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Computer Simulation of Precise Dew Point Initiation in Gas Pipelines Network System

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ABSTRACT:- Mathematical models have been developed to ascertain the exact position of commencement of dew point in gas pipelines network system transmitting gaseous components or complex hydrocarbon mixtures. Attainment of dew point in gas transmission pipelines leads to flow separation. Inadvertently, two-phase flow situation will result with liquid and gas holdups coexisting. The liquid holdup eventually settles at low points in the pipe as condensates. The condensate so formed obstructs flow leading to increased pressure drop along the line. The driving force of a flowing fluid stream is a function of the overall line pressure drop and line throughput. The higher the two militating factor, the higher the pumping and compression power. It is very worthy to note the exact point on a gas pipeline at which condensation will set in; drain plugs could be installed at such points for periodical removal of the condensate so formed. This will offset the high cost of investment on gas pipelines assets facilities.

KEYWORDS:- Burial Depth, Dew Point Temperature, Gas Fraction Mass flow-rate, Specific Heat Capacity, Internal fluid Convective Heat Transfer, Thermal Conductivity, Mixture Velocity, Heat Flux, Residual Heat, Flow Resident Time, Heat Flux..

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I INTRODUCTION

Gas pipelines network system run over a distance of thousands of kilometres traversing places of diverse temperature gradients [1, 2, 3]. This necessitates the need to find at what point along a pipeline at which condensation will commence after attainment of dew point for any particular gas or natural gas gaseous mixtures. The computer simulation approach is geared toward the determination the dew point temperature and the exact point or distance on the pipeline network system where the dew point of the hydrocarbon mixture will set in. At such points the remedial measure that could be taken is the instalment of drain plugs for removal of condensates; thereby getting rid of the problem of increased pressure drops that will ultimately result in increased pumping or compression power. This approach will result in a reduction of capital cost of pipeline assets and facilities even the inline equipment.

Hydrocarbon dew point determination is it the gas chromatography method, Chilled mirror method, or gas equation approach still shows a wide margin of deviation when results are compared. The dew point temperature is highly dependent on the operating steam pressure, environmental effects and gas composition [4, 5, 6]. In general terms, the accuracy of these methods is within -5% to 5%. Hence the need to consistently formulate models that could correlate the experimental results and mathematical models results to a close margin of accuracy.

II PURPOSE AND SIGNIFICANCE

Gas pipelines systems with reference to Natural Gas Pipelines approach due points temperatures by the reason of environmental effects, average flow stream pressure, bulk stream temperature, cooling associated with pressure drops at valves and fittings, the sudden expansion of the fluid stream in the pipeline among others. These effects can lead to condensation or liquid fallout from heavy hydrocarbon components of the gaseous mixture. The liquid fallout if not timely recovered could lead to increased line pressure drop, decreased the heating value of gas stream, increased pumping and compression power, reduction in line transmission efficiency, higher cost of investment and operation of gas pipeline assets and facilities and other undesirable effects.

In the gas pipeline network system, the point of attainment of dew point temperature must be ascertained d to enable installation of drain plugs for periodical removal of the liquid fallout and the condensates so formed. Gas chromatographs, chilled mirror, gas equations of state such as Peng Robinson, Redlich Kwong Soave and PG-SAFT methods had been used at one time or the other for hydrocarbon dew point determination, even the characterization of the gas stream. This paper is to exploit the fundamental heat flux concept for the determination of dew point temperature of the complex hydrocarbon mixture. This approach would generate comparative analysis with other existing methods of dew point calculation of natural gas stream in pipeline network system by computer simulation of the physical developed models.

III COMPUTER SIMULATION FOR THE PRECISE POSITION OF DEW POINT

The computational analysis core mathematical models are as outlined:

$$q = \frac{2\pi L\left(T_1 - T_4\right)}{\frac{1}{h_{in}} + \ln\left(\frac{r_2}{r_1}\right)/K_{As} + \ln\left(\frac{r_3}{r_2}\right)/K_{cs} + \ln\left(\frac{r_4}{r_3}\right)/K_{mw} + \ln\left[\left(\frac{d}{r_4}\right) + \sqrt{\left(\frac{d}{r_4}\right)^2 - 1}\right]/K_S} \tag{1}$$

$$h_{in} = 0.0225\frac{K_f}{2r_1}\left[\frac{2Vr_1}{\nu_f}\right]^{0.8}\left[\frac{C_{Pf}\nu_f\rho_f}{K_f}\right]^{0.4} \tag{2}$$

$$q = \frac{2\pi Vt\left(T_1 - T_4\right)}{\frac{1}{h_{in}} + \ln\left(\frac{r_2}{r_1}\right)/K_{As} + \ln\left(\frac{r_3}{r_2}\right)/K_{cs} + \ln\left(\frac{r_4}{r_3}\right)/K_{mw} + \ln\left[\left(\frac{d}{r_4}\right) + \sqrt{\left(\frac{d}{r_4}\right)^2 - 1}\right]/K_S} \tag{3}$$

$$q_R = \dot{m}_L C_{PL}\left(T_d - T_R\right) + \dot{m}_G C_{PG}\left(T_d - T_R\right)$$

$$T_d = T_R + \frac{q_R}{\dot{m}_L C_{PL} + \dot{m}_G C_{PG}} \tag{4}$$

Computational Algorithm Input Parameters

Inner radius of corrosion coating, r_1=0.4532m.
Inner pipe radius, r_2=0.4572m
Outer pipe radius, r_3=0.4682m.
Outer radius of insulation, r_4=0.50722m.
Thickness of corrosion coating, th=0.004m
Burial depth to the pipe centerline, d=1.4572m.
Thermal conductivity of carbon steel, K_{CS}=0.1569W/mK.
Thermal conductivity of mineral wool block, $K_{MW}=130\times10^{-3}$W/mK
Internal flow conductivity, K_f=0.123W/mK.
August, 2008 and January 2006 production data(ElfTotal Petroleum Nigeria Limited):
Specific heat capacity of liquid and condensate, C_{PL}=959.1696J/KgK.
Specific heat capacity of gas, C_{PG}=968.6694J/KgK.
Liquid density, ρ_L=589.207Kg/m3.
Gas density, ρ_G=73.2404Kg/m^3.Volume fraction of liquid and condensate in the pipeline, R_L=0.281546.
Reference pressure, P_b=1.01325bar.
Reference temperature, T_b=281K.
Average stream temperature, T_A=313K.

A. Simulation Programme for the Precise Position of Dew Point

```
% MAIN PROGEAMME FILE
% DETERMINATION OF THE EXACT POSITION OF DEW POINT TEMPERUTURE
% Initialization
% Internal pipe wall radius, r2(m)
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r2=0.4533;
%  Pipe outer wall radius, r3(m)
r3=0.4772;
%  outer radius of insulation, r4(m)
r4=0.5072;
%  Burial depth to the pipe centre, d(m)
d=1.4572
%  Kcs--thermal conductivity of carbon steel(W/mK)
Kcs=0.1569;
%  Thermal conductivity of the soil, Ks(W/mK)
Ks=1.85;
%  Kmw--thermal conductivity of mineral wool block((w/mK)
Kmw=130E-3;
%  Thermal conductivity of corrosion coating-Asphalt, Kas(w/mK)
Kas=0.74;
%  Internal flow thermal conductivity, Kf(W/mK)
Kf=0.123
%  CPL--specific heat capacity of Liquid and Condensates(J/KgK)
CPL=959.1696;
%  CpG--specific heat capacity of Gas(J/KgK)
CPG=968.669471;
%  August 2008 ElfTotal Production Data
%  GD--gas density(Kg/m3)
GD=73.2404;
%  LD--liquid density(Kg/m3)
LD=589.207;
%  RL--volume fraction of liquid in the pipeline
RL=0.280546;
%  Volume fraction of the gas flowing, VFG
VFG=1-RL;
%  Average internal flow heat capacity, CPA
CPA=RL*CPL+VFG*CPG;
% Density for two phase flow at no slip condition, D2P(Kg/m3)
D2P=LD*(1-VFG)+GD*VFG;
% Mixture flowrate, QM(m3/s)
QM=1.8;
%  Volume fraction of Liquid and Condensates flowing, QL(m3/s)
QL=RL*QM;
%  Volume fraction of Gas flowing, QG(m3/s)
QG=QM-QL;
%  T--mean or bulk temperature(K)
  TA=313;
%  T3==ambient temperature(K)
T3=291;
%  Td--dew point temperature of the mixture(K)
Td=67.5;
%  Average composition of the gas from production line for the month of August 2008(mole fraction)
C1A=0.869859;C2A=0.054574;C3A=0.020709;IC4A=0.004517;NC4A=0.006309;IC5A=0.002178;NC5A=0.0
01787;C6A=0.004627;N2A=0.000598;CO2A=0.034843;
% Molar mass of gaseous components
M11=16;M21=30;M31=44;M4I1=54;M4N1=54;M5I1=72;M5N1=72;M61=86;M71=100;M81=114;M91=128;
M101=142;MN21=28;MCO21=44;
  MAIR=28.97;
% Average molecular mass of gaseous mixture(PRODUCTION) in August,
2008MGASA=(C1A*M11+C2A*M21+C3A*M31+IC4A*M4I1+NC4A*M4N1+IC5A*M5I1+NC5A*M5N1+
C6A*M61+N2A*MN21+CO2A*MCO21);
%  Specific gravity of the mixture for the month of August, 2008
GAA=MGASA/MAIR;
%  To calculate gas absolute viscosity, GV(Pas--Ns/m2)
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% Absolute viscosity of the hydrocarbon components, GVHC, is expressed as:
GVHC=(8.188E-3-6.15E-3*(GAA)+(1.709E-5-2.062E-6*log10(GAA))*(1.8*TA+0.27))*1.02247E-5;
% Absolute viscosity of Nitrogen component
   GVN=(9.59E-3+8.48E-3*log10(GAA))*N2A*1.02247E-5;
% Absolute viscosity of carbon dioxide component
GVC=(6.24E-3+9.08E-3*log10(GAA))*CO2A*1.02247E-5;
% Absolute viscosity of gaseous mixture, GV(Pas-Ns/m2)
GV=GVHC+GVN+GVC;
% Internal flow kinematic viscosity, KVf(m2/s)
KVf= GV/D2P;
% L--length of pipeline(m)
forL=0:1000:850000
% D--nomonal pipe diameter(m)
forD=0.9144:0.9144:0.9144
% r1--inner wall radius of the pipe(m)
  r1=(D/2)-0.004;
% A1--pipe area of crossection
A1=pi*r1^2;
% V--average flow velocity(m/s)
V=QM/A1;
% t=resident time in the pipeline(s)
  t=L/V;
% m1--mass flowrate of gas fraction(Kg/s)
m1=GD*QG;
% m2=mass flowrate of liquid fraction(Kg/s)
m2=LD*QL;
% Q1--heat lost t0 the environment(J/s)
hin=0.0225*(Kf/(2*r2))*((2*V*r2)/KVf)^0.8*(CPA*KVf*D2P/Kf)^0.4;
  Q1=(2*pi*V*t*(TA-T3))/(1/hin+log(r2/r1)/Kas+log(r3/r2)/Kcs+log(r4/r3)/Kmw+log(((d)/(r4))+(((d/r4))^2-
1)^0.5)/Ks);
% Q2--bulk heat of the gas(J/s)
  Q2=m1*CPG*(TA-T3);
% Q3--bulk heat of the condensable component(J/s)
Q3=m2*CPL*(TA-T3);
% Q4--bulk heat of the mixture(J/s)
Q4=Q2+Q3;
% Q5--residual heat(J/s)
  Q5=Q4-Q1;
% Tdc--dew point of the condensable components(K)
Tdc=T3+Q5/(m1*CPG+m2*CPL);
if Tdc<=Td
disp('          Tdc        D         L')
fprintf('%20.7f\n',Tdc,D,L)
else
disp('      Dew point not yet established at diameter(D) and length(L)')
fprintf('%20.7f\n',D,L,Tdc)
end
end
```

IV MATHEMATICAL MODEL COMPUTATIONAL ANALYSIS

The mathematical models are as outlined in equations 1 to 4. The dew point of the hydrocarbon components is calculated using the Elf Total production data for the month of August 2008 and month of January 2006. Employing the chart for equilibrium constants for hydrocarbons at low temperature range, the dew points of the hydrocarbon mixture obtained by trial and error are as in Tables 1 and 2. The dew point of the gaseous mixture as in Tables 1 and 2 is approximately -205.5°C (67.5K)

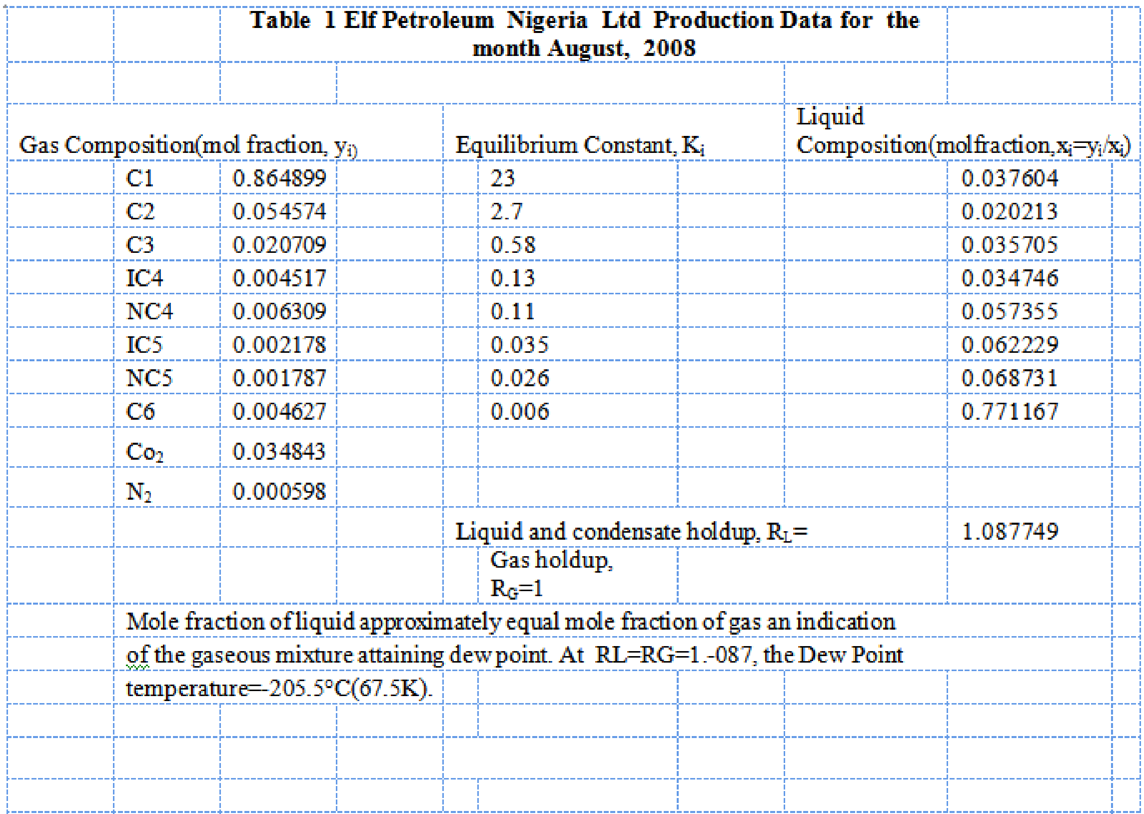

Table 1 Elf Petroleum Nigeria Ltd Production Data for the month August, 2008

Gas Composition(mol fraction, y_i)		Equilibrium Constant, K_i	Liquid Composition(molfraction,x_i=y_i/x_i)
C1	0.864899	23	0.037604
C2	0.054574	2.7	0.020213
C3	0.020709	0.58	0.035705
IC4	0.004517	0.13	0.034746
NC4	0.006309	0.11	0.057355
IC5	0.002178	0.035	0.062229
NC5	0.001787	0.026	0.068731
C6	0.004627	0.006	0.771167
Co_2	0.034843		
N_2	0.000598		
		Liquid and condensate holdup, R_L=	1.087749
		Gas holdup, R_G=1	

Mole fraction of liquid approximately equal mole fraction of gas an indication of the gaseous mixture attaining dew point. At RL=RG=1.-087, the Dew Point temperature=-205.5°C(67.5K).

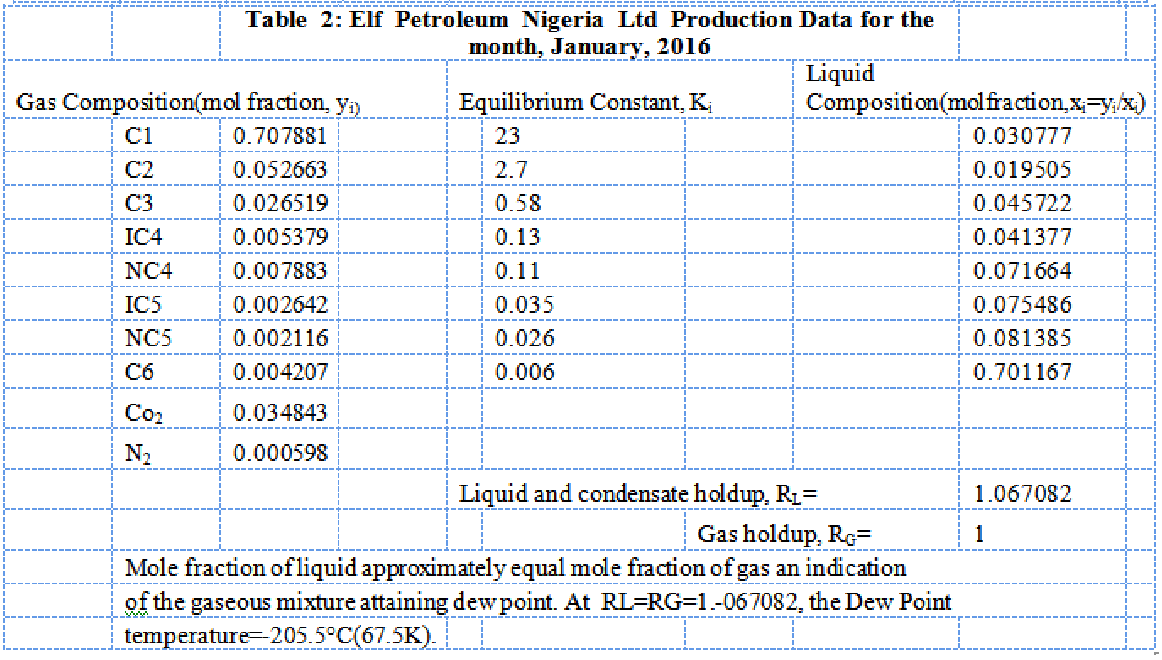

Table 2: Elf Petroleum Nigeria Ltd Production Data for the month, January, 2016

Gas Composition(mol fraction, y_i)		Equilibrium Constant, K_i	Liquid Composition(molfraction,x_i=y_i/x_i)
C1	0.707881	23	0.030777
C2	0.052663	2.7	0.019505
C3	0.026519	0.58	0.045722
IC4	0.005379	0.13	0.041377
NC4	0.007883	0.11	0.071664
IC5	0.002642	0.035	0.075486
NC5	0.002116	0.026	0.081385
C6	0.004207	0.006	0.701167
Co_2	0.034843		
N_2	0.000598		
		Liquid and condensate holdup, R_L=	1.067082
		Gas holdup, R_G=	1

Mole fraction of liquid approximately equal mole fraction of gas an indication of the gaseous mixture attaining dew point. At RL=RG=1.-067082, the Dew Point temperature=-205.5°C(67.5K).

Applying the computational algorithm for Elf Total August 2008 and January 20006 production data dew point was attained at a pipe length of 848km and pipe nominal diameter of 36"(0.9144m). The dew point temperature being T_d=67K. These results are subject to environmental pressure and temperature of 1bar and 291K respectively.

V MODEL APPLICABILITY

The computer simulated model is applicable to any gas network system to determine the dew point temperature of any gas or complex hydrocarbon mixtures and the exact distance from the upstream or downstream end of the pipeline. The determined dew point temperature is subject to the design and operational conditions of the line.

VI CONCLUSIONS

A computational algorithm has been developed to enable the determination of dew point temperature of a gas (hydrocarbon gaseous mixtures) and the precise points or distance relative to the inlet or outlet of the gas pipeline network system. The results obtained are remarkable. It is believed this approach will lend itself to optimal performance of our gas pipelines.

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