(40%) 1) A PWR with U-Tube Steam Generators has characteristics given below, where the reactivity parameters are referenced to Hot Zero Power (HZP), i.e. the system is at temperature corresponding to (Rx Pwr)_{REL} and (\dot{W}_T)_{REL} = 0 (557 °F). Core excess reactivity corresponds to that excess reactivity associated with fuel enrichment necessary to achieve the desired cycle length. The Doppler only power coefficient is a surrogate for the fuel temperature coefficient, simply expressed in terms of power as opposed to fuel temperature. The control rods are in four banks with their total worth given below and insert reactivity linearly with position as they move out, i.e. at “full out” they insert zero reactivity and at “full in” they insert their full worth. The control rods move in steps, with a 100 step overlap and 228 steps corresponding to full out. You can assume the banks move out in order A, B, C, D.

a) Determine the Boron Concentration necessary for the reactor to be critical at nominal full power with all rods out. You can assume coolant temperatures follow the given T_{ave} program.
b) Given the critical boron concentration from part a) determine the critical rod position at zero power.

Problem Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Excess Reactivity</td>
<td>9710 pcm</td>
</tr>
<tr>
<td>Moderator Temperature Coefficient</td>
<td>-11.8 pcm/F</td>
</tr>
<tr>
<td>Doppler Only Power Coefficient</td>
<td>-9.8 pcm/% Power</td>
</tr>
<tr>
<td>Soluble Boron Coefficient</td>
<td>-7 pcm/ppm</td>
</tr>
<tr>
<td>Control Bank A Worth</td>
<td>582 pcm</td>
</tr>
<tr>
<td>Control Bank B Worth</td>
<td>973 pcm</td>
</tr>
<tr>
<td>Control Bank C Worth</td>
<td>1171 pcm</td>
</tr>
<tr>
<td>Control Bank D Worth</td>
<td>893 pcm</td>
</tr>
</tbody>
</table>

T_{ave} Program: (T_{ave})_{REF} = 557 + 28\times(\dot{W}_T)_{REL}

(40%) 2) A PWR with Once Through Steam Generators is operating at nominal full power when a controller malfunction results in a step reduction in the feed pump speed. Assuming the pump speed remains at this reduced level, the reactor does not trip and all other control systems operate in their normal automatic mode, indicate all control system actions using logic flow diagrams (arrows as in the notes and lectures). You can assume all control valves have sufficient capacity to accommodate this upset. Sketch the response of the following variables:

a) Reactor power
b) Reactor fuel temperature
c) Average coolant temperature
d) Steam pressure
e) Steam generator level (boiling length)
f) Turbine control valve position
g) Turbine output
3) Pressurized Water Reactors incorporate two different steam generator designs (Once Through and U-Tube), each having different control and operating characteristics. For the given parameters, indicate for each steam generator design whether the parameter is Directly Controlled (DC), or Not Directly Controlled (NDC) during normal operation.

a) Control Rod Position  
b) Reactor Power  
c) Average Coolant Temperature  
d) Steam Generator Level  
e) Steam Pressure  
f) Feed Flow  
g) Steam Flow  
h) Turbine Control Valve Position  
i) Feed Control Valve Position  
j) Turbine Output

4) Provide brief answers (one or two sentences) to the following questions

a) Give two functions of the Chemical Volume Control System  
b) Why do PWRs have pressurizers and not BWRs?  
c) Why are LWR fuel bundles designed to be undermoderated?  
d) Why do RCPs in PWRs have large integral flywheels?  
e) Give two functions of the Residual Heat Removal System.  
f) Give three sources of water available to the Safety Injection System.  
g) What is the main advantage of using variable speed feed pumps in conjunction with a feed control valve to deliver feed flow in PWRs and BWRs?  
h) What is the main purpose of the suppression pool found in BWR containment.  
i) Why can PWRs with Once Through Steam Generators operate at constant steam pressure and constant $T_{ave}$?  
j) Describe the control strategy for soluble boron in BWRs.