Version ES/4

EGT3
ENGINEERING TRIPOS PART IIB

Thursday 25 April 2019 2.00 to 3.40

Module 4I10

NUCLEAR REACTOR ENGINEERING

*Answer not more than **three** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

*Write your candidate number **not** your name on the cover sheet.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Nuclear Energy Data Book (21 pages)
Engineering Data Book

10 minutes reading time is allowed for this paper at the start of the exam.

You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.

1 A cylindrical fuel rod has radius r_{out} and operates with linear heat generation rate q'. The fuel pellet outer surface temperature is T_{out}. In order to reduce the maximum fuel temperature, two solutions are proposed:

(i) Introduce a cylindrical voided region in the centre of the fuel rod occupying 10% of the original fuel volume.

(ii) Admix beryllium oxide to the fuel, 10% by volume, which will improve the thermal conductivity of the fuel by 50%.

(a) Which of the above cases will produce the greatest reduction in the maximum fuel temperature? [50%]

(b) Describe how each of the options above will affect the core reactivity, achievable burnup, and fuel cycle length. [20%]

(c) Explain why reducing the fuel temperature is beneficial. [10%]

(d) Propose three additional methods for reducing fuel temperature and list their pros and cons. [20%]

2 A reactor core is cooled by a turbulent flow of gas. The gas absolute pressure is much higher than the pressure drop across the core and the gas temperature is much higher than the temperature rise across the core. Suppose that the gas pressure is now doubled. The coolant pumping power and temperature rise of the gas across the core are to remain constant. The core geometry is also fixed.

(a) Determine the maximum possible increase in reactor power, stating any assumptions. [35%]

(b) For the power increase obtained in (a), determine the extent of temperature rise across the gas film as the rate of heat transfer increases. [35%]

(c) Discuss briefly the advantages of a core with a high pressure drop. [15%]

(d) Discuss briefly the advantages of a core with a low pressure drop. [15%]

3 The AP-1000 reactor design includes a large tank of water at the top of the reactor containment shield building. The water in the tank is at atmospheric pressure and has specific heat capacity of 4.2 kJ kg^{-1} K^{-1}.

(a) Describe the purpose of this tank and the basic operating principles of the safety system that it is part of. [20%]

(b) Make an estimate of the mass of water that this tank would need to contain in order to provide protection for 72 hours in a large-break Loss of Coolant Accident. The reactor thermal power is 3000 MW_{th}. The primary system water coolant volume is 300 m^3 and the system nominal operating pressure and temperature are 150 bar and 300 °C respectively. State clearly any assumptions. [30%]

(c) In the case of a severe (Beyond Design Basis) accident, list all the energy sources and possible heat sinks in a PWR containment. [20%]

(d) A PWR operates at 3000 MW_{th}. Each fuel assembly fed into the reactor is irradiated for 3 years. Consider two cases:

(i) The fuel is replaced in two batches. The fuel cycle length is 18 months.

(ii) The fuel is replaced continuously (as in CANDU reactors).

Calculate and compare the decay heat 1 hour after shutdown at the end of an equilibrium cycle, for each fueling scheme. [30%]

4 (a) Describe the impact of the magnitude and sign of reactivity feedback coefficients on a reactor core spatial power distribution. [25%]

(b) Describe the impact of the magnitude and sign of reactivity feedback coefficients on the cost of electricity produced by a nuclear power plant. [25%]

(c) Propose 3 methods for altering the Moderator Temperature Coefficient (MTC) in a PWR. In each case, describe the physical effects responsible for the change in MTC. [25%]

(d) Using typical PWR data provided in Table 1 below, estimate the Fuel Temperature Coefficient, MTC and xenon reactivity worth of the reactor. [25%]

State	**Fuel temperature, °C**	**Coolant temperature, °C**	**Core reactivity, pcm**
Cold Zero Power	80	80	0
Hot Zero Power	300	300	− 2000
Hot Full Power, no Xe	900	300	− 4000
Hot Full Power, Xe-equilibrium	900	300	− 6000

Table 1

END OF PAPER

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