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①

$\boxed{80}$

1. $T = 625K$, $t = 400 days$, $\delta_0 = 500 \mu m$

(a). $\delta(\mu m) = \delta^* + k_L(t - t^*)$

13/18

where $\delta^* = 5.1 exp(-550/625) = 2.115 [\mu m]$

$k_L = 7.48e+6 \cdot exp(-12500/625) = 0.01542 [\mu m/day]$

$t^* = 6.62e-7 \cdot exp(11949/625) = 113.007 [day] \approx 113 day$ → 133 dy

$\delta = 2.115 [\mu m] + 0.01542 [\mu m/day] \cdot (400 - 113)$ → 133

$= \underline{6.5405 [\mu m]}$

(b). $f_H = 0.18$, $PBR = 1.56$, $\rho_{Zr} = 6.5 g/cc$, $\rho_{ZrO_2} = 5.68 g/cc$, $t = 1yr$ → 365 days

$$C_H = \frac{2 f_H \delta \rho_{ZrO_2} f^o_{ZrO_2} \frac{M_H}{M_O}}{(t - \frac{\delta}{PBR}) \rho_{Zr}} \times 10^6$$

$f^o_{ZrO_2} = \frac{32}{91+32} = 0.26$

$\frac{M_H}{M_O} = \frac{1}{16}$

take this to find δ

$\left(2 f_H \delta \rho_{ZrO_2} f^o_{ZrO_2} \frac{M_H}{M_O}\right) = 2 \cdot 0.18 \cdot 6.5405 \cdot 5.68 \cdot 0.26 \cdot \frac{1}{16}$

$= \underline{0.2173}$

t = initial cladding thickness

- right process

$\left(t - \frac{\delta}{PBR}\right) = 365 - \frac{6.5405}{1.56} = \underline{360.807}$

$C_H = \frac{0.2173}{360.807} \times 10^6 = \underline{602.26 [wt\ ppm]}$

2. It is oxygen diffusion model. with following assumptions:
① Transport of O species is rate limity
3/4 ② Transport of charged species by diffusion only
③ Homogeneous oxide layer
④ No source/sinks of ions in oxide - through the oxide layer
⑤. All oxigen is used to create oxide
⑥. No loss of oxide.

3. $PBR = \frac{V_{oxide}}{V_{metal}}$, ✓ The ratio of the volume per unit of the metal oxide to the volume per unit of the corresponding metal.

4/4 PBR<1 : Thin oxide layer. ✓
1<PBR<2 : oxide layer approately swelly (Passivation)
PBR>2 : Too much swell.

4. Hydride occurs at crack tips. - hydride rim is main type of hydride
Hydrogen moves from bulk material to crack tips. Due to high stress
8/14 on the crack tip, ✓ hydroge potential on the tip becomes lower.
Hydrogen moves to the tip due to the potential. difference. and they are precipitated on the tip.

Hydride effect : loss of ductility. (embrittlement) ✓

5. $\left(\rho = \delta k = \frac{k-1}{k} \right)$ ← Reactivity. ✓ RIA describes the situations where reactivity suddenly change.
11/14

RIA in PWR : Reactivity increases a lot, because of insertion or ejection of control rod. ✓

RIA in BWR : Reactivity increases a lot, because of the separation of control rod blade from its drive mechanism. ✓

RIA leads to a fast rise in fuel power & temperature ✓ - needed more here
→ Fuel failure (Radiated material leaks to the coolant)
→ Rapid steam generation → Damage reactor coolant pressure boundary → damage fuel.

6. Loss of Coolant accident (LOCA) : It is one of the design basis for the reactor, define safety limits for its operations. ✓
LOCA happens due to the loss of coolant. ✓

12/14

Steps : ①. loss of coolant (coolant pressure decreases) ✓
②. Inner pressure of fuel increases ✓
③. Cladding balloon out and potentially burst. ✓

In high temperature, ✓ creep strength of Zr is reduced
→ plastic deformation → ✓ rupture → Balloning ✓ block coolant flow. ✓

LOCA's time scale is different with RIA (LOCA is larger (min))

-still needed more

7. Burnup makes material having less ductility. ✓ (Corrosian, ✓ hydrogen embrittlement, irradiation ✓ hardening). High burnup increases the possibility of failure. ✓

5/5

8. · Acquire coping time : The time required for the water to boil away, the fuel to melt, the molten fuel to breach the primary pressure boundary.

4/8

· It operates more time with loss of active cooling
· It operates without lower performance in normal
· Lifespan of fuel is improved. Improve safety margin

-didn't quite get there...
-good conceptual thinking

9. Corrosion happen on the Zr with high temp steam.

4/6

In high temp, oxygen increases alot ✓
→ heat cannot be distributed due to the high oxygen
→ Breakaway oxygen results in increased hydrogen pickup ✓
→ Embrittle the Claddy ✓

-needed more

10. ① Pallet Cladding mechanical interaction (PCMI) ✓
→ Maximum Risk for failure. Pallet fragment causes shear stress to the cladding. (Limit the hoop stress)

4/4

② Cladding elongation and assemble bow ✓
→

③ Cladding oxydation & hydrogen pickup ✓

(4) Claddy wear ✓

(5) Power to melt ✓

11. on the cladding surface, Ni, Fe and Co are precipited. So CRUD happens.

4/6

It prevents heat transfer ✓ and lower the perfomance of fuel. ✓
process ⇒ (local over heating) → Burst of Claddy → Prevent coolant movement.
→ Radiation field increases -Safety? activation of CRUD

12. In BWR: Intergrannular SCC is the key Chemistry Control issue — ① Injection hydrogen → ✓
② Control electro chemical potential ✓ → ③ Control ISCC

6/6

In PWR: ① A hydrogen overpressure on primary system ✓
→ Corrosion Control & ② Increasing PH → ✓ Corrosion Control
Injection Zn^{+2} → eject ^{60}Co from CRUD ✓