Massachusetts Institute of Technology Nuclear Science and Engineering

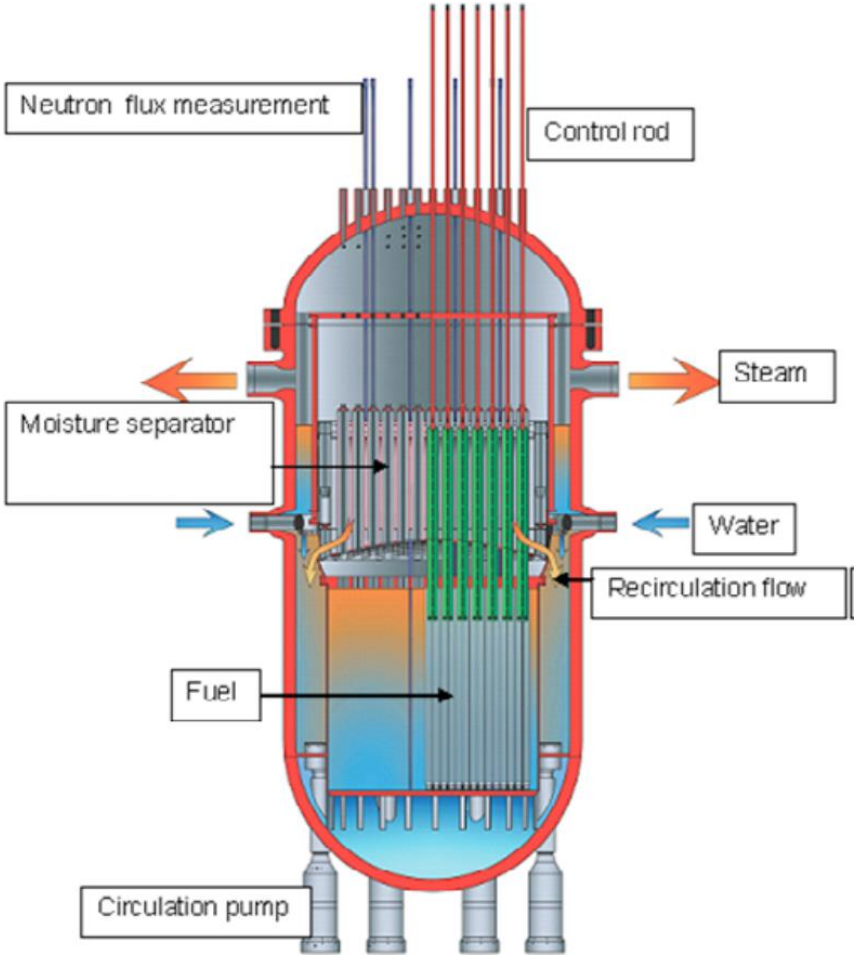
Doctoral Qualifying Oral Exam. Part 2 Question. Nuclear Reactor Engineering

February 2016

Trying to leverage the combined operating experience of PWR and BWR reactors, the concept of a High Pressure Boiling Water Reactor (HP-BWR) has been proposed, which could potentially make the best of both worlds. The focus is to leverage existing experience while decreasing the cost and improving the economics of the plant.

Based on these concepts some bounding design limits are provided.

- **Operating Pressure 15.5MPa [existing PWR vessel experience]**
- **Electrical Output 1000MWe [market driven output]**
- **Fuel: 656 Standard 9x9 ABWR design [Maximum Linear Power q'=44 kW/m]**
- **Reactor pressure vessel Inner diameter 5.6m**
- **Reactor pressure vessel Height 13m**



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

1. What are the thermal Hydraulics Implications of the proposed design, starting from the thermodynamic efficiency?
2. What are the implications on fuel and cladding materials?
3. What are the Neutronics and control implications?
4. Propose a containment design to couple to the HP-BWR reactor design.
5. In conclusion, what economics improvements do you expect in comparison with a standard BWR/ABWR reactor?

Table 1. Properties of saturated water at 15.5 MPa

Parameter	Value
T_{sat}	344.8°C
ρ_f	594.37 kg/m^3
ρ_g	101.93 kg/m^3
h_f	1,629 kJ/kg
h_g	2,596 kJ/kg
$C_{p,f}$	9.0 kJ/(kg°C)
$C_{p,g}$	14.0 kJ/(kg°C)
μ_f	6.8×10^{-5} Pa·s
μ_g	2.3×10^{-5} Pa·s
k_f	0.46 W/(m°C)
k_g	0.121 W/(m°C)
σ	0.004 N/m

Figure 1. Saturated water density curve

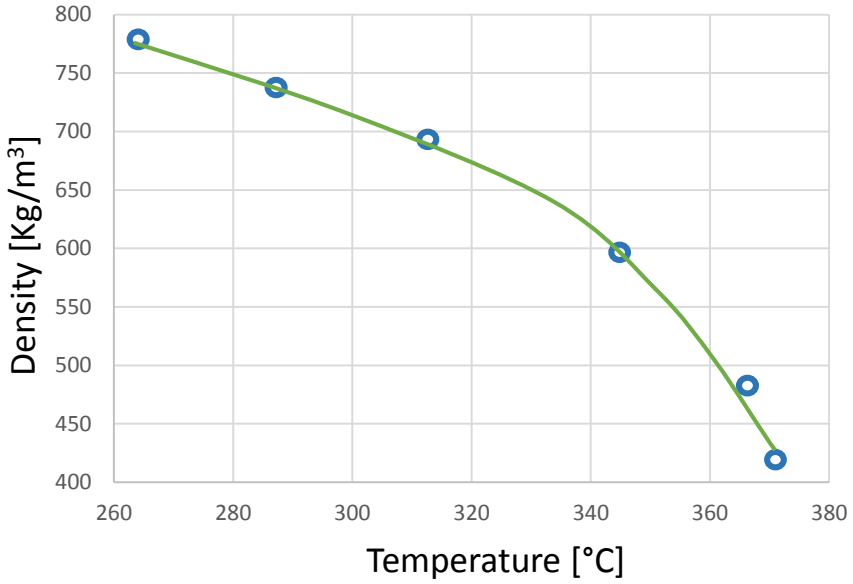


Table 2. Properties of saturated water at 7.6 MPa

Parameter	Value
T_{sat}	291.4°C
ρ_f	729 kg/m^3
ρ_g	40.1 kg/m^3
h_f	1,297 kJ/kg
h_g	2,764 kJ/kg
$C_{p,f}$	5.5 kJ/(kg°C)
$C_{p,g}$	5.7 kJ/(kg°C)
μ_f	8.9×10^{-5} Pa·s
μ_g	1.9×10^{-5} Pa·s
k_f	0.562 W/(m°C)
k_g	0.065 W/(m°C)
σ	0.016 N/m