Massachusetts Institute of Technology Nuclear Science and Engineering

Doctoral Qualifying Oral Exam. Part 2 Question. Nuclear Reactor Engineering

February 2018

In the Westinghouse **Small Modular Reactor** (LWR) all primary system components are housed inside the Reactor Pressure Vessel (RPV), as shown in Figure 1. The nominal reactor core power is 800 MWt. The RPV and steam generator pressures are 15 and 7MPa, respectively.

Reactor containment: in order to achieve the required modularity and transportability, Westinghouse wants to encase the reactor in a cylindrical containment with hemispherical endcaps, with a diameter of 10m as shown in Figure 2 and a thickness of 20 mm.

- **Electric Output: 225 MWe (Reactor Power: 800 MWt)**
- **Power Density 80 KW / liter**
- **Fuel Type: 17x17 PWR fuel, <5% enriched UO2 2.4 m Active Length**
- **Power Density**
- **Operating Pressure 15MPa [Secondary system 7.6MPa]**
- **Reactor Vessel Diameter 3.5m**
- **Containment Diameter 10m, thickness 20mm**

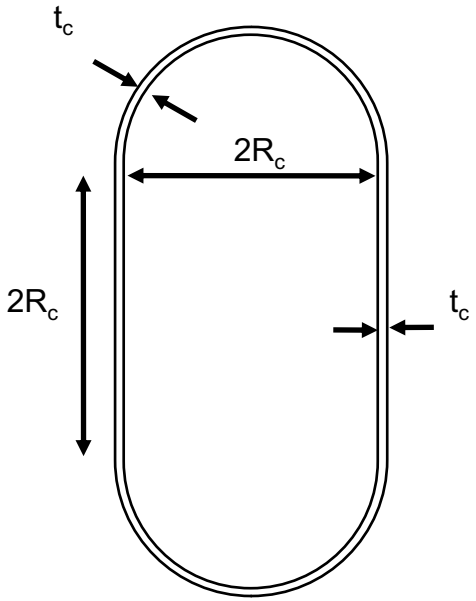

Figure 2. Containment geometry

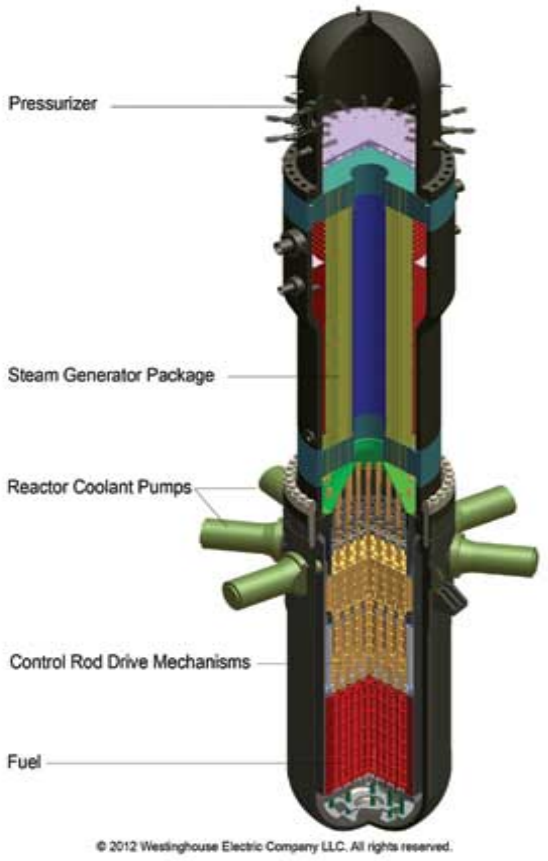

Figure 1. Westinghouse SMR concept

You are asked to evaluate the following aspects for the SMR plant concept. As far as possible give quantitative answers to the questions below:

1. List and discuss *(functioning, where are they used, advantages and disadvantages)* active and passive systems that could be used to control the containment pressure and temperature during LOCA accidents.
2. Select one of the discussed pressure control ideas, justify its selection and assemble (without solving) a set of equations that you would use to dimension it appropriately to respect the maximum pressure.
3. According to the given dimensions for the containment, what is the maximum pressure that the containment could sustain assuming temperature independent properties from Table 1 (select the material of your choice and justify your selection).
4. Estimate the reduction in vessel fluence relative to a PWR, assuming that the Westinghouse SMR has twice as much space between the core and the vessel.
5. The simplification of the reactor has driven the elimination of chemical reactivity control, but the reactor still adopts a 24months refueling cycle. Discuss methods that could allow you to achieve such refueling target.

Table 1. Properties of Containment Steels

Carbon steel	Stainless Steel
S_y = 200 MPa ρ = 7900 kg/m^3 E = 190 GPa ν = 0.30 Price = 1 $/kg	S_y = 250 MPa ρ = 8000 kg/m^3 E = 183 GPa ν = 0.29 Price = 4 $/kg