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Designing a methodology for the optimization of pipelines on the basis of pressure drop

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Abstract: Crude oil is transported from wells to the production equipment, from production equipment to refineries and then from refineries to the more end users through pipelines. In this paper, an attempt has been to optimize the pipe lines on the basis of the pressure drop. Different methodologies are employed to find the pressure drop in gas line, liquid line and two-phase line. If lines are designed on the basis of the pressure drop, one can increase the life of the production equipment and in turn can increase the productivity of the well. In this paper, pressure drop is calculated for the three lines i.e. gas line, liquid line and the two-phase line for the loose- consolidated, water drive sandstone reservoir in the offshore, south Louisiana. If pressure in the pipeline increases to such an extent that the pipeline explodes and can cause damage to the pipeline and lowers the productivity of the well. So, pipelines are designed according to the fluid entering the line and pressure drop exerted by the fluid

Keywords: pipelines, gas line, liquid line, two-phase line

1. Introduction

Pipe-lines are simply referred to as the transportation system for crude oil to the various stations. Crude oil is transported from the well to the group gathering station and from group gathering stations to the refineries only through the pipelines. Various types of pipelines are designed in the transportation of pipe-lines. These are well flow line, inter-connected piping gathering/sales pipeline and transmission line[1]. Well flow line is that piping system that is directly connected to the well head or Christmas tree. This line can also be termed as the producing line. This line carries all the produced well fluids from the well to the first line of producing system. It can be separator or scrubber in which an attempt has been made to separation gaseous components from the liquid components. Crude oil entering the flow line contains gaseous compounds and also some abrasive particles which can cause damage to the pipelines and these lines should be sized in an effective way so that this damage should be minimized. The second type of line includes inter-connected piping. In this type of piping, lines are connected between various components of oil treating equipment i.e. separators, scrubbers, heater treater, compressor units, flare systems, storage tanks etc. These lines should sized according to the equipments in which they are fed in. this is due to the reason that different types of impurities are purified in different equipments and all the equipments have different corrosional effects on the line and exert varying amount of frictional force and as a result have different value of pressure drop. For example- in separator, all the gaseous components are separated while leaving the liquid components at the bottom while leaving the liquid components at the bottom. Liquid components contain water as well as crude oil and also contain some amount of gas. While in case of heater treater, gas , water as well as the crude oil is released from different lines. Fluid containing crude oil and mixture of water or crude oil/water emulsion has different action on pipeline as compared to the pure crude oil or water leaving the treater through the line. Therefore, these lines should be sized in most efficient way in order to achieve optimized separation of crude oil. The next type of pipe-line under consideration is gathering or sales line. This type of pipeline transfers the crude oil to the refineries from the group gathering station (GGS) or the central tank farm (CTF). These are the long distance lines and crude oil has to travel long distances to reach the refineries. These lines have to go through different types of forces exerted by the crude oil like corrosional forces, frictional forces and abrasive forces[9]. Once we have value for pressure drop lines can be sized easily and in this average life of the pipelines can be optimized. The last type of line is transmission line. From this line, purified products such as natural gas, diesel and other refined petroleum products travel long distances from refineries to its users. The various types of lines discussed above are depicted in figure1. There different criterion for finding the pressure drop in different lines. In this paper, an attempt has been made to find the pressure drop in liquid line, gas line and the two phase line. Factors affecting the pressure drop in pipelines are physical properties of fluids, the desired mass flow rate of fluid, height of the fluid when it is entering the line and height of the fluid when it is leaving the line.The physical properties of fluid include viscosity of the fluid, reynold number, and density of the fluid.

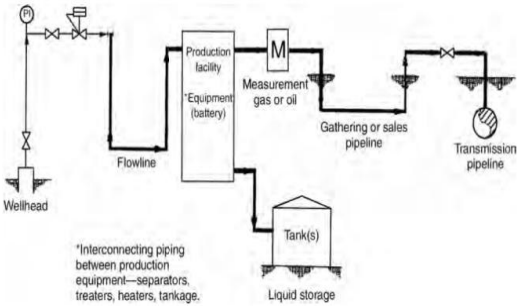

Fig 1.Type of pipe lines. (from well head to refineries)

Pipelines can explode due to high pressure [3][10].

1.2 Methodology used for designing liquid line

To determine the pressure drop in pipelines, different criterion is employed for gas line[2], liquid line[4] and two-phase line[6]. To determine the pressure drop in liquid line, firstly calculate the specific gravity and then calculate reynold number for liquid under consideration from the equation (1).

$R_e = [92.1*(S.G)*Q_l]/ (d*\mu)$ (1)

Now, calculate friction factor or moody friction factor. It is a function of Reynolds number and relative roughness of the pipe i.e. (ε /d). Once calculation of friction factor has been made, calculate pressure drop (ΔP)[5]. Pressure drop is calculated using equation (2). $\Delta P=11.5x10^{-6}[fLQ_l^2(S.G.)]/d^5$ (2) If the viscosity of the liquid entering the line is not known, then we can calculate using the equations (3), (4),(5),(6).

$\mu=10^x-1$ (3)

$X=y(T)^{-1.163}$ (4)

$Y=10^z$ (5)

$Z=3.0324-0.02023G$ (6)

1.3 Methodology used for designing gas-phase line

Input parameters for gas-phase line are gas flow rate, gas gravity(specific gravity of gas entering the line),length of the line, operating pressure, operating temperature. Firstly, calculation of gas viscosity has to be made. To calculate viscosity of the gas at operating temperature and pressure, calculate the value of viscosity at 1atm from the following graph.

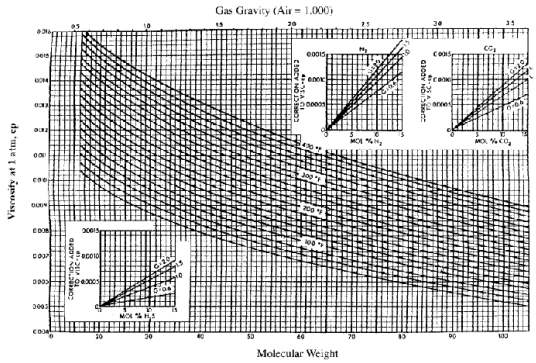

Fig2. Carr's atmospheric gas viscosity correlation

Then, calculate value of μ/μ_1 from the following figure.

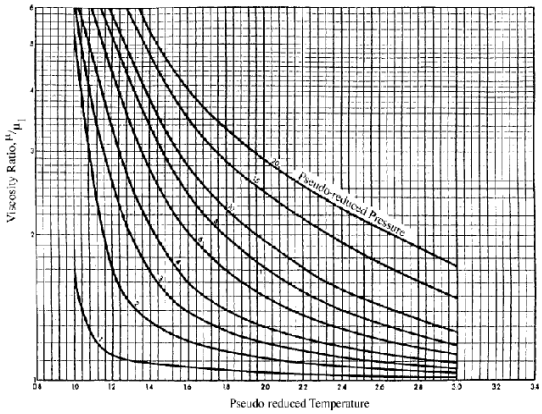

Fig 3. Carr's viscosity ratio correlation

Now, calculate gas compressibility factor (Z) from the figure4.

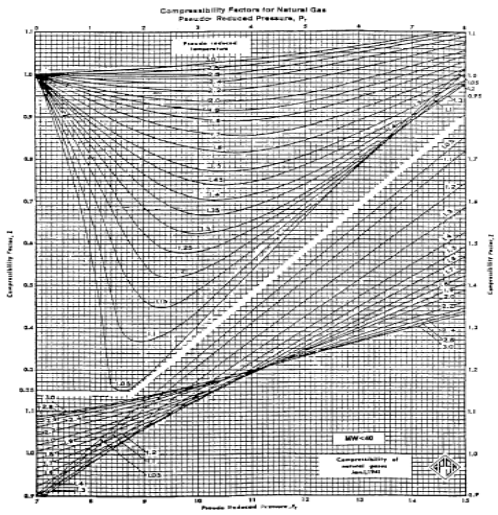

Fig 4. Standing and Katz compressibility chart.

Calculate reynold number from the equation (7).

R_e=20,100(Q_g*S)/(d*μ) (7)

calculate (P_1^2-P^2) from equation (8)

P_1^2-P^2=25.15*(Q_g^2*z*T_1*f*L)/d^5 (8)

Calculate friction factor from fig 5,

Calculate pressure drop from equation (9)

ΔP=25.1*[S*Q_g^2*Z*T_1*f*L]/d^5 (9)

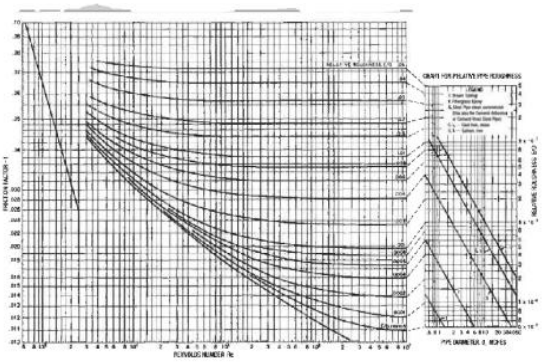

Fig 5. Friction factor chart

1.4 Methodology for pressure drop in two-phase line

Input parameters for designing a two-phase gas line are gas compressibility factor[8] (same as calculated for gas line), specific gravity of liquid, specific gravity of gas, gas flow rate, liquid flow rate and gas-liquid ratio. Now, calculate flow rate of the mixture[7]. It can be calculated using the equation

(10) W=3180*(Q_g*S) +14.6[Q_l*S.G.]

(10) Now, Calculate gas liquid ratio and density of the mixture (ρ_m) using equation (11).

ρ_m=[12,409(S.G.)P+2.7*(RSP)]/[198.7P+RTZ] (11)

Now, calculate pressure drop of the mixture using equation (12)

ΔP=6.9*10^{-8}(L*W^2)/ (ρ_m *d^5) (12)

2. Calculations

Input parameters for gas line, liquid line and two-phase line are given in the table 1. Firstly, calculate the pressure drop for the liquid line. In this paper, all the lines are assumed to be 4-inch and all the calculations are performed for 4-inch line. For that, calculate Reynolds number

.R_e=92.1(0.324*5000)/(3*4)
=12.43*10^{-3}.

Material of the pipeline is assumed to be old steel. For old steel value of ε is 0.004. therefore value of ε /d is 0.001. value of friction factor is 0.029. now, find the pressure drop (ΔP).

s.no.	Input parameters	Value
1.	Operating temperature	90^0F
2.	Operating pressure	1000 psi
3.	Gas gravity	0.6
4.	Oil gravity	0.324
5.	Length of the pipe	7500 ft
6.	gas flow rate	3.5MMcfd
7.	Liquid flow rate	5000 bpd
8.	Viscosity of liquid	3 cp
9.	Diameter of the line	4 inch

Table 1. Input parameters

ΔP=11.5*10^{-6}(7500*5000^2*0.324)0.029/(4^5)
=682.25 psi.

Therefore value of pressure drop for liquid line is 682.25psi.

Now, calculate pressure drop for gas line. One assumption is made during calculation in gas line i.e.ΔP<10%P_1. Firstly, calculate gas viscosity. Gas viscosity is calculated from fig 2 and fig 3. From fig 2 value of μ/μ_1 comes out to be 1.2. from fig 3 gas viscosity at given temperature and pressure is calculated which comes out to be 0.01284. calculate reynold number from the equation(7).

R_e=20,100(3.5*0.6)/(0.01284*4)
=8.2*10^5

The value of friction factor comes out to be 0.0187. Value of gas compressibility factor is 0.8.

P_1^2-P_2^2=25.15*0.6*$(3.5)^2$*0.8*550*7500*0.0187/4^5
=11.14*10^3 psi.

ΔP= 12.6*0.6*550*0.8*7500*3.5^2*0.029/1000*4^5
=8.65psi.

The pressure drop in gas line using general equation is found to be 8.65 psi.

Calculate pressure drop for two-phase line. Firstly, calculate flow rate of the mixture i.e. W.

W= (3180*3.5*0.6)+(14.6*5000*0.324)
=30330 lb/hr.

Gas liquid ratio is given by-

R =3500000/5000
=70 ft^3/bbl

Density of the mixture at 1000psi is given by-

ρ_m=[12409(0.324)*1000+2.7*70*0.6*1000/(198.7*1000+70*550*0.8)
=18 lb/ft^3

The value of pressure drop is given by-

ΔP= 6.9*10^{-8}*7500*30330^2/(18*4^5)
= 25.82 psi.

3. Result and discussion

From the above discussion, an attempt has been made to find the pressure drop in various lines i.e. gas line liquid line and the two-phase line. Values of the pressure drop in various lines have been given in the table 2. Maximum pressure drop occurs through liquid line and the least through the gas line. This is due to the reason that gas being lighter than liquid exerts less pressure than the liquid. The effect of gas can be seen in the two-phase line[11]. Once, the pressure drop has been calculated, then the lines can be designed on the the basis of the pressure drop.

S.No.	Name of the line	Pressure drop (psi)
1.	Gas line	8.65
2.	Liquid line	862.25
3.	Two-phase line	25.82

Table 2. pressure drop in various lines

4. Nomenclature

Z =Gas compressibility factor
T=Operating temperature, rankine
P=Operating pressure,psi
D=Diameter of the line, inch
μ=Viscosity of the liquid,cp
Q_l=liquid flow rate, bpd
Q_g=Gas flow rate,MMcfd
F=moody friction factor
ε = roughness, ft
Ɛ /d=relative roughness
R_e=Reynolds number
S =specific gravity of gas
S.G.=specific gravity of liquid
ΔP=pressure drop, psi
ρ_m=density of the mixture
R= gas liquid ratio
L=length of the pipeline
μ_1=viscosity of the gas at 1 atm, cp
P_1=pressure at the entrance of the line,psi
P_2=pressure when the fluid leaves the line,psi

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Author Profile

Deepankar chadha is studying the B.tech degree in petroleum Engineering from DIT university in 2013. I have published papers in imperial journal for interdisciplinary research and HCTL open journal of technology innovations and research. My paper titled ”designing a methodology for the optimization of horizontal and vertical separators on the basis of internal diameter” is presented in google scholar.