Massachusetts Institute of Technology Nuclear Science and Engineering

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

February 2019

The Light water **Small Modular Reactor** (SMR) shown in Figures 1 and 2 aims at achieving inherently safe power operation while also allowing for a safe transition from normal operating conditions to a passive shutdown condition. The design includes the three main barriers of protection of traditional PWRs, with the added benefit of an external pool of water to filter out radionuclides that might escape from the containment pressure vessel.

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.

- **Electric Output: 225 MWe (Reactor Power: 800 MWt)**
- **Fuel Type: 17x17 PWR fuel, <5% enriched UO2**
- **Operating Pressure 15MPa [Secondary system 7 MPa]**
- **Containment Thickness 20mm**

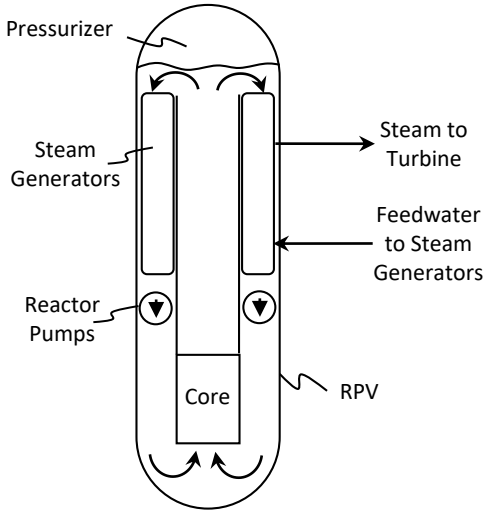


Figure 1. Schematic of the small modular PWR primary system

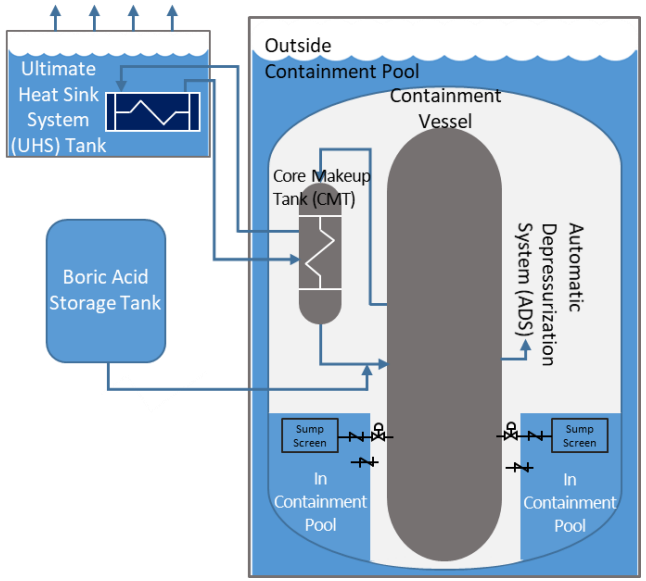
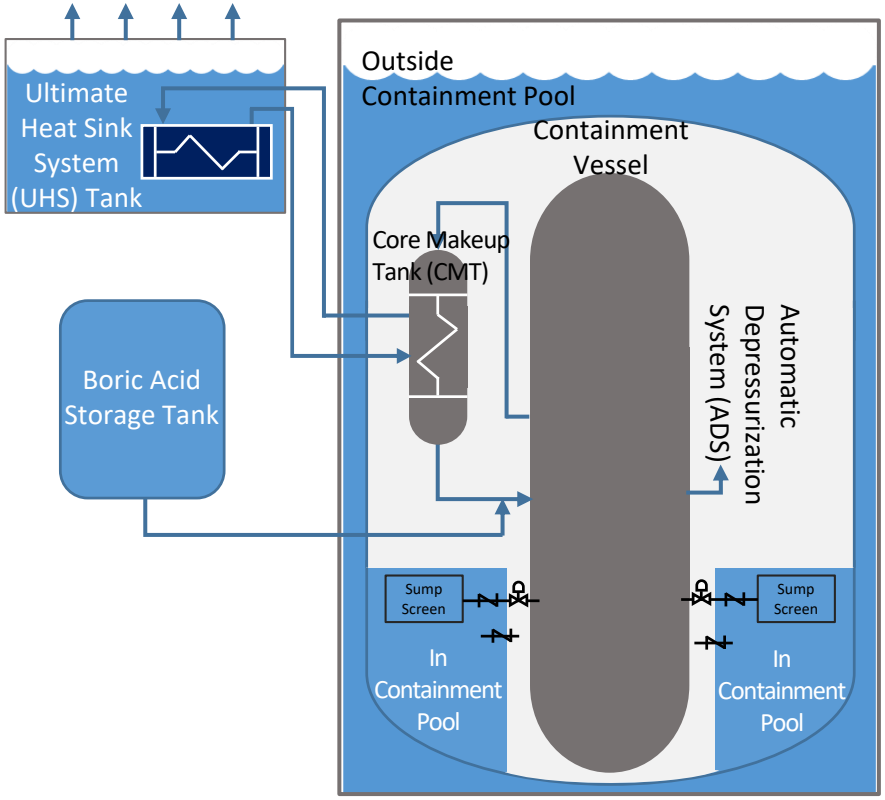


Figure 2. Emergency Systems (larger figure on page 3)

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. What are the safety functions performed by each of the systems in Figure 2?
2. Size the UHS water inventory to allow the reactor to deal with a station blackout for 24 hours.
3. Assemble (without solving) a set of equations that you would use to calculate the maximum decay heat that could be removed by the long term cooling method shown in Figure 3, following a LOCA.
4. Propose an approach to calculate the neutron leakage (>100 keV) out of the system if the reactor was operating at full power, while both the primary and the external containment are filled with water.
5. Identify all materials degradation concerns for this reactor concept, in both normal and off-normal operating conditions.



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(larger figure on page 3)

Figure 3: Long-Term Core Cooling for LOCA