SCHOOL OF CHEMICAL AND ENERGY ENGINEERING
UNIVERSITI TEKNOLOGI MALAYSIA

SKPN 4123 NUCLEAR REACTOR MATERIALS — Semester I 2018-2019
Test 2 — 90 minutes

1. List five types of damages that can be caused by radiation.

   Vacancies or Knock-ons

   Interstitials

   Ionization

   Thermal Spikes

   Impurity Atoms

   i. Explain the difference between ionization and excitation.

      ***Ionization** is complete removal of an electron from an atom following the transfer of energy from a passing charged particle*

      Excitation describe an interaction where electrons acquire energy from a passing charged particle but are not removed completely from their atom.

   ii. For radiation damage on materials, explain the difference between radiolysis and ionization.

      Radiolysis – breaking of chemical bonds by ionizing radiation

      Ionization - complete removal of an electron from an atom following the transfer of energy from a passing charged particle

(10 marks)

2. List three main types of metals used as structural material in an LWR.

   Steel, Zirconium Alloy, Nickel alloys

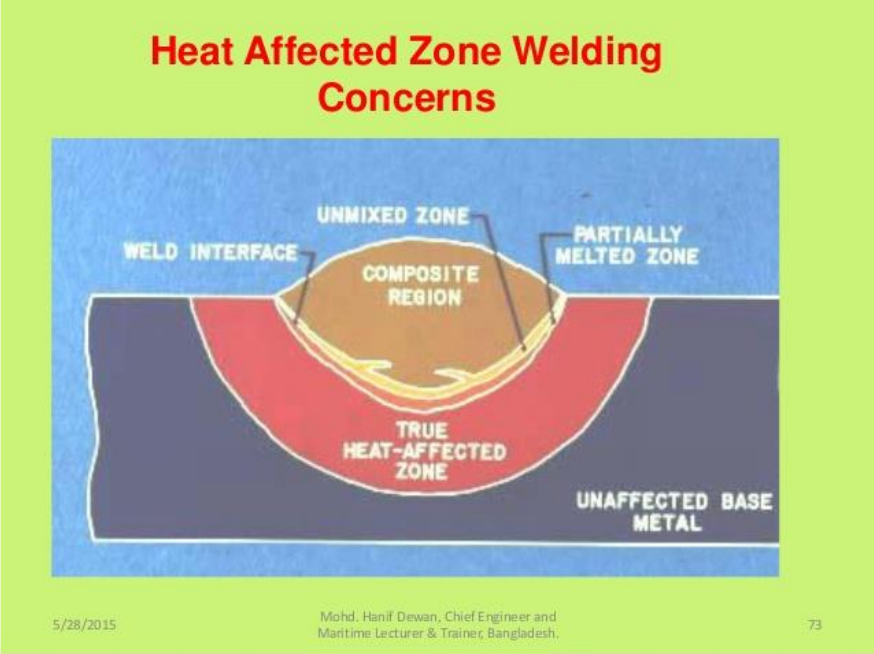
   i. List five major components of an LWR and the type of materials they are fabricated from (from your list above)

Component	Parts	BWR	PWR
Reactor Pressure Vessel (RPV)	Vessel and Head Cladding Stud bolts	Low alloy steel: SA533 Gr.B Cl.1 SA508 Cl.2, SA508 Cl.3 Stainless steel: Type308L high-strength low alloy steel: SA540 Gr.B Cl.3	Low alloy steel: SA533 Gr.B Cl.1 SA508 Cl.2, SA508 Cl.3 Stainless steel: Type308L high-strength low alloy steel: SA540 Gr.B Cl.3
RPV Internals (RPVI)	Core support plate Shroud Core internals, etc. Support/bolt, etc.	Low carbon stainless steel: Type304L, Type316L Nickel alloy: Alloy 600, Alloy X750	Stainless steel: Type 304 Cold-worked type 316 SS Nickel alloy: Alloy X750
Fuel Assembly	Fuel cladding Channel box	Zircaly-2 Zircaly-4	Zircaloy-4 -
Steam Generator (SG)	Shell Tubesheet Tube	- - -	Low alloy steel: SA533 Gr.B Cl.2 Low alloy steel: SA508 Cl.3 Nickel alloy: Alloy 600, Alloy 690
Piping	Pipes	Low carbon stainless steel: Type304L, Type316L Carbon steel: SA106 Gr.B	Stainless steel: Type304, Type316 Carbon steel: SA516 Gr.70

(10 marks)

3. Explain how welding affects material properties. Use appropriate sketches in your explanation. Discuss one method to mitigate the adverse effects of welding.

   The heat-affected zone (HAZ) is a ring surrounding the weld in which the temperature of the welding process, combined with the stresses of uneven heating and cooling, alter the heat-treatment properties of the alloy. The effects of welding on the material surrounding the weld can be detrimental—depending on the materials used and the heat input of the welding process used, the HAZ can be of varying size and strength. The thermal diffusivity of the base material plays a large role—if the diffusivity is high, the material cooling rate is high and the HAZ is relatively small. Conversely, a low diffusivity leads to slower cooling and a larger HAZ. The amount of heat injected by the welding process plays an important role as well, as processes like oxyacetylene welding have an unconcentrated heat input and increase the size of the HAZ.



Post Weld Heat Treatment is performed after welding, generally at a higher temperature and with different objectives than Preheat/Interpass heating.

PWHT method is applied with the work piece at temperatures up to 600° F (316° C).

Local PWHT of carbon and low alloy steels is typically performed below the lower critical transformation temperature and is therefore referred to as subcritical.

The lower and upper critical transformation temperatures indicate where the crystal structure of steel begins and finally completes a change from body centered cubic (BCC) to face centered cubic (FCC) upon heating (the reverse upon cooling).

(15 marks)

4. For corrosion;
   i. With the help of a diagram, state the three factors that cause stress corrosion cracking.

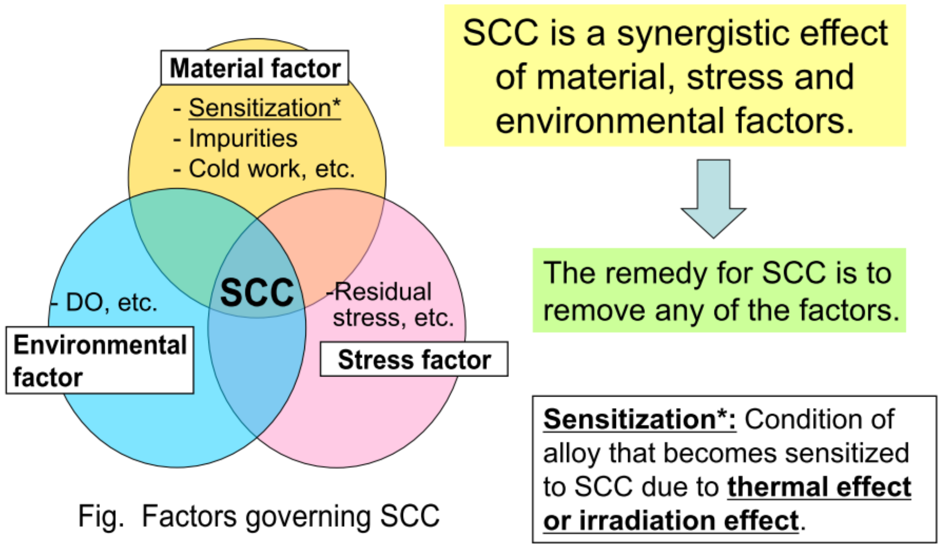


Fig. Factors governing SCC

ii. List and very briefly describe the five stages of SCC propagation.

i. *Initial condition - This stage represents the as-manufactured state of the material before exposure to the environment.*

ii. *Precursors - The precursor stage characterizes the exposure of the material to the operating environment.*

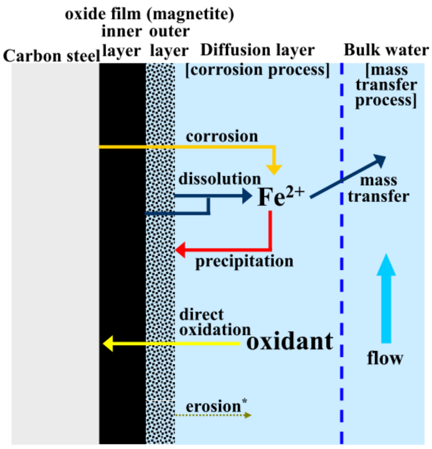
iii. *Incubation - During this stage the surface and microstructural changes occur that lead to crack initiation at the surface of the material.*

iv. *Proto-cracks - The formation of proto-cracks (cracks less than a few microns) results from vacancy coalescence, intergranular corrosion, etc.*

v. *Propagation - This stage represents the process in which the crack interacts both with the local stress field and the local chemical/irradiation conditions.*

iii. Explain the Flow Accelerated Corrosion phenomenon and discuss its mechanisms with the help of a sketch.

FAC mechanism: Two processes 1: corrosion process [production of soluble Fe 2+ and their accumulation at the oxide water interface] 2: mass transfer process [flowing water removes the soluble ferrous ions by a convective mass transfer mechanism]



(20 marks)

5. For fuel assembly;

   i. List and explain the factors in determining fuel rod spacing.

   Neutron travel distance.

   U-235/Pu-240 fission when they absorb a neutron with the correct energy level. when an U or Pu atom fissions, it releases about 3 neutrons. Most are traveling way too fast to be absorbed by U or Pu. They collide with the hydrogen atoms in water, to slow down. The distance between fuel pins should be just enough to allow the neutrons to slow down, but have a high chance of being absorbed by fuel and causing more fission events. Make the gap too large or too small can lose neutrons.

   Coolant flow.

   Enough room between the pins is important to get adequate coolant flow. Too little flow, steam forms, and impedes the heat transfer. Too much flow can cause the water to smoothly, and impede heat transfer.

   ii. Describe the partial length rod used in BWR. Explain the function and importance of partial length rods.

   Partial length fuel rods extend from the lower tie plate and terminate at an intermediate level below the upper tie plate.

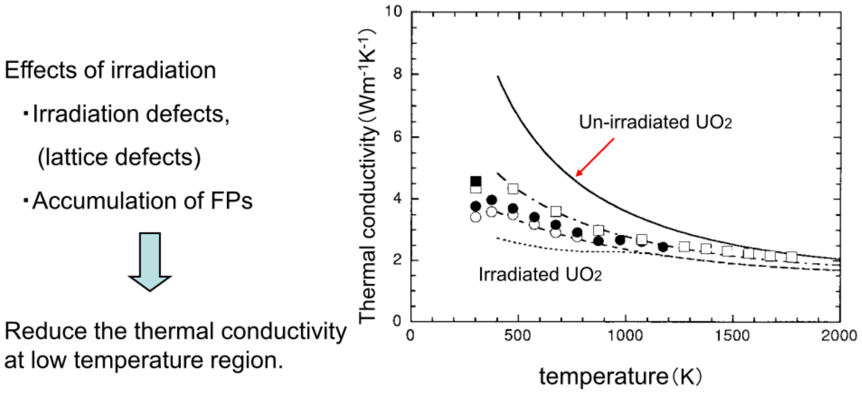
   The upper portion of the partial length control rod is stabilized by one of the fuel spacers.

   This arrangement reduces the amount of fuel in the upper core region.

The steam environment in the upper part of an operating core readily allows for the production of Pu-239.
The creation of Pu239 in the upper region of the core effectively adds new fuel to the core and adversely affects the reactor shutdown margin at the end of a fuel cycle.

iii. Explain why Zircaloy is chosen for fuel cladding. Explain one disadvantage of Zircaloy in this function.
low thermal neutron cross section and high melting point are important
Zircaloy-2 has good material properties and was chosen due to its superior heat transfer capacity as compared to other zirconium alloys
Above 300C, Zr + 2H2O → ZrO2 + 2H2 occurs to produce Hydrogen.

iv. Discuss how irradiation affects thermal properties of fuel rods.



Comparison of thermal conductivity model of irradiated UO_2 and experimental data

(20 marks)