Scientific Research Outcome Report

Integrated Studies on Crude characterization, Wax Deposition and modeling to improve flow assurance for some Indian oilfields

1. **Faculty Name:** Dr Anirbid Sircar

2. **Branch / Department:** School of Petroleum Technology

3. **Researcher's Name along with designation:**

   Mr. Anand Gupta, DGM, ONGC (PhD Scholar, SPT, PDPU)

4. **Research Title:** Integrated Studies on Crude characterization, Wax Deposition and modeling to improve flow assurance for some Indian oilfields

5. **Major Goal of this Scientific Research Project**

   This report investigates how the technique of small angle neutron scattering (SANS) helps elucidate the phenomenon of wax deposition in a petroleum crude oil. The product is a gel below the cloud point. The onset and growth of this waxy gel, and changes in its nanostructure, are recorded as a function of temperature over the range $10 \leq T/°C \leq 65$. Wax has a definite characteristic length of about 100 Å (10 nm) which can be observed at temperatures as high as 57°C, however study indicates that the wax also contains very large structures - of the order of a micrometer - over the temperature range 30° - 50°C.

   The structural studies are supplemented by corresponding sets of viscosity and stress data taken from the gelling wax when subjected to an applied shear. We observe that the stress will increase as the temperature falls - i.e. as the system gels - but, in general, will then reach a maximum and tend to decline.

   The wax results are compared with those from a similar system in which the wax is replaced by n-docosane (C22), one of the major components of the wax. Significant differences between the behavior of the wax and the pure component in the solvents are noted. Rheological studies and Thermodynamic models on wax deposition like

Lira Galeana model, Erickson model, Pederson Model, Cutinho's model and Won's model, Matinz model etc is under investigation.

6. Major Activities

- To study the current progress in flow assurance with focus on wax deposition for paraffinic base crudes.
- To perform crude characterization. (Completed)
- Rheological studies of crude oil (Completed)
- To test suitable wax inhibitors
- To develop thermodynamic model for paraffin deposition for a trunk line along with qualitative and quantitative analysis (Ongoing)
- Testing of thermodynamic models with real time data

7. Specific Objectives & Research Hypothesis

The critical role of economics in crude oil production makes wax deposition a significant economic concern to the industry due to (a) Capital Investment (b) Lost production (c) Risk element in development. The project aims at simulating wax deposition models and find out inhibitors to minimize the same.

8. Material and Methods along with necessary diagrams

Reheometer (PDPU)

Crudes of various Viscosity (Given by ONGC)

OLGA software (help of NALCO)

9. List of equipment, technical facilities/resources used from PDPU for the above mentioned research activity

MATLAB, Reheometer

10. Significant Results/key outcomes/achievements along with necessary pictures / diagrams / images

Fig. Reheometer Experimental set-up

The following are the properties of the crude samples which are used in the study.

Table 1: Characteristics of Crude Oil of X Field

WELL NO	PAY ZONE	POUR POINT	WAX %	ASPHALTENE%	RESIN %
X#A	K-VI+VII	36	14.35	2.79	22.26
X#60	K-X	45	37.34	2.20	8.39
X#113	K-V	33	22.45	0.19	6.20
X#46	K-V+VI	39	39.38	0.57	12.08

RESULTS

In the first set of experiments we have considered the variation of viscosity with time at different shear rate without pre-treating and after pre-treating the crude sample of X#A. Viscosity at 30 sec^{-1} is higher than the viscosity at shear rate of 50sec^{-1}. Similarly it can be seen from the result that as the shear rate is increased at constant temperature viscosity is decreased. The graphical result also shows that the viscosity is decreased after pre-treatment of crude sample as compared to sample without pre-treatment. Comparing the result of after pre-treatment and before pre-treatment, it is seen that after pre-treatment the peaks are reduced comparatively.

In the second set of experiments, three different crude samples having different wax percentage are tested. X#46 has the highest wax content and highest viscosity while X#113 has the lowest wax content and lowest viscosity and X#60 has the moderate viscosity and wax content. The results show the reduction in viscosity with increasing shear rate. Also the viscosity is decreased as the wax percentage is reduced.

It is also observed that xylene reduces the viscosity of crude oil. The experimental results indicate that there is greater reduction in viscosity with 2% xylene compared to 1% xylene. It can be seen from the graph that PPD reduces the viscosity of crude oil.

INHIBITION MECHANISM OF XYLENE

The wax deposition-inhibiting action of the xylene-based inhibitor is attributed to its interaction with the forming wax aggregates. The xylene-based inhibitor has structures with segments that interact with the forming wax crystal and prevent wax crystal growth.

The waxes in crude oils are paraffinic and vary in amount and molecular weight distribution. When waxy crudes are cooled down, the paraffinic wax starts to crystallize in the form of thin plates, needles, or micro crystals. As wax components come out of solution, the needles compact into a three-dimensional network. Plates curl on their edges, forming hollow needles that can then network. In the present investigation, the xylene exhibited good performance as wax deposition inhibitor and flow improver. In addition to this it also facilitates greater adsorption of the inhibitor molecules onto the wax crystal networks and prevents the interlocking of the three-dimensional wax networks. The ability to form a stable suspension in the crude oil makes the inhibitor effective at concentration in the parts-per-million range, compared to the concentration of the wax crystals.

INHIBITION MECHANISM OF PPD

Pre-treatment of crude oils with PPD is an attractive alternative to solve wax deposition problems during transport of crude oils along pipelines. Wax crystal modifiers are chemicals capable of growing into wax crystals and to alter their growth and surface properties. These chemicals reduce the affinity of crystals to interlock and form three-dimensional networks, thereby lowering the pour point and the viscosity. For that, they are commonly named as pour point depressants (PPD). (Coto, B., et al., 2014)

Observations

The viscosity of a crude oil is one of its most important physical properties in flow assurance study. We can use the rheological measurements to give estimation about Flow Assurance.

Crude oils and the mixtures of different fields were characterized using Rheometer. The study shows that viscosity decreases as the shear rate is increased. The samples are analysed in both without pre-treatment and after pre-treatment. The peaks obtained in the graphs without pre-treatment is due to the non-homogenous nature of crude oil. Peaks are obtained when the crystal particles present in the crude sample strike the Rheometer. By pre-treating the crude oil the peaks obtained are reduced.

The samples were also analysed using xylene and PPD. The use of xylene and PPD showed a decrease in viscosity at constant shear rate. The decrement in viscosity is higher with 2% xylene as compared to 1% xylene. Also the decrement in viscosity with 2% PPD is higher than with 1%PPD. By comparing the results obtained for xylene and PPD at different concentration and shear rate, we can see that reduction in viscosity with xylene is higher as compared to PPD.

The wax deposition-inhibiting action of the xylene-based inhibitor is attributed to its interaction with the forming wax aggregates. The xylene-based inhibitor has structures with segments that interact with the forming wax crystal and prevent wax crystal growth. In the present study, the xylene exhibited good performance as wax deposition inhibitor and flow improver. The ability of xylene to form stable solution in the crude oil makes the inhibitor effective. The formulation has a good wax-deposition inhibiting, pour-point depressing, and viscosity-reducing effect for the tested crude oils.

11. Impact of the research outcomes or findings that address the intellectual merit and broader impacts of the research work

The research will help the oil fraternity to predict wax deposition on the trank line and to mitigate the same.

12. How the results have been shared/ disseminated ,you can list any of following: Publications, Ph.D on going

Publications

(1) Gupta, A. and Sircar, A. (2015) Need of flow assurance for crude oil pipelines: A Review. **International Journal of Multidisciplinary Science and Engg**, Vol 6, Issue2, Feb 2015. pp.44-49.ISSN:2045-7057. IF: 0.4

(2) Saini, R., Anto, R., Gupta, A., Sircar, A., (2015) Crude Characterization on Rheometer for Flow Assurance (To be submitted)

PhD (On Going)

Mr. Anand Gupta, DGM, ONGC is currently doing his Ph.D on Wax Deposition Studies

13. **Give also name of other PDPU individuals involved in the research**

Rincy Anto, M.Tech. Student, SPT, PDPU

Rajshree Saini, M.Tech. Student, SPT, PDPU

14. **Which organizations have been involved as partners?**

ONGC, Ahmedabad

15. **Have other collaborators been involved?**

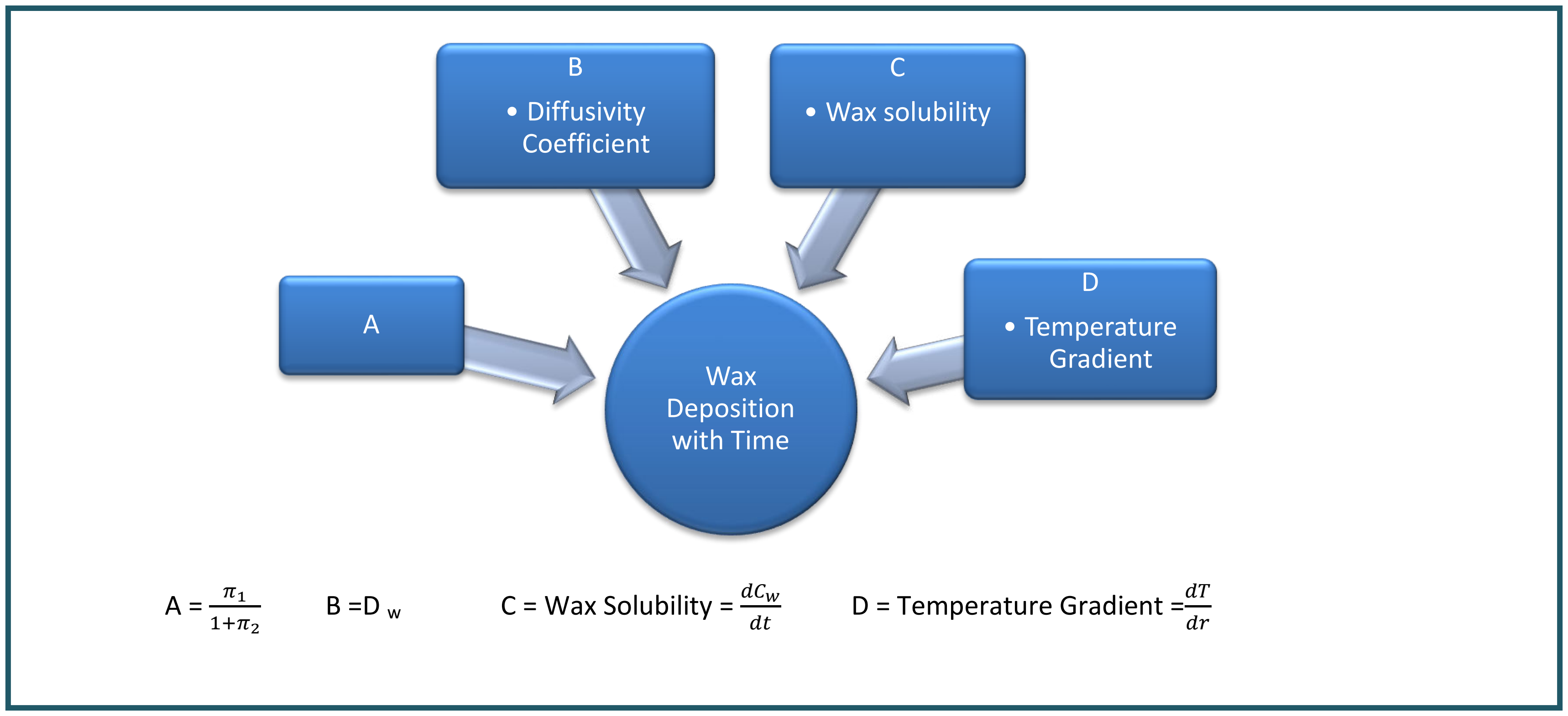
NALCO, Pune

16. **Mention if any infrastructure got added out of research outcome to PDPU institutional resources**

Nil

17. **Includes up to six images (images are optional)**

ALGORITHM FOR MATZIN MODEL



$\rho_L = density\ of\ liquid\ (oil)$ = Kg/m^3 = Rho

$v_L = Flow\ rate\ of\ oil$ = m/s = v

$\mu_L = Viscosity\ of\ oil$ = Kg/m/s = mu

$d = Inside\ diameter\ of\ pipe = 0.205\ m$

$d_w = Diameter\ of\ pipeline\ after\ taking\ into\ account\ wax\ buildup$ = m

$\delta = wax\ layer\ thickness$ = m = del

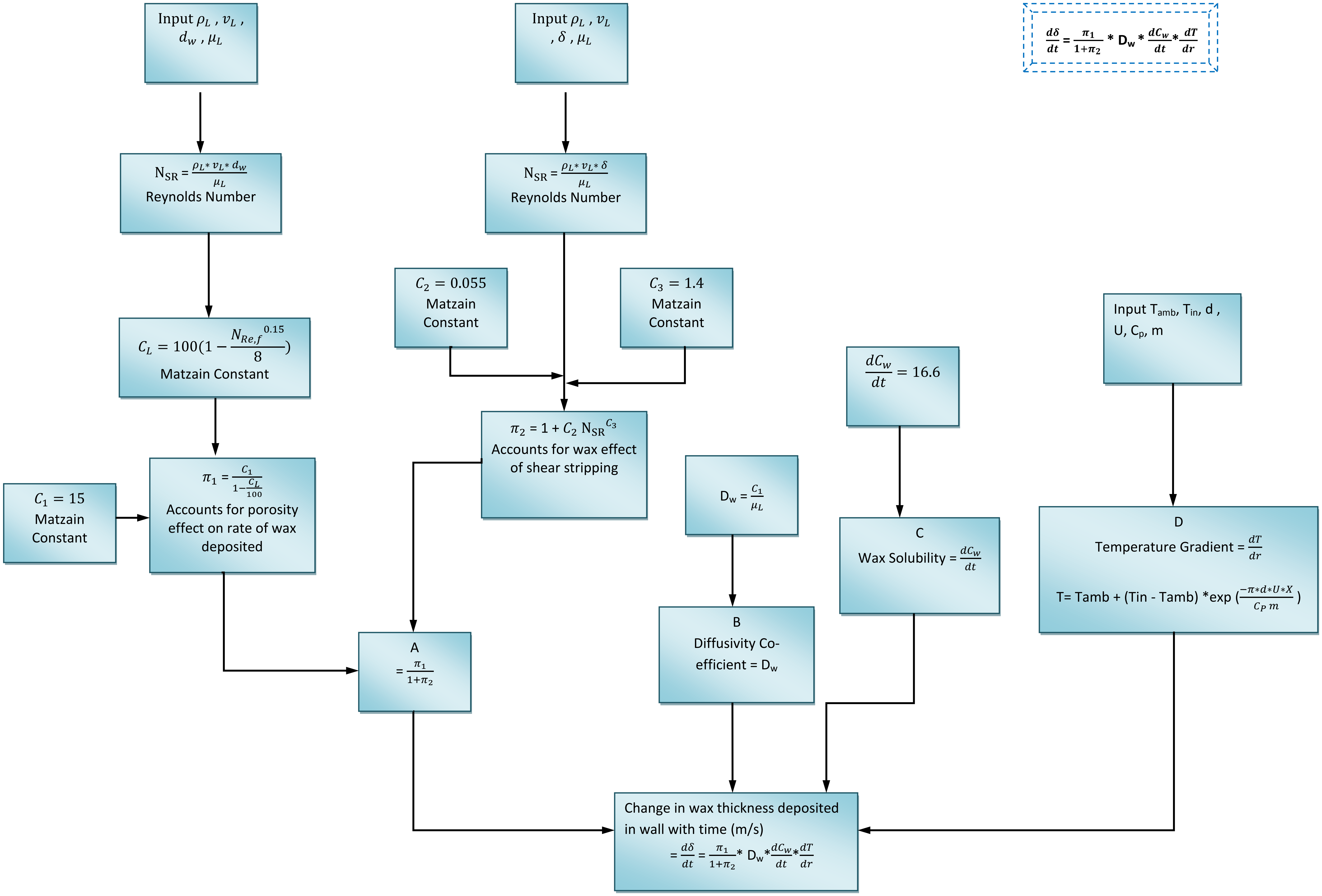
$T_{amb} = Ambient\ temperature$ = °C

$T_{in} = Inlet\ temperature$ = °C

$C_P = Heat\ Capacity$ = 1.9

$m = Mass\ flow\ rate$ = Kg / m^3

$$\frac{d\delta}{dt} = \frac{\pi_1}{1+\pi_2} * D_w * \frac{dC_w}{dt} * \frac{dT}{dr}$$



Oluwatosin Emmanual Ajayi, 2013.Modelling of control wax deposition and loosening in oil and gas production systems. NTNU Thesis, PP:1-116