Imtiaz

87

Ans to Q - 1 :

1(a)

Critical time for transition

20/20

$$t^* = 6.62\times10^{-7}\times e^{\frac{11949}{T}}$$

$$= 133 \text{days}$$

T = 625 K

t = 400 days

now,

$$K_L = 7.48\times10^{6}\, e^{\frac{-12500}{625}}$$

$$= 0.01542$$

$$\& \ \delta^* = 5.1\times e^{-\frac{550}{625}}$$

$$= 2.1154\ \mu m$$

∴ Oxide thickness after 400days,

$$\delta = 2.1154 + .01542\times(400-133)$$

$$= 6.2325 \text{ microns.}$$

δ after 1year,

$$= 2.1154 + .01542\times(365-133)$$

$$= 5.693\ \mu$$

1(b) weight ppm of hydrogen after one year,

$$C_H^{clad} = \frac{2f \times \delta \times \rho_{oxide} \times f^{o}_{ZrO_2} \times \frac{M_H}{M_o} \times 10^6}{\left(t - \frac{\delta}{PBR}\right)\times \rho_{metal}}$$

$$= \frac{2\times.18\times 5.693\ \mu m \times 1.48\ g/cm^3 \times \frac{1}{16}\times10^6}{\left(500 - \frac{5.693}{1.56}\right)\times 6.5\ g/cc}$$

$$= 58.76\ ppm$$

f = .18

δ = 5.693 microns

$$\rho_{oxide} \times f_{ZrO_2} = \left(\frac{32}{91+32}\right)\times6\ \rho_{ZrO_2}$$

$$= 1.48\ g/cm^3$$

=

ρ_{metal} = 6.5 g/cc

PBR = 1.56

Ans to the Q No-2

3/4

1) dissociation of O_2 in the oxide layer

2) Absorption of O_2 in the oxide layer

3) O_2 species travel through the clad

4) Oxidation of Zn occurs & release e^-

5) e^- passes through the clad outside

6) e^- reacts with H^+ to form H_2

$$Zr + 2H_2O \rightarrow ZrO_2 + 2H_2$$

- these are all of the steps
- which is rate limiting?

Ans to Q No-3

PBR is the ration of oxide to metal. $PBR = \frac{V_{oxide}}{V_{metal}}$

4/4 If,

PBR < 1, oxide layer is thin, no protective effect

PBR > 2, oxide layer chips off, no protection effect.

1< PBR < 2, provides passivation effect.

Ans to Q No-4

Hydride form outside of the oxide layer in the Zr

10/12 Cladding. H_2 is freed from the reaction through the reaction,

$Zr + 2H_2O \rightarrow ZrO_2 + 2H_2$, - why does it form on the outside?

- H_2 pickup causes embrittlement & delayed hydride cracking.
- DHC extends as, H_2 migrates from bulk material to the hydride crack tip due to stress difference between bulk & crack tip.

Impacts of hydride —

① localized hydrides form blisters which reduces ductility

② blisters are elliptic which covers almost half of clad thickness.

③ They covers wide axial & azimuthal direction.

③

Ans to the Q No - 5

10/12

RIA is a reactivity initiation ~~effect~~ accident which happens due to a change in the initial reactivity. The reasons for the changes may vary.

In PWR —

- control rod ejection accident
- due to coolant pressure, control rod may withdrawn from the core. (positive reactivity)
- In most severe cases, reactivity changes within 0.1 s.
- Most severe CREA occurs at normal coolant temp & pr & zero reactor power.

In BWR -

- Control rod withdrawal accident
- A control rod may separate from its drive mechanism
- After the separation it may drops out in a free fal inside the core (positive reactivity) (~~close to reactor~~
- Most severe CDRA Occurs on atm pr., zero power and room temperature.

this can lead to serious accident sometimes like DNBR phenomena, fuel melting & more severe similar to chernobyl accident, which is a RIA.

- wanted more description on temperature increase + effects

Ans to the Q No-6

8/10

LOCA is a loss of coolant accident which may happens due to the blockage of coolant flow in the system (sub assembly) or tube rupture etc by any process.

- still wanted more on the material impacts + overall effects

Although both RIA & LOCA increase the core temp, induces DNBR phenomena & lead to core melting at one point they are diff in occurance & mitigation as well

RIA	LOCA
-> due to insertion of ~~positive~~ reactivity	-> due to less coolant flow in the core
-> Can be mitigated through negative reactivity insertion or if the core is negative void co-efficient. (c)	-> needs to circulate ECCS & other heat removal systems, neg reactivity insertion will not help much.

Ans to the Q-7

Two pathways (2 for clad) - four options, but yes 2 clad, 2 fuel

6/6

- Coatings on cladding (Ti_3SiC_2, Cr)
- Alternate clad (SiC, FeCrAl)

2 for fuel -

- UO_2 dopants (Cr, SiC, BeO)
- Alternate fuels (USi, UN, UC)

~~the 2 pathway~~

Ans to Q No-8

6/6

- ~~Reacting A high temp above 600°C, oxide~~
- Zr oxidizes with exothermic reaction when T<600°C (linear kinetics)
- at high temp, oxide layer cracks & produces breakaway oxide.
- This results in loss of passivation which makes the

(8)

rate linear & localized.

Ans to the Q NO-10

Two limiting phenomena;

1) Clad elongation & assembly bow

4/4

- Irradiation causes clad axial growth (due to fast neutrons)
- Clad & pellet contacts causes axial elongation
- Reduced fuel rod pitch causes fuel to bow.

2) Clad wear

when max clad wall thickness crosses ASTM criteria (max reduction of 10%)

Ans to Q No-11

CRUD:

5/6

- Chalk river unidentified deposits in Ni alloy & stainless steel surface - cladding surface
- It may be dissolved ions (Ni, Fe, Co) on other FP -st -outside of the fuel -no FPs
- CRUD degrades heat production, irradiation produces radionuclide ^{60}Co, ^{63}Ni. - heat transport, ↑ local T

(7)

Ans to the Q No-~~12~~ 13

5/9

MOX | LWR

1) Compared to LWR, fuel column is short; fuel dia is less,

2) much higher heating rate than LWR

3) Fuel can stay longer (high burnup) in mox core than LWR

4) Guarantee absence of fuel melting

5) Cooling of the fuel pin upto very high burnup etc.

good start, but didn't really cover key phenomena.. reconstruction, JOG, FCI, etc.

Ans to the Q No-12

4/6 In LWR two water chemistry control —

① O_2 control - electrochemical potential?

② pH control

controlling pH can reduce the probability of CRUD formation which degrades the heat production, reduces heat transfer, increase fuel T.

Initial O_2 O/m ration is 1.93 ~ 2 which changes with time & changes in fuel stoichiometry. After the production of Mo O/m stabilizes at the value of ~ 2. Increase in O_2 species that is O/m causes clad corrosion (ZrO_2 formation which reduces the thermal conductivity - yes, but this isn't water chemistry.. this is fuel ...

#9? 0/4