









$C_{AO}$	170 (kg/m <sup>3</sup> )
$C_{Ai}$	25 (kg/m <sup>3</sup> )
T	30 days
$D_{WO}$	$1.52 \times 10^{-10}$ (m <sup>2</sup> /s)

AT 30°C (303K)

$C_{AO}$	170 (kg/m <sup>3</sup> )
$C_{Ai}$	35 (kg/m <sup>3</sup> )
T	30 days
$D_{WO}$	$1.60 \times 10^{-10}$ (m <sup>2</sup> /s)

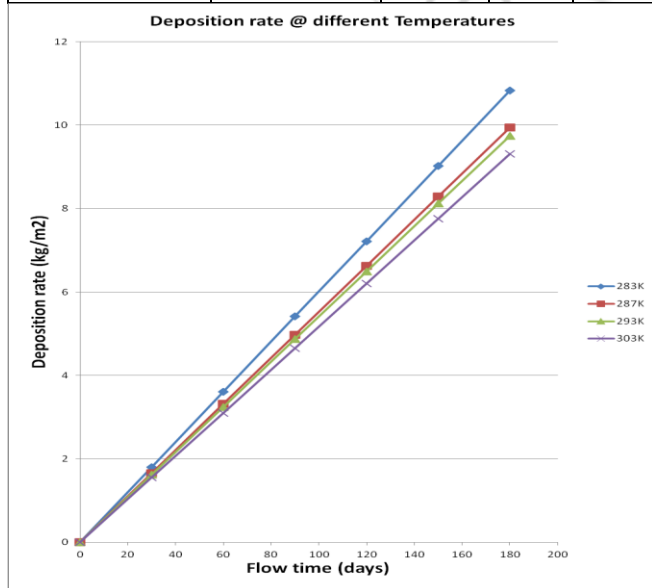
The output of the model (equation 3.4) obtained at varying temperatures (as tabulated above) are then tabulated as shown below, which is also plotted in figure 4.1.

**Table 4.2:** Wax deposition rate @ different Temperatures (Model output)

Deposition rate (kg/m <sup>2</sup> s) @ different temperatures				
Flowing time (days)	283 <sup>0</sup> k (10 <sup>0</sup> C)	Flowing time (days)	283 <sup>0</sup> k (10 <sup>0</sup> C)	Flowing time (days)
0	0	0	0	0
30	1.8047	30	1.8047	30
60	3.6094	60	3.6094	60
90	5.4142	90	5.4142	90
120	7.2189	120	7.2189	120
150	9.0236	150	9.0236	150
180	10.8283	180	10.8283	180

**Table 4.3:** Wax deposition rate @ different Temperatures Laboratory Results

Deposition rate (kg/m <sup>2</sup> s) @ different temperatures				
Flowing time (days)	283 <sup>0</sup> k (10 <sup>0</sup> C)	287 <sup>0</sup> k	293 <sup>0</sup> k	303 <sup>0</sup> k
0	0	0	0	0
30	1.7910	1.5462	1.5089	1.4321
60	3.4094	3.2343	3.0243	2.9762
90	5.1922	4.8092	4.7941	4.5502
120	7.0234	6.5461	6.3042	5.9845
150	8.9872	8.1908	7.9980	7.5342
180	10.5432	9.7345	9.5674	9.1067



**Figure 4.1:** A plot showing variation in deposition rate for different operating temperatures

## 4. Discussion of Result

From Table 4.1 above, it can be seen that when temperature was 10°C (283<sup>0</sup>K) the concentration of wax in the flowing fluid was 5kg/m<sup>3</sup> and when the temperature was 30°C the concentration was 35 kg/m<sup>3</sup>. This shows that wax concentration is a thermodynamic property i.e it varies with changes in temperature. It can therefore be deduced that Wax solubility in a solvent increases with increase in temperature.

Also from Table 4.1 it can be seen that when temperature was 10°C (283<sup>0</sup>K) the Diffusivity of Wax in oil was  $1.45 \times 10^{-10}$  m<sup>2</sup>/s and when the temperature was 20°C Diffusivity increased to  $1.52 \times 10^{-10}$  m<sup>2</sup>/s. This shows that Diffusivity of wax in oil is a thermodynamics parameter which increases with increase in temperature.

It can be seen from Table 4.2 that for a flowing time of 3 months, the Deposition rate was 1.8047kg/m<sup>2</sup>s at 283K and 1.5511 kg/m<sup>2</sup>s at 303K. This shows that the rate of Deposition of wax along pipeline wall reduces with increase in temperature; this is also confirmed in figure 4.1 with temperature of 303K showing the lowest deposition rate. Therefore figure 4.1 serves as a tool for determining the deposition rate at different operating temperatures and which would allow the selection of the temperature with minimum deposition rate as system or operating temperature.

Comparing table 4.2 (model output) and 4.3 (experimental results), it was observed that at the flowing time of 30 days at operating temperature of 10°C (283<sup>0</sup>K) the deposition rate was 1.7910 kg/m<sup>2</sup>s for laboratory result and at the same operating condition it was 1.8047 kg/m<sup>2</sup>s for model result. This shows a very high predictive accuracy of the model since the percentage difference is negligible. This trend can also be seen at other operating conditions 287<sup>0</sup>k, 293<sup>0</sup>k and 303<sup>0</sup>k respectively.

## 5. Conclusion

The approach employed in this work is easily accessible since the application requires constant thermodynamic data (properties that varies with temp) and rheological properties of the crude. The following conclusion can be deduced from this research work.

1. A new model for prediction of wax deposition during turbulent and laminar flow of crude oil in pipeline using penetration theory has been developed.
2. A tool for determining the deposition rate at different operating temperatures and which would allow the selection of the temperature with minimum wax deposition rate as system or operating temperature has been developed

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