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UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, December 2017

Program/course: B.Tech. (APE, CE +RP, APE (GE))	**Semester : VII**
Subject: Pipeline Transportation of Oil and Gas	**Max. Marks : 100**
Code : PTEG 441	**Duration : 3 Hrs.**
No. of page/s: 3	

Note: Assume Suitable and necessary data if required and Justify

SECTION-A

5 Marks *4 = 20 MARKS

Answer ***all*** the questions

1. Explain the variation in water performance curves while transporting crude oil through pipelines.
2. Distinguish between $NPSH_A$ and $NPSH_R$
3. Explain the terms '*Adiabatic efficie*ncy' and '*Hydraulic Balance'* in Compressors
4. Name the different types of surveys used in pipeline projects.

SECTION-B

Answer ***all*** Questions **10Marks*4 = 40 MARKS**

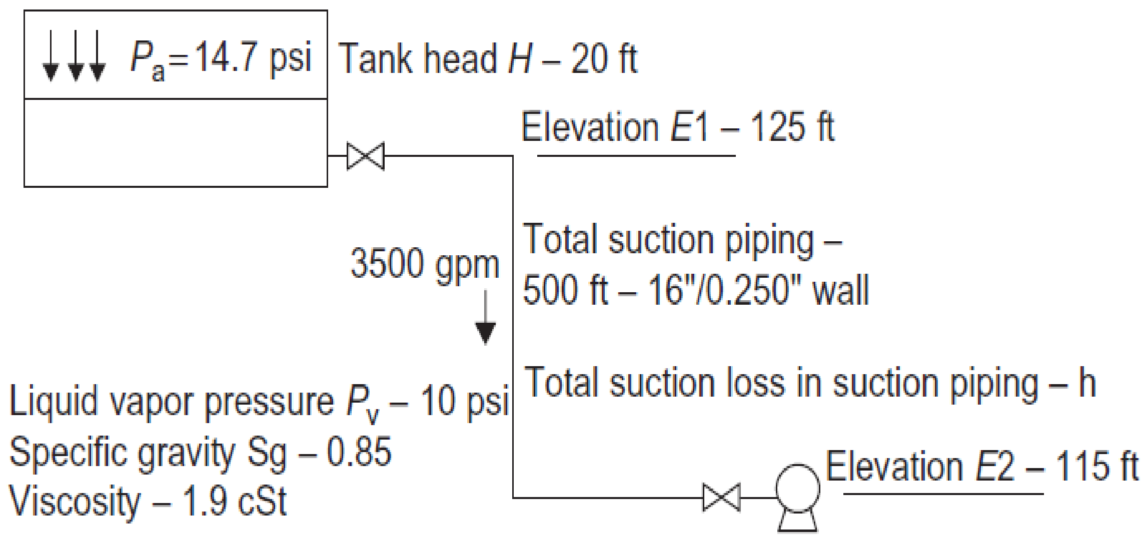
5. Calculate the compressor horsepower required for an adiabatic compression of 106 MMSCFD gas with inlet temperature of 68°F and 725 psia pressures. The discharge pressure is 1305 psia. Assume the compressibility factors at suction and discharge conditions to be Z_1 = 1.0 and Z_2 = 0.85, respectively, and the adiabatic exponent = 1.4, with the adiabatic efficiency = 0.8. If the mechanical efficiency of the compressor driver is 0.95, what BHP is required? Also, calculate the outlet temperature of the gas.
6. What are the components and functions of the SCADA system?
7. Explain Cathodic Protection in Pipeline Network

8. Mention the reasons for two phase formation in pipelines. Explain with figures the various flow patterns in the two phases. Explain Bakers Chart for identification of two phase flow pattern in pipeline.

<u>Section-C</u>

Answer any ***<u>Two</u>*** Questions **20 Marks*2 =40MARKS**

9. A Centrifugal pump is used to pump a liquid from a storage tank through 500 ft of suction piping as shown in the figure below.



- **a.** Determine the NPSH available at a flow rate of 3000 gal/min
- **b.** The pump vendor's data indicate the NPSH required is 35 ft at 3000 gal/min and 60 ft at 4000 gal/min. Can this piping system handle the higher flow rate without the pump cavitating?
- **c.** If cavitation is a problem in (b) above, what changes must be made to the piping system to prevent pump cavitation at 4000 gal/min.

10. A natural gas pipeline, 140 miles long from Dover to Leeds, is constructed of NPS 16, 0.250 in. wall thickness pipe, with an MOP of 1200 psig. The gas specific gravity and viscosity are 0.6 and 8×10^{-6} lb/ft-s, respectively. The pipe roughness can be assumed to be 700μin. and the base pressure and base temperature are 14.7 psia and 60°F, respectively. The gas flow rate is 175 MMSCFD at 80°F, and the delivery pressure required at Leeds is 800 psig. **a)** Calculate the pressure required at inlet to deliver the gas at Leeds? **b)** Can the gas be delivered at the calculated inlet pressure from Dover? If not, mention the reasons. **c)** Assuming if only one intermediate compressor is installed at mid-point of the pipeline at Kent, will it be able to deliver the gas at Leeds at the required delivery pressure. Mention reasons. **d)** If not calculate the exact location of compressor. Also for this location, calculate the suction pressure and compression ratio at Kent. Assume Z= 0.85

11. A pipeline from origin station A to delivery point B is 48 miles long and is 18 inch in nominal diameter, with a 0.281 inch wall thickness. It is constructed of 5LX-65 grade steel. At origin station A, crude oil of specific gravity 0.85 and 10 cSt viscosity enters the pipeline at a flow rate of 6000 bbl/hr. At first intermediate station C (milepost 22) a new stream of crude oil with a specific gravity of 0.82 and 3.5 cSt viscosity enters the pipeline at a flow rate of 1000 bbl/hr. The mixed stream then continues to another intermediate station D (milepost 32) where 3000 bbl/hr is stripped off the pipeline. The remaining volume continues to the end of the pipeline at delivery station B. **(a)** Calculate the pressure required at origin station A and the composition of the crude oil arriving at terminus B at a minimum delivery pressure of 50 psi. Assume elevations at A, C, D, and B to be 100, 150, 250, and 300 feet, respectively. Use the Colebrook-White equation for pressure drop calculations and assume a pipe roughness of 0.002 in. **(b)** How much pump HP will be required to maintain this flow rate at A, assuming 50 psi pump suction pressure at A and 80% pump efficiency? **(c)** If a positive displacement (PD) pump is used to inject the stream at C, what pressure and HP are required at C?

APPENDIX

(All Notations have the Usual Standard Meaning)

1. CNGA Equation:

$$z = \frac{1}{\left[1 + \frac{\left(P_{av} \times 344,400 \times 10^{1.785G}\right)}{T_f^{\,3.825}}\right]}$$

2. Colebrook – White Equation(a) and Modified Colebrook White Eqn.(b)

(a) $\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{e}{3.7D} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right)$ (b) $\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{e}{3.7D} + \frac{2.825}{\mathrm{Re}\sqrt{f}}\right)$

3. Coversion Equations for SSU to Centistokes

i) $Centistokes = 0.226(SSU) - \frac{195}{SSU} \qquad SSU \leq 100$

ii) $Centistokes == 0.220(SSU) - \frac{135}{SSU} \qquad SSU \succ 100$

4. Miller Equation

$$Q = 4.06(M)\left(\frac{D^5 \times P_m}{S_g}\right)^{0.5}, \; M = \log_{10}\left(\frac{D^3 \times S_g \times P_m}{c_p^2}\right) + 4.35$$

Q=Flow rate, bbl/day; D=Pipe internal diameter, in. ; Cp=Liquid viscosity, centipoise

Pm=Frictional pressure drop, psi/mile; Sg=Liquid specific gravity

5. Shell MIT Equations

$$R = 92.25\left(\frac{Q}{\nu D}\right); \; R_m = \frac{R}{7742}$$

$f = \frac{0.00207}{R_m}$ (Laminar flow); $f = 0.0018 + 0.006621\left(\frac{1}{R_m}\right)^{0.335}$ (Turbulent flow)

$$P_m = 0.241\left(\frac{f \times S_g \times Q^2}{D^5}\right)$$

Where, R=Reynolds number, dimensionless; Rm=Modified Reynolds number, dimensionless Q=Flow rate, bbl/day; D=Pipe internal diameter, in.; ν=Kinematic viscosity, cSt; Pm=Frictional pressure drop, psi/mile; f=Friction factor, dimensionless; S_g=Liquid specific gravity; Q=Flow rate, bbl/day; D=Pipe internal diameter, in.

6. AGA Equations

For the fully turbulent zone, $F = 4\log_{10}\left(\frac{3.7D}{e}\right)$

For the partially turbulent zone, $F = 4D_f \log_{10}\left(\frac{\text{Re}}{1.4125F_t}\right)$ $F_t = 4\log_{10}\left(\frac{\text{Re}}{F_t}\right) - 0.6$

7. Equivalent Diameter

$$De = D_1\left[\frac{1+K}{K}\right]^{2/5}, \quad K = \sqrt{\left(\frac{D_1}{D_2}\right)^5\left(\frac{L_2}{L_1}\right)}$$

8. Reynolds Number for Gases:

$$a)\ SI: \text{Re} = 0.5134\left(\frac{P_b}{T_b}\right)\left(\frac{GQ}{\mu D}\right) \quad b)\ USCS: \text{Re} = 0.0004778\left(\frac{P_b}{T_b}\right)\left(\frac{GQ}{\mu D}\right)$$

9. Reynolds No. for Crude Oil Pipelines

a) R=92.24 Q/(ν D) Where: Q=Flow rate, bbl/day; D=Internal diameter, in. ;

ν=Kinematic viscosity, cSt

b) R=353,678 Q/(νD)

Where: Q=Flow rate, m^3/hr.; D=Internal diameter, mm; ν= Kinematic viscosity, cSt

10. Pressure Drop per unit length for oil pipelines (USCS)

$$P_m = 0.0605\left(fQ^2 \right)\left(\frac{S_g}{D^5} \right)$$

Pm= pressure drop due to friction (psi/mile); Q= Liquid flow rate (bbl./day) D=Pipe internal diameter, in.

11. Horsepower required to compress gas in compressor

$$HP = 0.0857QT_1\left(\frac{\gamma}{\gamma - 1} \right)\left(\frac{Z_1 + Z_2}{2} \right)\left(\frac{1}{\eta_a} \right)\left[\left(\frac{P_2}{P_1} \right)^{\frac{\gamma}{\gamma-1}} - 1 \right]$$

12. Adiabatic Efficienecy of Compressor

$$\eta_a = \left(\frac{T_1}{T_2 - T_1} \right)\left[\left(\frac{z_1}{z_2} \right)\left(\frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right]$$

13. BHP required to pump the liquid

$$BHP = \frac{QP}{2449E}$$

Q=flow rate (bbl./hr.); **P**=Differentia pressure (psi)

14. $\frac{L}{D} = 30 \quad \textit{for elbow}; \quad \frac{L}{D} = 8 \quad \textit{for gate valves}$