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MANIPAL INSTITUTE OF TECHNOLOGY
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## VII SEMESTER B.TECH. (CHEMICAL ENGINEERING)
## MAKEUP EXAMINATION, DEC 2018
# SUBJECT: NATURAL GAS ENGINEERING [CHE 4001]
## (31/12/2018)
## REVISED CREDIT SYSTEM

Time: 3 Hours MAX. MARKS: 50

**Instructions to Candidates:**

- Answer **ALL** the questions. Read the questions carefully.
- Missing data may be suitably assumed.
- Refer formulae sheet

<table>
<tr><td><b>1A.</b></td><td>What is natural gas? Define the following terminology in one line (i) proved reserves (ii) potential reserves (iii) pool (iv) field (v) reservoir?</td><td><b>5</b></td></tr>
<tr><td><b>1B.</b></td><td>A well produces 0.75 specific gravity natural gas; calculate the compressibility factor at 2000 psia, and 250 $^{0}$F using Brill and Beggs Method.</td><td><b>5</b></td></tr>
<tr><td><b>2A</b></td><td>Explain following well deliverability testing method (a) Flow-After-Flow test and (b) Isochronal test</td><td><b>4</b></td></tr>
<tr><td><b>2B.</b></td><td>A gas well produces 0.65 specific gravity natural gas. The average reservoir pressure is 4,505 psia. Reservoir temperature is 180 °F. The well was tested at two flow rates:
<table>
<tr><th></th><th>Test Point 1</th><th>Test Point 2</th></tr>
<tr><td>Flow rate</td><td>1,152 Mscf/d</td><td>1,548 Mscf/d</td></tr>
<tr><td>Bottom-hole pressure</td><td>3,025 psia</td><td>1,685 psia</td></tr>
</table>
Estimate the deliverability of the gas reservoir under a pseudo-steady state flow condition at a flowing bottom-hole pressure of 1200 psia using the backpressure model with pressure-squared approach.</td><td><b>3</b></td></tr>
<tr><td><b>2C.</b></td><td>Explain sonic and subsonic flow regime using the typical choke performance curve?</td><td><b>3</b></td></tr>
<tr><td><b>3A.</b></td><td>A 0.6 specific gravity gas flows from a 2-in. pipe through a 1-in orifice-type choke. The upstream pressure and temperature are 800 psia and 75 $^{0}$F, respectively. The downstream pressure is 200 psia (measured 2 ft from the orifice). The gas-specific heat ratio is 1.3, Viscosity of gas is 0.01245 cp. (a) What is the expected daily flow rate? (b) Does heating need to be applied to ensure that the frost does not clog the orifice? Consider $z_{up}/z_{outlet}$ as 1.</td><td><b>4</b></td></tr>
<tr><td><b>3B.</b></td><td>What is nodal analysis? How to perform the Nodal analysis at the bottom-hole node. Write the procedure in detail.</td><td><b>6</b></td></tr>
</table>

| | | |
|---|---|---|
| **4A.** | Explain the following flow regimes using schematic (a) Mist flow (b) Bubble flow (c) Annular flow (d) Slug flow (e) Churn flow | **4** |
| **4B.** | Derive radial flow basic equation of a single phase, compressible fluid through porous and permeable rock $\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial p}{\partial r}\rho\right)=\frac{\varphi\mu c_t}{k}\rho\frac{\partial p}{\partial t}$ | **3** |
| **4C.** | Calculate Absolute Open Flow (AOF) conditions using pseudo-steady state analytical expression for radial-flow gas reservoir with pressure approach<br>For the below given well conditions.<br>Effective permeability to gas: 0.25 md<br>Pay zone thickness: 98 ft<br>Equivalent drainage radius: 1,690 ft<br>Gas formation volume factor : 0.002757 rb/scf<br>Wellbore radius: 0.228 ft<br>Reservoir pressure: 4,613 psia<br>Temperature: 180 °F<br>The average gas viscosity: 0.022 cp<br>The average gas compressibility factor: 0.96<br>Assume both Darcy skin factor and Non-Darcy coefficient to be zero. | **3** |
| **5A.** | Explain the process of dehydration of natural gas by solid desiccant dehydration plant using process flow diagram? Outline advantages of this process? | **5** |
| **5B.** | What is gas sweetening process? Outline various gas sweetening processes used in natural gas processing field? | **2** |
| **5C** | Explain gas pipeline cleaning using the pigging operation and why it is used? | **3** |

## Formulae Sheet

### ☑ Pseudocritical Properties

$$P_{pc} = 709.604 - 58.718\gamma_g$$

$$T_{pc} = 170.491 + 307.344\gamma_g$$

### ☑ Compressibility Factor: Brill and Beggs' Correlation Constants

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

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

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

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

### ☑ Pseudosteady state flow IPR for radial flow gas reservoir using pressure square approach and pressure approach

$$q = \frac{kh\left[\bar{p}^2 - p_{wf}{}^2\right]}{1424\bar{\mu}\ \bar{z}\ T\left[\ln\left(\frac{0.472r_e}{r_w}\right) + s + Dq\right]}$$

$$q = \frac{kh\left[\bar{p} - p_{wf}\right]}{141.2\text{X}10^3\,\bar{B}_g\ \bar{\mu}\left[\ln\left(\frac{0.472r_e}{r_w}\right) + s + Dq\right]}$$

### ☑ Gas Reservoir Deliverability: Empirical Models (Forchheimer and Backpressure model)

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

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

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

$$f = \left[\frac{1}{1.74 - 2\log\left(\frac{2\varepsilon}{d_i}\right)}\right]^2$$

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

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

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

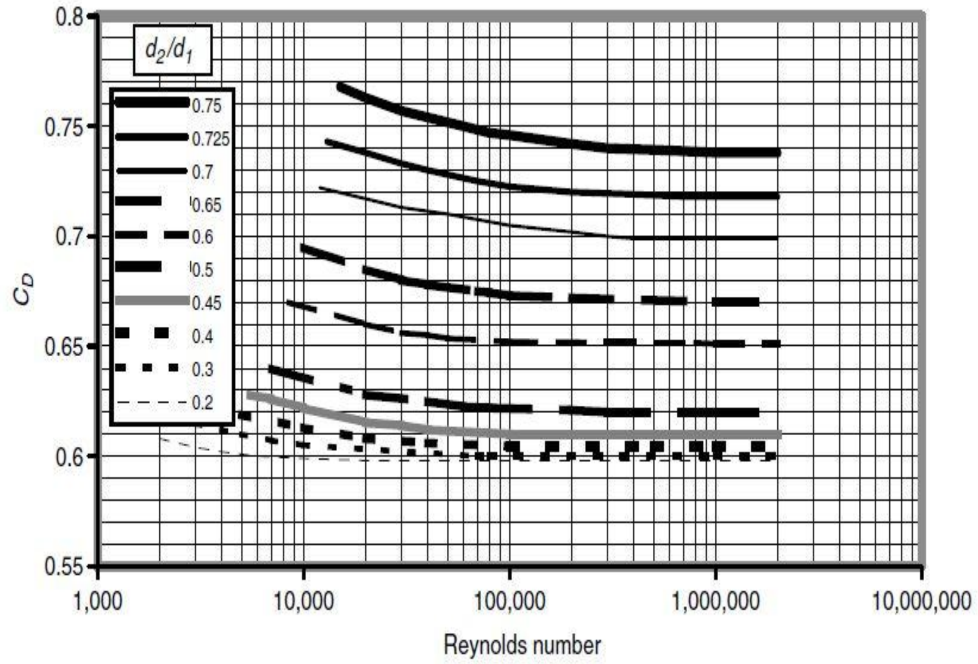

***Figure 5.3*** *Choke flow coefficient for orifice-type chokes (data used, with permission, from Crane, 1957).*

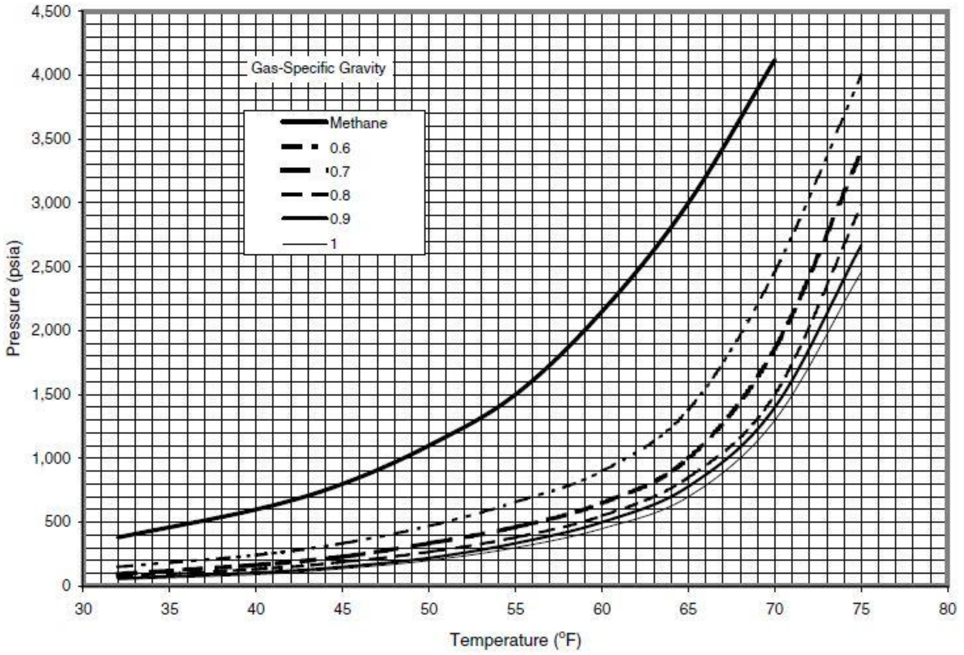

**Figure 12–4 Hydrate-forming conditions of natural gases (Courtesy of SPE-AIME).**