxid} \times f^o_{ZrO_2} \times \frac{M_H}{M_O} \times 10^6}{\left(t - \frac{\delta}{PBR}\right) \times \rho_{Zr}} = \boxed{10.36\ wt\text{-}ppm}$ ✓

$f^o_{ZrO_2} = \frac{2 \times 16}{91 + 32} = 0.26$ ✓

$f = 0.18$ ✓

$\rho_{oxid} = 5.68\ g/cc$ ✓

$\rho_{Zr} = 6.5\ g/cc$

$\frac{M_H}{M_O} = \frac{1}{16}$ ✓

$t = 500\ \mu m$ ✓

$PBR = 1.56$ ✓

→ need to add initial hydrogen

②

$\delta = .005\ cm = .0005\ dm = 50\ \mu m$

$Area = 2.5 \times 2.5\ cm^2 = .25 \times .25 = .0625\ dm^2$ ✓

4/4

$\delta = \frac{w}{14.7}$ ✓

$.005\ cm = 50\ \mu m$

$\therefore w = 735\ mg/dm^2$ ✓

$m_2 - m_1 = w \cdot Area = 735 \times .0625$ ✓

$= \boxed{45.94\ mg}$

③ metallic fuel redistribution

Zr diffuses via soret diffusion up the temperature gradient and Also possesses different solubilities in each U phase.

4/6 Which leads to different content of Zr in radial rings.

Ⓐ gama phase → high Zr content.

Ⓑ beta phase → low Zr content

Ⓒ δ/α phase → as fabricated Zr content

and each phase has different elastic and thermal properties.

④

material → plutonium + uranium, highly irradiation tolerant

→ clad is steel

8/8

→ Operates at higher linear heat generation rate twice higher than LHR in LWR

→ Smaller diameter than LWR fuels

→ with stands higher damage, higher mechanical stability

environmental

→ sodium is coolant in SFRS

→ higher neutron flux.

→ T center line reaches 2000°C higher than thermal LHR

Pu bearing display 4 regions of a restructed pellet

- central void
- columnar grain growth region
- equiaxed grain growth region
- as-sintered region

- Chemically

- O/M ratio in the range of 1.93 - 2 ✓

oxygen redistributed radially - migrating dow the thermal gradient

- O/M become very low at <u>HOT</u> areas ✓

- O potential increases until Mo start to oxide leaving metallic inclusions
  - near the periphery → depleted Pu
  - in the central area → enriched Pu

  } for irradiated Mox ✓

- Achieve very high burn up and the most common fission element percipitates Mo, Ru, Tc, Rh, Pd ✓

- formation of JOG happens in MOX due to the migration of the fission products to the cold region of the pellet and then accumulate between the fuel and the cladding ✓

- all correct, probably provided more info than necessary

8/8

(5) (1) The central void forms due to the accumulation of voids and pores existing in the fuel along a thermal gradiant.

(2) The columnar grain
- The pores filled with gas and has higher temperature gradient fuel evaporating from hot face and condense on the cold face which induces an inverse displacement of the lenticular pores that climb the thermal gradiant to the center of the pellet
This transition destroy the initial fuel in elongated columnar grain and this happens at T vapour ~ 1800°C

(3) - Below T = 1800°C equiaxed region
have grains undergone significant growth
- At the periphery of the fuel pellet T are low to limit grain growth so the microstructure doesn't undergo rapid changes.

(4) as - Fabricated
Initial O/M is 1.93 - 2.00
the oxygen is redistributed radially, migrating down and bringing the composition ~~near~~ close to stoichiometry near the peripheiry

⑥ RIA

Large rapid insertion of ractivity caused by inadvert ejectio. (PWR) or drop (BWR) of control rod ✓

8/8

effects

lead to fast rise in fuel power ✓ and T, lead to failure of fuel rods and release ✓ radio active material into fuel or coolant. which cause rapid steam generation ✓ and pressure pulses ✓ damagin the core if this hot fuel releasedinto the water.

⑦ in LOCA

the coolant flow is reduced or lost ✓ (like pipe break) when this happens (pressure drops, and the Emergency shut down system is engaged) ✓, EECS removes the heat

7/8

At LOCA

Cladding plastically deform due to ✓ decrease of system pressure out side the fuel and decrease incladding strength ✓

Zralloy → transforms from α to $\alpha+\beta$ → $T > 800°C$

and to β $T > 1000°C$ ✓

creep strength of Zr falls.

- oxidation is key here also

⑧

① pellet clad mechanical interaction ✓

4/4 ② Cladding elongation and assembly bow. ✓

⑨ ~~e~~quality of water , including minimizing oxygen ✓
to reduce electrochemical corrosion potential and oxygen
8/8 and to control pH ✓
to control corrosion

H serves as getter for O

water chemistry is the component of water O, H
and controlling them.

⑩ pressure build up ✓

fission librate oxygen which binds the carbon
8/8 ~~layer~~ buffer and form CO ✓

irradiation growth ✓

fuel kernel swell as a function of time and
buffer will shrink ✓

PyC layers will initially shrink under irradiation. ✓

(11) #11 0/10 #12 0/4

(13) <1 oxidation is thin and will be broken

4/4 >2 oxidation chips off, and not protective

$1 < PBR < 2$ oxidation is passivating and provides

a protecting effect against further surface

$$PBR = \frac{\text{Volume per unit of metal oxide}}{\text{Volume per unit ~~for~~ of metal}}$$