UNIVERSITY OF CAMBRIDGE

ENGINEERING TRIPOS PART IIB
ENGINEERING TRIPOS PART IIA

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Saturday 7 May 2005 2.30 to 4

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Module 4D1

PETROLEUM 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.*

*There are no attachments.*

**You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator**

1 At low temperatures and high pressures hydrocarbon gases and water combine to form solid gas hydrates. Figure 1 below is a phase equilibrium diagram. One curve is for pure methane, and the other is for 90% methane 10% ethane. To the left of the curves a hydrate is stable, and to the right the hydrate dissociates into gas and water. Large reserves of gas hydrates have been formed naturally, and are thought to be an important source of energy for the future.

(a) Describe where hydrates are most likely to be found, basing your answer on the phase equilibrium diagram and on your knowledge of petroleum geology and geography. [35%]

(b) Describe one or more schemes that could be used to produce gas from hydrates, and outline the investigations you would carry out to confirm the economic feasibility of the schemes. [65%]

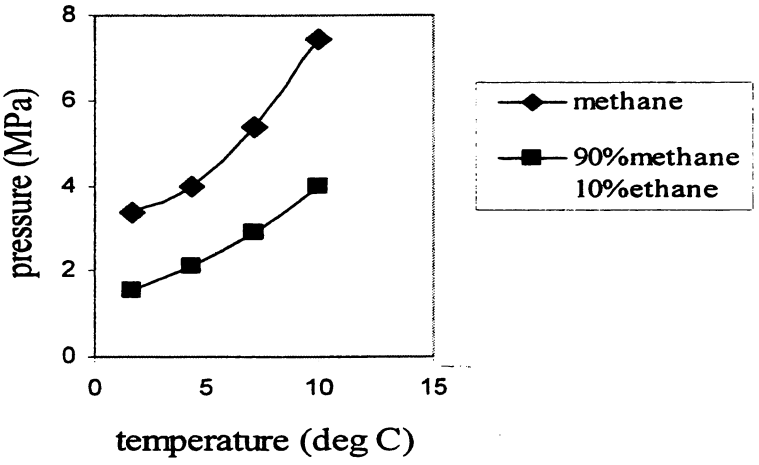


Figure 1

2(a) Consider a one-dimensional Buckley-Leverett idealisation of displacement of oil by water, in which all quantities are functions of time $t$ and one space coordinate $x$.

(i) Derive the conservation equation for water

$$\phi \frac{\partial S}{\partial t} + \frac{\partial q_w}{\partial x} = 0$$

where
$S$ is water saturation
$\phi$ is porosity
$q_w$ is water flow rate (volume per unit time per unit area) [15%]

(ii) write down the corresponding equation for oil [5%]

(iii) show that if the total flow rate $q_{tot}=q_w+q_o$ is independent of $x$, and if

$$\frac{q_w}{q_{tot}} = F(S)$$

then

$$\frac{\partial S}{\partial t} + \frac{q_{tot}}{\phi}\frac{dF}{dS}\frac{\partial S}{\partial x} = 0$$

and that this implies that a saturation S advances with a velocity $\frac{q_{tot}}{\phi}\frac{dF}{dS}$ [25%]

(b) Results like those in part (a) of the question are of limited value in understanding response to water injection in real reservoirs. Explain what their value is. [15%]

(c) Explain how the more complex behaviour of a real reservoir is analysed in practice. [40%]

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3 A group of gasfields lies under the North Sea to the north-east of Norfolk, about 150 km north-east of Cambridge, in water depths of about 25 m. The gas is produced to steel fixed platforms, and by pipelines to shore and thence south-west to the Midlands and the London area. The fields have been in production for 30 years, and are largely depleted.

It is proposed that the reservoirs and the platform and pipeline installations could be used to transport and store carbon dioxide produced by power stations and cement plants, so that it is not dumped into the atmosphere and does not contribute to climate change. It is thought unlikely that this scheme will come into operation for at least 15 years from now. It would be desirable to store the carbon dioxide for at least 1000 years.

(a) Describe the advantages and disadvantages of this proposal. [40%]

(b) A major concern is that the reservoirs will leak carbon dioxide, and that it will escape to the atmosphere and nullify the benefits of the scheme. Describe what investigations you would recommend to clarify this concern. [20%]

(c) Describe possible legal difficulties with the scheme, and how they might be resolved. [20%]

(d) Describe alternative uses of the platforms and pipelines if the carbon dioxide storage scheme is not adopted. [20%]

4 Figure 2 below is a plan and cross-section of the Shtokmanovskoye gasfield, in the Barents Sea between Norway and the Russian territory of Novaya Zemlya, in 200 m of water approximately 50°E 72°N. Novaya Zemlya consists of two inhospitable and volcanic large islands some 300 km east of the field. The section is along the bent line through the exploration wells marked 1 2 and 3. Depths are measured from the sea surface. The porosity is between 20 and 25%, and the permeability 500 to 1500 mD.

(a) Estimate the recoverable volume of gas under standard conditions (temperature 15°C, pressure 101.3 kPa), assuming that the reservoir temperature is 140°C, that the reservoir pressure is hydrostatic, and that the compressibility factor can be taken as 0.8 under reservoir conditions and 1 under standard conditions. [30%]

(b) The operators of the field intend to export the gas to North America. Outline a technically feasible production and transportation scheme. [40%]

(c) A NGO (non-governmental organisation) intends to object to the scheme on safety and environment grounds. Advise the organisation on the relevant issues. [30%]

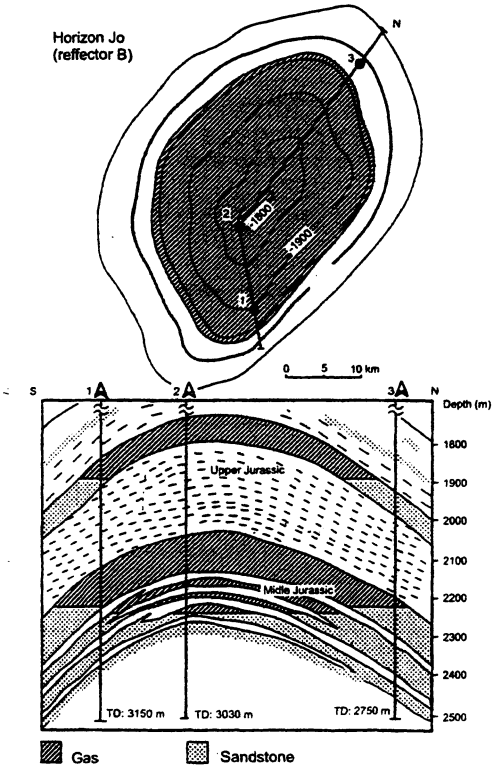


Figure 2

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5 Imagine that you are an adviser to a UK Chancellor of the Exchequer (Minister of Finance) whose government has just been re-elected. During the election campaign he has promised that the new government will adhere to the Kyoto agreements, that it will grow the economy by 3 per cent each year, that it will abandon plans to increase taxes on fuel, and that it will continue the phase-out of nuclear power stations. Figure 3 is a forecast of UK oil and gas production, in terms of oil equivalent, with gas 'converted' to oil on an energy basis.

The Chancellor has promised a major statement on energy policy. Prepare a policy statement advising him what to say. [100%]

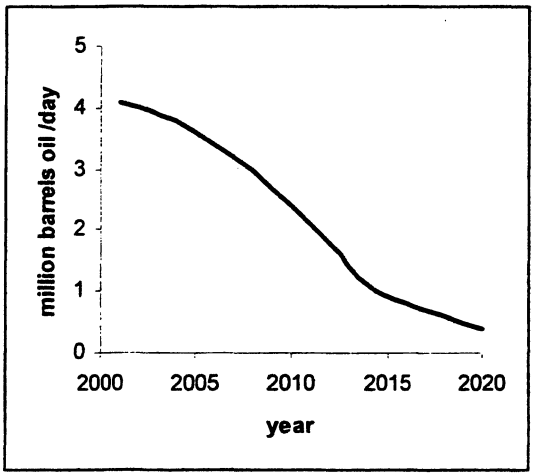


Figure 3

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