| Reg. No. | | | | | | | | | | |
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# MANIPAL INSTITUTE OF TECHNOLOGY
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**VII SEMESTER B.TECH. (CHEMICAL ENGINEERING)**
**END SEMESTER EXAMINATIONS, NOV 2017**
SUBJECT: NATURAL GAS ENGINEERING [CHE 4001]
**REVISED CREDIT SYSTEM**
**(25/11/2017)**

Time: 3 Hours MAX. MARKS: 50

**Instructions to Candidates:**
☑ Answer **ALL** the questions. ☑ Refer page 2 for formulae sheet. ☑ Missing data may be suitably assumed.

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| **1A.** | Discuss the types of natural gas resources. | **3** |
| **1B.** | For the natural gas composition given in the below table, calculate the gas formation volume factor in bbl/scf, if the gas density is 15.32 lb/ft$^3$. | **3** |

| Component | $C_1$ | $C_2$ | $C_3$ | i-$C_4$ | n-$C_4$ | i-$C_5$ | n-$C_5$ | $C_6$ | $C_{7+}$ | $N_2$ | $CO_2$ | $H_2S$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mol.fraction | .775 | .083 | .021 | .006 | .002 | .003 | .008 | .001 | .001 | .05 | .03 | .02 |

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| **1C.** | For the natural gas described in Q.No. 1B, calculate the compressibility factor at 5000 psia, and 200 $^oF$. | **4** |
| **2A.** | A gas well produces 0.65 specific gravity natural gas. The average reservoir pressure is 4,505 psia. Reservoir temperature is 180 °F. Estimate the deliverability of the gas reservoir under a pseudo-steady state flow condition at a flowing bottom hole pressure of 1,050 psia. The well was tested at two flow rates: | **4** |

| | **Test Point 1** | **Test Point 2** |
|---|---|---|
| Flow rate | 1,152 Mscf/d | 1,548 Mscf/d |
| Bottom hole pressure | 3,025 psia | 1,685 psia |

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| **2B.** | Suppose that a vertical well produces 2 MMscf/d of 0.71 gas-specific gravity gas through a 2.259 in tubing set to the top of a gas reservoir at a depth of 10,000 ft. At tubing head, the pressure is 800 psia and the temperature is 150 °F; the bottom hole temperature is 200 °F. The relative roughness of tubing is about 0.0006. Calculate the pressure at 5000 psia along the tubing length. Use the average temperature and compressibility factor method of wellbore performance. Consider the average pressure as 870 psia for properties calculations. | **6** |
| **3A.** | A 0.66 specific gravity gas flows from a 2-in pipe through a 1.5-in orifice-type choke. The upstream pressure and temperature are 600 psia and 75 °F, respectively. The downstream pressure is 200 psia (measured 2 ft from the orifice). The gas-specific heat ratio is 1.3. Consider Orifice choke coefficient as 0.75. (i) What is the expected daily flow rate? (ii) Does heating need to be applied to assure that the frost does not clog the orifice? (iii) What is the expected pressure at the orifice outlet? | **6** |
| **3B.** | Draw and explain the nature of plots for the following:<br>i) Natural gas production forecast ii) Nodal analysis at wellhead node (WPR and CPR)<br>iii) Tubing pressure profile iv) Nodal analysis at bottom hole node (IPR and TPR)<br>Clearly mention the parameters of both the axis of each plot. | **4** |

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| **4A.** | Calculate the gas capacity of a 20” X 7-1/2’ size horizontal oil/gas separator for the following conditions.<br>Gas-specific gravity: 0.8 — Empirical factor values: 0.40 to 0.50<br>Compressibility factor: 0.8427 — Condensate gravity: 60 $^{o}$API<br>Operating pressure: 1000 psig — Operating temperature: 100 $^{o}$F<br>Gas density: 3.83 lb/ft$^3$ at given conditions. | **3** |
| **4B.** | Derive the equation: $\sum_{i=1}^{N_c} \frac{z_i(1-k_i)}{n_V(k_i-1)+1} = 0$. Clearly state the assumptions.<br>Hint: The equation can be used in flash calculations of separation of natural gas. | **3** |
| **4C.** | Describe the features of low-temperature separation of natural gas. | **4** |
| **5A.** | Explain the process of dehydration of natural gas by adsorption. | **5** |
| **5B.** | List down the advantages of and operating problems with liquid-desiccant dehydration of natural gas. | **5** |

**Formulae Sheet**

☑ **Pseudocritical Properties**

$$P_{pc} = 709.604 - 58.718\gamma_g \qquad P_{pc} = 678 - 50(\gamma_g - 0.5) - 206.7y_{N_2} + 440y_{CO_2} + 606.7y_{H_2S}$$

$$T_{pc} = 170.491 + 307.344\gamma_g \qquad T_{pc} = 326 + 315.7(\gamma_g - 0.5) - 240y_{N_2} - 83.3y_{CO_2} + 133.3y_{H_2S}$$

☑ **Compressibility Factor: Brill and Beggs’ Correlation Constants**

$$A = 1.39(T_{pr} - 0.92)^{0.5} - 0.36T_{pr} - 0.1$$

$$C = 0.132 - 0.32\log(T_{pr})$$

$$B = (0.62 - 0.23T_{pr})P_{pr} + \left(\frac{0.066}{T_{pr} - 0.86} - 0.037\right)P_{pr}^2 + \frac{0.32P_{pr}^6}{10^{9(T_{pr}-1)}}$$

$$D = 10\hat{}(0.3106 - 0.49T_{pr} + 0.1824T_{pr}^2)$$

☑ **Gas Reservoir Deliverability: Empirical Models (Forchheimer and backpressure model)**

$$\bar{p}^2 - p_{wf}^2 = Aq + Bq^2 \qquad q = C(\bar{p}^2 - p_{wf}^2)^n$$

☑ **Wellbore Performance: The Average Temperature and Compressibility Factor Method**

$$p_{wf}^2 = Exp(s)p_{hf}^2 + \frac{6.67X10^{-4}[Exp(s)-1]fq_{sc}^2\bar{z}^2\bar{T}^2}{d_i^5\cos\theta} \qquad s = \frac{0.0375\gamma_g L\cos\theta}{\bar{z}\bar{T}} \qquad f = \left[\frac{1}{1.74 - 2\log\left(\frac{2\varepsilon}{d_i}\right)}\right]^2$$

☑ **Choke Performance: Gas Passage for Subsonic and Sonic flow**

$$Q_{sc} = 1248CAP_{up}\sqrt{\frac{k}{(k-1)\gamma_g T_{up}}\left[\left(\frac{P_{dn}}{P_{up}}\right)^{\frac{2}{k}} - \left(\frac{P_{dn}}{P_{up}}\right)^{\frac{k+1}{k}}\right]} \qquad Q_{sc} = 879CAP_{up}\sqrt{\left(\frac{k}{\gamma_g T_{up}}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

******** END ********