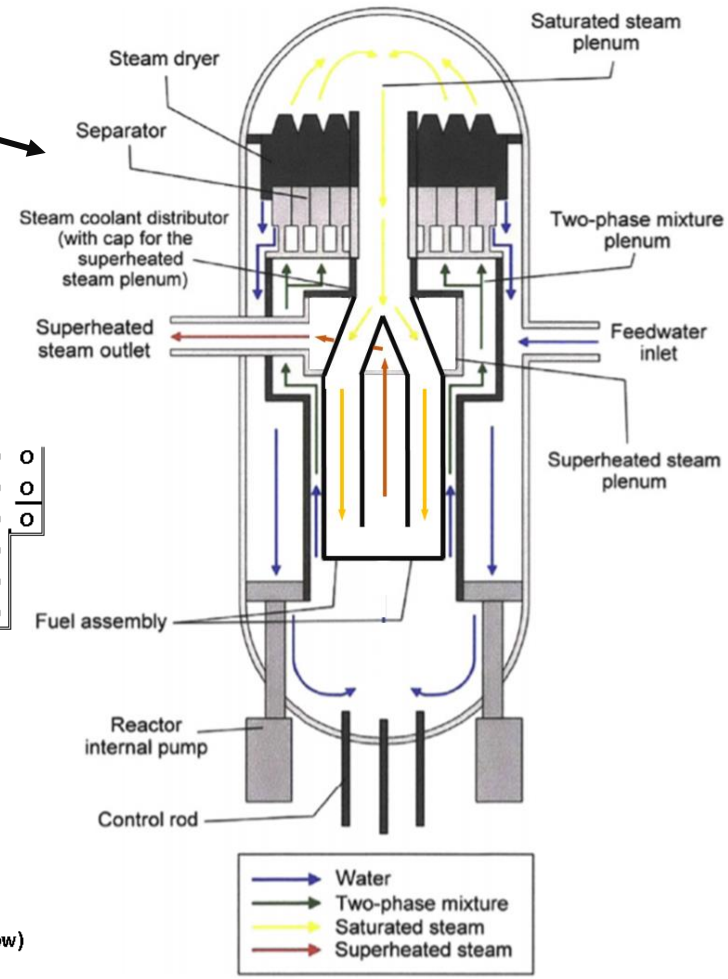
Massachusetts Institute of Technology Nuclear Science and Engineering

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

February 2017

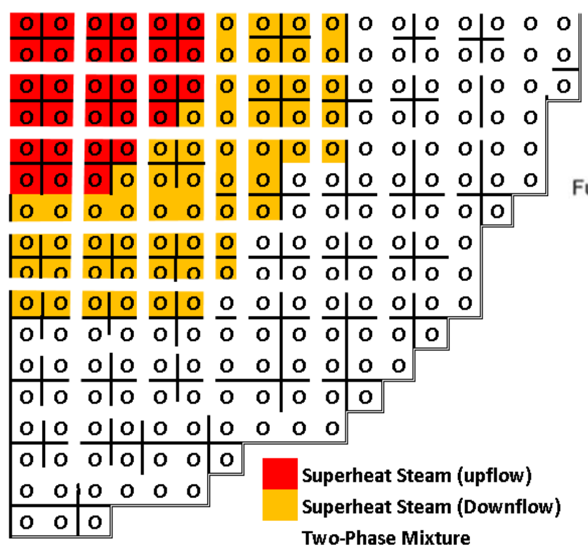
One of the concept proposed for the 21st century **Light Water Reactor** (LWR) plant is the **Super Heated** (SH) **Boiling Water Reactor** (BWR). A key requirement for this design is a thermodynamic efficiency higher than 40%, which can be achieved through a higher steam outlet temperature.

Coolant flow description: the reactor features a three pass core. (1) Water (blue arrows) enters the external ring of assemblies (2)Two-phase mixtures (green) is sent to separators and driers (3) steam is sent downword through and intermediate ring of assemblies (orange below) and (4) the superheated steam flows upward through the central ring of assemblies and to the outlet.



Adapted from (Ko and Kazimi)

- **Electrical Output 1000MWe [market driven output]**
- **Operating Pressure 7.6MPa [existing BWR vessel experience]**
- **Fuel: Standard 9x9 BWR design [Maximum Linear Power q'=44 kW/m]**



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

1. What steam temperature is required to achieve the 40% efficiency goal? Does this have any implication on the fuel design?
2. Taking a fuel assembly (and assuming a constant linear power of 20kW/m) cooled by steam, calculate the mass flow rate required to keep the cladding temperature within the design limit.
3. Discuss the neutronic challenges of producing superheated steam in the reactor core, and propose potential design changes that could improve efficiency and stability.
4. Discuss safety performance implications of the SH-BWR.

Table 1. Properties of saturated water at 7.6 MPa

Parameter	**Value**
T_{sat}	291.4°C
ρ_f	751 kg/m^3
ρ_g	40.1 kg/m^3
h_f	1,236 kJ/kg
h_g	2,764 kJ/kg
$C_{p,f}$	5.3 kJ/(kg°C)
$C_{p,g}$	5.0 kJ/(kg°C)
μ_f	9.8×10^{-5} Pa·s
μ_g	1.9×10^{-5} Pa·s
k_f	0.574 W/(m°C)
k_g	0.065 W/(m°C)
σ	0.019 N/m