(25%)  1) A 3400 Mwt PWR is operating at 100% power in automatic control when it experiences a load reduction of 10%. When the system has stabilized at its new power level, how far must the control rods have moved to maintain \( T_{\text{ave}} \) at its programmed value?

\[
T_{\text{ave}} \text{ Program: } T_{\text{ave}} = 547 + 7.059 \times 10^{-3} \dot{Q}
\]

Moderator Temperature Coefficient \( \left( \frac{\Delta \rho}{\Delta T_{\text{mod}}} \right) = -14 \times 10^{-5} \text{ F}^{-1} \)

Doppler Only Power Coefficient \( \left( \frac{\Delta \rho}{\% \Delta \dot{Q}} \right) = -14.5 \times 10^{-5} \text{ (\% } \dot{Q})^{-1} \)

Integral Rod Worth \( \rho(z) = 2700 \times 10^{-5} (z-H) \)

Core Height (H) 12 ft

(25%)  2) Pressurized Water Reactors are implementing so-called “\( T_{\text{hot}} \) Reduction Programs” to reduce long term metallurgical problems. For example, the operation of a plant with a design \( T_{\text{hot}} \) of 618 °F might be modified so that the plant would operate at the same rated full power with a \( T_{\text{hot}} \) of 608 °F.

a) Assuming the plant operates with U-Tube Steam Generators, explain the changes in primary and secondary coolant system parameters, control positions, etc. that will achieve a reduction in \( T_{\text{hot}} \) without a reduction in generated output.

b) What will be the limiting factor in how far \( T_{\text{hot}} \) can be reduced without having to reduce the station generated output?

Note: Due to design conservatism, the main steam throttle valve is normally only opened approximately 85% when the plant is running at its full design power.

(25%)  3) A Boiling Water Reactor is operating at 100 % power when a malfunction in the speed controller of the recirculation pumps results in a 10 % step decrease of the recirculation mass flow rate. Assuming the recirculation pumps remain operational and continue to accept signals from the speed controller, sketch the transient response of (a) reactor power, (b) recirculation mass flow rate, (c) reactor steam pressure, and (d) critical heat flux ratio. Explain the behavior the shapes of your curves in terms of system response. You may assume no reactor trip.

(25%)  4) Provide brief answers to the following questions:

a) A PWR with Once Through Steam Generators has a sudden steam generator level increase. What is the impact on the primary side temperature and reactor power? Justify your answer.

b) In the design of light water reactor cores, how is the flow area determined?

c) What is the limiting criteria for determining linear heat rate? Given a linear heat rate, how is the fuel rod radius determined?

d) What limits the soluble boron concentration in Pressurized Water Reactors?

e) How does fuel rod spacing impact reactor control?

f) Why are PWRs referred to as natural load followers and not BWRs?

g) What would be the concern with boiling in the core of a liquid metal reactor?
h) One concern with older operating nuclear power plants is embrittlement of the reactor vessel due to neutron irradiation. One technique for reducing the neutron flux in the vicinity of the reactor vessel is to design a fuel loading pattern which places burnt (less reactive) fuel on the core periphery. What safety concerns, if any, are associated with this type of loading pattern.

i) A four loop plant is running at 75% power with one primary coolant loop inactive, i.e. the reactor coolant pump is not in operation. What concerns are associated with restart of the inactive reactor coolant pump?

j) Discuss the major design differences between the secondary sides of Pressurized Water Reactors and Boiling Water Reactors.

Day of wrath, and doom impending,  
David’s word with Sibyl’s blending:  
Heaven and earth in ashes ending,  
What shall I, frail man, be pleading?  
Who for me be interceding,  
When the just are mercy needing

Dies Irae

Any sufficiently advanced technology is indistinguishable from magic.

Arthur C. Clarke