UNIVERSITY OF ABERDEEN SESSION 2013–2014

Degree Examination in EG5066 Energy Technologies: Current Issues and Future Directions

1st January 2014 09.00–12.00

Notes: *(i) Candidates ARE permitted to use an approved calculator.*

(ii) Candidates ARE permitted to use steam tables, which will be provided.

(iii) Candidates ARE permitted to use refrigerant tables, which will be provided.

(iv) Data sheets are attached to the paper.

PLEASE NOTE THE FOLLOWING

(i) You **must not** have in your possession any material other than that expressly permitted in the rules appropriate to this examination. Where this is permitted, such material **must not** be amended, annotated or modified in any way.

(ii) You **must not** have in your possession any material that could be determined as giving you an advantage in the examination.

(iii) You **must not** attempt to communicate with any candidate during the exam, either orally or by passing written material, or by showing material to another candidate, nor must you attempt to view another candidate's work.

Failure to comply with the above will be regarded as cheating and may lead to disciplinary action as indicated in the Academic Quality Handbook (`www.abdn.ac.uk/registry/quality/appendix7x1.pdf`) Section 4.14 and 5.

Candidates must attempt 3 out of 4 questions.

Question 1

(a) Boiling water reactors (BWR) and pressurised water reactors (PWR) are the most common nuclear reactor types used to produce electricity worldwide. Describe the main differences between them.

[05 Marks]

The BWR has a **single loop of primary coolant***, i.e., the water boiled in the reactor is the same steam that is passed through the turbines, cooled, then recirculated back into the reactor. The PWR contains* **2 coolant loops***: the first water loop remains in the reactor with the water being boiled through fission and is then used to create steam (in a steam generator) from a secondary loop. The secondary loop moves the turbines, and is then cooled and sent back to the steam generator.*

(b) Describe the stages of the uranium cycle, i.e., from mining to disposal.

[05 Marks]

- *Uranium mining and milling: uranium ore is extracted from mines and separated from other metals;*
- *Uranium conversion: the uranium is chemically purified and converted into uranium hexafluoride (UF_6);*
- *Uranium enrichment: natural uranium (∼0.7% of U^{235}) is converted into enriched uranium with 3-5% of U^{235};*
- *Fuel fabrication: enriched uranium is converted into uranium dioxide and allocated in the nuclear fuels;*
- *Reactor and services: the U^{235} fuel is loaded into the reactor and during the operation (i.e., nuclear fission), heat is produced (whilst the uranium is decayed) and converted into electricity;*
- *Interiam storage of spent nuclear fuel (SNF): the fuel assembly containing spent fuel is stored in the reactor (in pools/ponds, i.e., cooled with circulate water) for a few years before being transferred into an interim storage (for a few decades) to reduce radioactivity and decay-heat before permanent disposal;*
- *Waste disposal: final destination of the SNF.*

(c) CO_2 produced in fossil fuel-based power plants can be captured, transported and stored in deep geological formations. After captured, CO_2 is compressed until reach supercritical state and transported via pipelines. What are the main technological challenges for long distance transport?

[05 Marks]

Transporting CO_2 via pipelines requires that fluid be kept during all path in a single phase stage – either as gas or liquid phases. It is necessary to undertake a strict monitoring/controlling of the pressure drop conditions through the pipeline with intermediate pumps or compressors. In either phase, CO_2 will need to be free of water (to avoid formation of gas hydrates) and contaminants (e.g., SO_x can react with water to produce H_2S that can potentially act as a corrosion agent in the pipeline metal). For short distances, pressure conditions may be ensured without the use of pumps or compressors, but by substantially increasing the inlet pressure. However this would require extra energy for the compression process and the pipeline wall would need to be reengineered to sustain larger pressure.

(d) Four main mechanisms are assumed to be responsible for holding the CO_2 within the pores of the underground geological formations: (i) physical trapping, (ii) dissolution trapping; (iii) mineral trapping; (iv) capillary trapping. Explain these mechanisms.

[05 Marks]

- *Physical trapping (also known as structural and stratigraphic trapping): CO_2 is contained below 'impermeable' or low-permeability rocks (i.e., caprock sealing integrity);*
- *Dissolution trapping: CO_2 is dissolved in brine – the resulting solution is denser and slowly sink through the storage aquifer;*
- *Mineral trapping: Insoluble carbonates and bicarbonates $\left(CO_3^{-2},\ HCO_3^{-}\right)$ are formed and precipitated by the reaction of CO_2 and the surrounding rocks;*
- *Capillary trapping: CO_2 can be trapped as micro-bubbles in the pore space.*

END OF PAPER