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(RESEARCH ARTICLE)

Flow assurance, simulation of wax deposition for Rawat field using PIPSIM software

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Abstract

One of the most relevant flow assurance issues in oil transportation is indeed the phenomena of wax deposition. Wax deposition occurs when the temperature along the pipeline falls below a point where it is described as Wax Appearance Temperature (WAT) The deposition may cause a lot of problems to the industry and definitely will involve expensive cause to overcome the problem. The flow system was built for Rawat field which is consists of (13) wells in the Rawat/Wateesh field. In this studies a series of cases were carried out at different flow rates, ambient temperature to study falling temperature through f pipline using PIPESIM Software and providing data from central petroleum laboratory and Rawat operating company. To check that temperature at all points along the flow line and trunk line is above the pour point and wax appearance temperature, check the requirement of heater, heat tracing and insulation for the pipelines more ever is used to studies the influence of changing flow rate, ambient temperature and water cut for pipeline temperature. The line size, line velocity and heat duty of the system have been calculated using excel program.The results show that the minimum temperature criteria for pipelines should be above 54C to avoid gelling of the fluid, Wax precipitation analysis results indicates that the minimum wax precipitation temperature for Wateesh W-was approximately 62°C and the same for Rawat RC-1 well were approximately 58°C.the flowlines size were determined 4" and 6" for trunk line.Also The results show that there is a direct relation between the wax deposition and temperature, It was observed that wax deposit increases with decreasing the temperature. On the other hand, an increase in flow rate results in a decrease in the wax deposition.

Finally, hot insulation of the flow lines and trunk line was required, Electrical Heat Tracing to heat the fluid to 75 Deg, chemical injection such as wax inhibitors and pigging process to control the wax deposition.

Keywords: Flow Assurance; Wax Deposition; PIPSIM Software; Rawat field

1. Introduction

The term Flow Assurance was devised by Petro bras in the early 1990s meaning "Guarantee of Flow". The safe and efficient delivery of hydrocarbons from the well to the collection facilities is the most important component of Flow Assurance.

Flow-assurance Study is an endeavour to clear all doubts on liquid mobility from the down-hole towards the surface and thereafter through the surface pipes and equipment all through to the end. It deals with the risks and problems arising from the properties and behavior of the produced hydrocarbons, associated fluids, and solids. Flow Assurance is applied during all stages of system selection, detailed design, surveillance, troubleshooting operation problems, increased recovery in late life etc., to the petroleum flow path (well tubing, subsea equipment, flow lines, initial processing and export lines). It is sometimes referred to as "cash assurance" because breakdown in flow assurance

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anywhere in the entire cycle would be expected to lead to monetary losses, which shows the economical importance of ensuring the flow.

In the last decade Flow Assurance has emerged as a major technical discipline and has gained attention due to its impact in the petroleum industry. It has given rise to an inter disciplinary research wherein along with the development in laboratory and use of various chemicals, emphasis on modeling and simulating the pipeline under various conditions has been studied at large. This has led to the development of real time data monitoring software and Flow Assurance Advisory systems. These systems rely on good model predictions and available sensor readings in the production system. These software's are still growing and various rigorous and robust models for flow assurance issues have been customized based on specific field characteristics [1].

1.1. Problems of fluid flow assurance

The main flow assurance problems in offshore and onshore oil fields are hydrates, wax deposition, asphaltenes, slugging, naphthenates, scales, corrosion and emulsions. Among above flow assurance challenges, hydrates, wax deposition, asphaltenes, naphthenates and scales cause deposition in pipeline and these issues are the most significant areas being considered today due to exorbitantly higher cost of maintenance and troubleshooting during oil productions. Figure 2 shows solid depositions in pipeline responsible for flow assurance issue [2], [3]. Other issues such as slugging, corrosion, erosion and emulsions create operational issues during production.

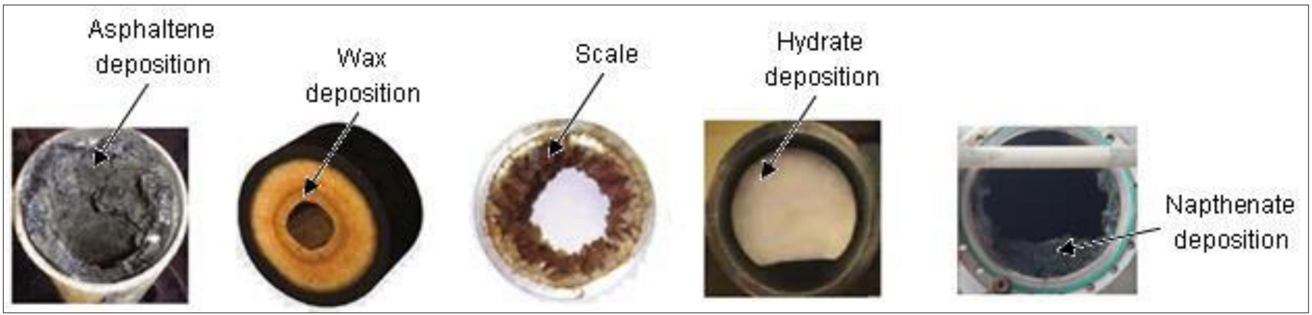

Figure 1 The above Figure Represent the Solid Deposition in Pipeline

One of the main unsolved challenges in Flow Assurance is wax deposition in the pipeline. Many researchers in last decades reported and studied that waxes build-up are a complex and very costly problem for the petroleum industry. For subsea pipelines, it has become especially important to resolve the issue of wax build-up, as large scale of oil production in colder regions will be faced with more severe wax deposition [4].

Wax deposition has been a big challenge for the Oil & Gas industry since its inception. Additionally, the current global demand of energy has driven the oil exploration and Production to remote environments where avoiding wax deposition requires innovative Solutions for cooler and deeper scenarios [5].

Wax deposition occurs when paraffin components in crude oil (alkanes with carbon numbers greater than 20) precipitate and deposit on the cold pipeline wall when the inner wall temperature falls below the wax appearance temperature [6].

Wax deposits related to flow assurance problems consist of around 40-60% of macrocrystalline waxes and less than 10% of micro-crystalline waxes. Additionally, the compositionof the deposit varies through time considering that fresh wax deposits present asignificant fraction of oil. However, this oil fraction decreases through time making thedeposit more solid or harder [7].

Three important concept should be well understood to have a comprehensive knowledgeabout wax appearance and related issues. Wax appearance temperature, pour pointand wax content give a fundamental basis for wax deposition studies.

1.2. Wax appearance temperature

Wax precipitation occurs if paraffin petroleum reservoir fluid is cooled down to the waxappearance temperature (WAT), which is defined as the highest temperature where solidwax molecules start to appear in the reservoir fluid. The term cloud point is also applied,based in a standardized procedure to determine WAT [8]

1.3. Pour point

The pour point is the lowest temperature at which the oil flows freely under its own weight. This is measured under specific test conditions established by the ASTM D-97 standard. The pour point is considerably lower than the WAT, and crude oils that have significant paraffin content usually present high pour points. During shutdown periods, the temperature can drop below the pour point, making the flow restarting a challenging task. The pour point analysis should be combined with viscosity and yield stress measurements to perform a good rheological fluid evaluation; however, it is a useful rough indicator of flow behavior [9].

1.3.1. Wax content

In a wax precipitation curve (Fig.2) the highest temperature represents the wax appearance temperature, where the crystallization of waxy component starts due to cooling. At low temperatures, the precipitation curve usually has an asymptotic trend, which represents the total wax content in oil. The total wax content in an oil can be measured using standards, such as UOP46-64 or UOP46-85.These standards were developed by the Universal Oil Products Company, now Honeywell UOP.

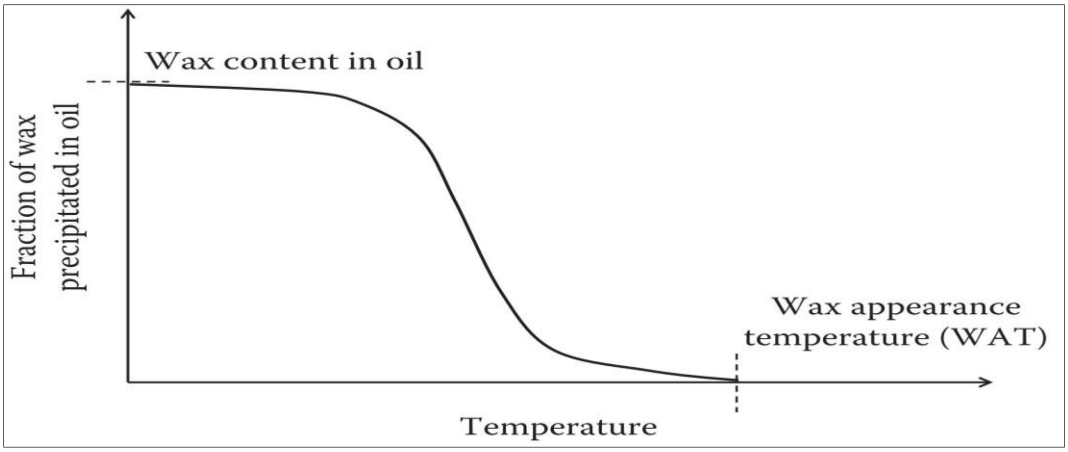

Figure 2 Wax precipitation curve

The WAT and wax content are the first two parameters to be checked to determine if wax deposition can be a problem during the production of certain well. Practically speaking, crude oils with more than 2% of wax content and a WAT higher than the subsea floor temperature, which commonly is around 4 _C, can present wax deposition problems [10].

1.4. Factors affecting wax deposition

The amount of wax deposition normally depends upon following three factors:

- Flow Rate
- Temperature Differential and Cooling Rate
- Surface Properties

Flow Rate: Slower the flow rate, higher the chances of wax deposition is a rule of thumb. In conditions of Laminar flow, the wax deposition may increase with the flow rate ([11]

Temperature Differential and Cooling Rate*:* Temperature differential between the bulk of solution and the cold surface is another factor that affects wax deposition (Wax deposition increases with an increase in temperature difference [12]

Surface Properties: The conditions of the internal surfaces of the pipelines also affect wax deposition. The presence of adsorbed oil films on the metal surfaces reduces the adherence of paraffins to the surface

There are several method can be used to control the wax deposition, but most the methods have limitation for longer pipelines. The common methods used are pigging, chemical injection, pipeline insulation and active heating). For a short pipeline, approximately 30 km long, pipeline insulation can be used to control wax deposition. Insulation is enough to limit the temperature loss to the surrounding, which eliminates the need to perform regular pigging Pipeline insulation can include the external insulation coating on single pipes or pipe-in-pipe systems [9]

1.5. Rawat Field

Rawat Petroleum Operating Company (RPOC) is currently operating Block 25 (approximately 25000 sq. km in area) located in South of Sudan (approximately 350 Km South-East of Khartoum at MSL 400 M). Originally Rawat Petroleum Operating Company planned to start Production from the recent discoveries in RAWAT &WATEESH Oilfields, with crude oil production rate with approximately 7000 - 9000 BOPD from thirteen13 wells (10 wells at RAWAT oilfield and other 3 wells at WATEESH oilfield). The two oil fields are about 4 km apart. Final Crude handling is to be carried out in EPF where the processing facilities are to be installed. The treated crude oil from RPOC's EPF will be exported through the transit pipeline system to Aljabalyain CPF which is belonging to another operator BAPCO (BASHAYER PIPELINE COMPANY).

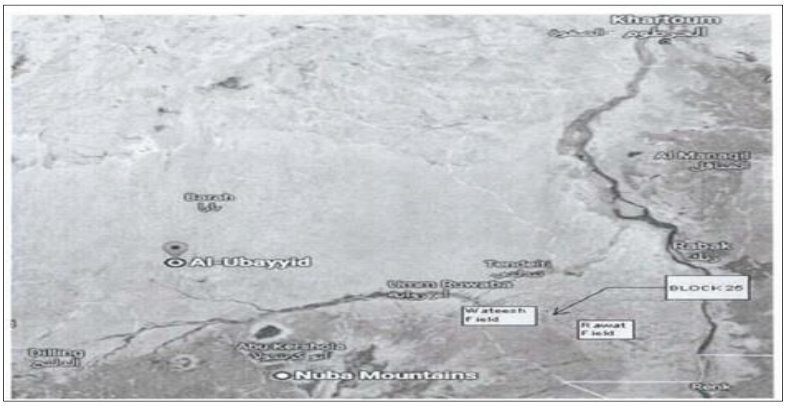

Figure 3 Location of Block 25

2. Materials and methods

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Rawat Petroleum Operating Company (RPOC) is the operator for Block 25. Which is located in Southern part of Sudan at about 350 km South West of Khartoum, the capital of Sudan. Block 25 with an area of 25.000 km' approximately is an exploratory block awarded to Sudapet. Sudan (100%) who appointed the joint operating company Rawat Petroleum Operating Company (RPOC) to manage exploration and production and other activities.RPOC plans to start early production from the recent discoveries in Rawat&Wateesh oilfields. With approximately 7000-9000 BOPD crude oil production from 13 wells, 8 Wells at Rawat oilfield and other 5 wells at Wateesh oilfield, Rawat field wells RC-1, RC-3, RC-4. RC-5, RC-6, RC-8, RC·9 and RC-10 were located close to the new proposed EPF therefore flow lines 4" from these wells were connected directly to EPF inlet manifold. Wateesh field wells W-l, W-2 & W-4 and Rawat field wells RC-2 & RC-7 were located far from the proposed EPF location and low production potentiality, therefore new OGM1 were considered at the Wateesh field to connect these wells. Produced fluids from these wells were flow to the new OGM1 through individual well flow lines. From OGM1 the gathered fluid were pumped to the EPF inlet manifold through 6" trunk line.

All the well flow lines were been piggable and a provision for portable pigging facility were considered. Heating were done to increase the temperature of the produced fluid above the crude oil pour pointand all the pipe lines were provided with hot insulation and heat tracing to maintain the temperature at the required level In order to achieve the goal of early production strategy.

2.1. Main Facilities

- Wellheads and Flow lines
- Oil Gathering Manifold Station (OGM)
- Chemical Injection
- Trunk Line
- EPF Inlet Manifold
- Drain System
- Portable Pig Launcher

2.2. Simulation Software

PIPESIM software will be used for Hydraulic and Thermal analysis of the pipelines. The Various steps that used in the Hydraulic and Thermal Analysis will be as given below:

- The available PVT data (detailed PVT analysis data is available for Rawatwell andWateeshwell) the wax analysis will be done using Multi Flash option available in Pipesim to evaluate the Wax Precipitation temperature range.
- Based on the Wax Precipitation temperature range estimated, the minimum temperature to maintain for the produced fluid will be defined.
- Assumed line sizes will be revisited to meet the allowable temperture limits at various locations and also to meet the velocity criteria.
- Based on the selected pipe sizes and for the various flow conditions thermal analysis will be performed to evaluate the requirement of heat tracing and hot insulation for the pipelines.

2.3. Distances among Wells and EPF

The distances between Wells and EPF are given in the table below:

Table 1 Distance Between Well and EPF

No.	Initial Point	Terminal Point	Distance (m)
1	Rawat C-1	EPF	0.49
2	Rawat C-3		0.66
3	Rawat C-4		1.0
4	Rawat C-5		0.6
5	Rawat C-6		1.43
6	Rawat C-8		0.95
7	Rawat C-9		1.2
8	Rawat C-10		1.47

No.	Initial Point	Terminal Point	Distance (m)
1	Rawat C-2	OGM	2.20
2	Rawat C-7		2.2
3	Wsteesh-1		1.04
4	Wsteesh-2		1.05
5	Wsteesh-4		1.22

No.	Initial Point	Terminal Point	Distance (m)
1	OGM	EPF	3.15

2.4. Design Flow Rates for Hydraulic Study

The production table given below are the early production details and will be used for the initial estimation of the line sizes.

Design flow rates of various systems in the gathering network was estimated using the maximum flow rates given in the Table and 10% design margin is added, Trunk line capacity will be the total design flow rates from Wateesh wells and Rawat Wells (RC-2 & RC-7) and the EPF design capacity is based on the combined designed capacities of OGM1 and all directly flowing wells tie-in to EPF.

Table 2 Maximum and Minimum Production Rates

Well name	Total Liquid Flow Rate(bbl/day)		WC%	Oil flowrate (BOPD)		Water flowrate (BWPD)		GOR (SCFD/STB)	Gas (SCFD)	
	min	max		min	max	min	max		min	max
RC-1	200	750	14	172	645	28	105	6.146	1057	3964
RC-2	100	300	14	86	258	14	42	6.146	529	1586
RC-3	200	1000	14	172	860	28	140	6.146	1057	5285
RC-4	200	1500	14	172	1290	28	210	6.146	1057	7928
RC-5	200	1500	14	172	1290	28	210	6.146	1057	7928
RC-6	200	1500	14	172	1290	28	210	6.146	1057	7928
RC-7	100	300	14	86	258	14	42	6.146	529	1586
RC-8	200	1000	14	172	860	28	140	6.146	1057	5285
RC-9	200	750	14	172	645	28	105	6.146	1057	3964
RC-10	200	750	14	172	645	28	105	6.146	1057	3964
W-1	100	500	19	81	405	19	95	3.77	305	1527
W-2	50	200	19	41	162	9.5	38	3.77	153	611
W-4	100	500	19	81	405	19	95	3.77	305	1527

2.5. Crude Oil Properties

Crude oil properties of individual wells in the Rawat and Wateesh fields to be used in the simulation study are given below:

Table 3 Individual Well Crude Properties

Well Name	Well Head Temp (°C)	°API	Density @ 15°C g/ml	Pour Point (°C)	Wax Content (wt%)	Water Cut,%	WAT (°C)	GOR (scf/stb)
RC-1	45	29.84	0.8762	45	33.1	14	72.68	6.146
RC-2	45	30.87	0.8707	>48	71.47	14	72.07	6.146
RC-3	45	28.08	0.8862	+51	69.5	14	23	6.146
RC-4	45	26.90	0.8925	>48	33.1	14	72.68	6.146
RC-5	45	29.84	0.8762	45	33.1	14	72.68	6.146
RC-6	45	29.84	0.8762	45	33.1	14	72.68	6.146
RC-7	45	30.87	0.8707	>48	71.47	14	72.07	6.146
RC-8	45	29.84	0.8762	45	33.1	14	72.68	6.146
RC-9	45	29.84	0.8762	45	33.1	14	72.68	6.146
RC-10	45	29.84	0.8762	45	33.1	14	72.68	6.146

W-1	45	28.60	0.8829	>48	45.19	19	71.86	3.77
W-2	45	26.71	0.8935	48	65.82	19	71.71	3.77
W-4	45	28.60	0.8829	>48	45.19	19	71.86	3.77

2.6. Heat Duty calculation

The heat duty of the electrical heater will be calculated using the equation given below.

$$\text{Heat Duty} = \frac{Q*\rho(T_{out}-T_{in})cp}{3600} \text{.........................} \quad 2\text{-}1$$

$$CP = \frac{C_{oil}*\rho_{oil}(100-wc)+ C_{water}*\rho_{water}*wc}{\rho_{oil}(100-wc)+\rho_{water}*wc} \text{.........................} 2\text{-}2$$

$$\rho = \frac{\rho_{oil}(100-wc)+\rho_{water}*wc}{100} \text{.........................} 2\text{-}3$$

Heat Duty: The heater duty of the electrical heater in (Kw).

- Q: The flowrate of the well flow (m^3/h).
- ρ: The density of the well flow (kg/m^3).
- ρ_{oil}: The density of the crude oil (kg/h).
- ρ_{water}: The density of the water (kg/h).
- T_{out}: The outlet temperature of the electrical heater in (°C).
- T_{in} : The inlet temperature of the electrical heater in (°C).
- Cp: The heat capacity of the well flow in (KJ/(kg °C)).
- C_{oil} : The heat capacity of the crude oil in (KJ/(kg °C).
- C_{water}: The heat capacity of the water in (KJ/(kg°C)).
- WC: water cut of the well flow in (%).

2.7. Flow Line Size

To calculate size of flow line we need:

- Production profile
- Velocity

The equation for calculate:

V=(0.0119*Q)/D^2.........................2-4

Where the velocity should be 0.3----3 m/s

- V=Velocity (ft/s)
- Q=flow rate (BBPd)
- D=Diameter (in)

2.8. Simulation Cases

2.8.1. Case-1 Pipe line Without Insulation at Winter Condition

Design flow rates from all the 13 producer wells with initial proposed size of 4 inch for the flow lines and 6 inch for the trunk line. Normal water cut of 14% for Rawat field and 19% for Wateesh field will be considered. Insulation and heat tracing requirements will be predicted based on the minimum temperature of produced fluid in the flow lines/trunk line.

2.8.2. Case-2 Insulated Pipeline at Winter Condition

Design flow rates from all the 13 producer wells with initial proposed size of 4 inch for the flow lines and 6 inch for the trunk line, normal water cut of 14% for Rawat Field and 19% for Wateesh field will be considered. 6 Brag Landing Pressure at EPF. In this case is the pipeline is insulated.

2.8.3. Case -3 Minimum Flow rate in Summer Condition

Minimum flow rates from all the producer wells with initial proposed size of 4 inch for the flow lines and 6 inch for the trunk line. Water cut will be assumed as 14% for Rawat Field and 19% for Wateesh field. 6 Barg Landing Pressure at EPF.

This case runs in summer condition.

3. Result and Discussion

3.1. Flow Line Size Calculation

Table 4 Flow Line Size

Well name	**R1**	**R3**	**R4**	**R5**	**R6**	**R8**	**R9**	**R10**	**R2**	**R7**	**W1**	**W2**	**W4**
Flowrate	825	1200	1650	1650	1650	1100	825	825	330	330	550	220	550
Size													
2	0.748	1.088	1.496	1.496	1.49	0.997	0.748	0.748	0.299	0.299	0.498	0.199	0.498
4	0.187	0.272	0.374	0.374	0.374	0.249	0.187	0.187	0.074	0.074	0.124	0.049	0.124
6	0.083	0.120	0.166	0.166	0.166	0.110	0.083	0.083	0.033	0.033	0.055	0.022	0.055
8	0.046	0.068	0.093	0.093	0.093	0.062	0.046	0.046	0.018	0.018	0.031	0.012	0.031

3.2. Wax Precipitation

Wax precipitation analysis results indicates that the minimum wax precipitation temperature for Wateesh W-1 will be approximately 62°C and the same for Rawat RC-1 well will be approximately 58°C. However as per the individual well crude properties provided by RPOC, the wax appearance temperature for W-1 crude is 71.86°C and the same for RC-1 crude is 72.68°C.

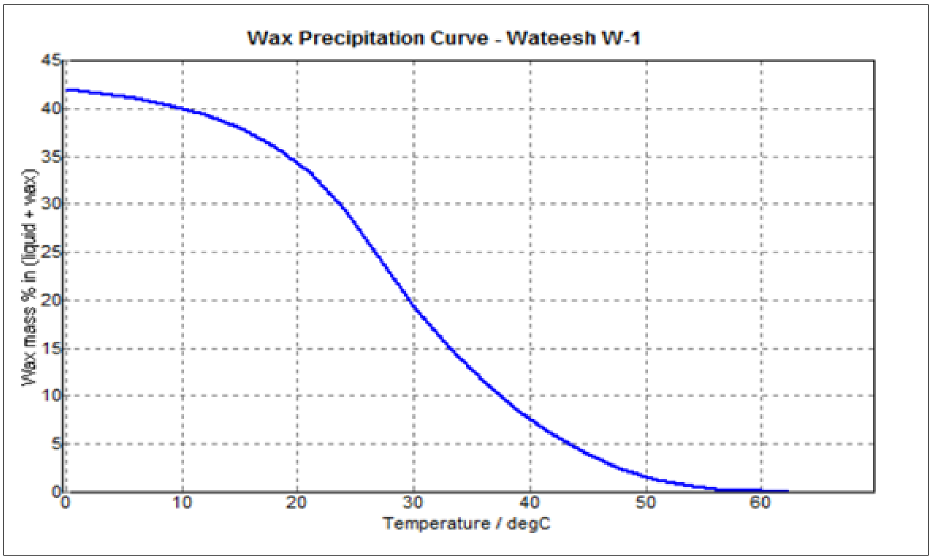

Figure 4 Effect of Temperature on the Wax Precipitation for Wateesh field

Therefore the outlet temperature of the well pad heater at the Wateesh and Rawat wells shall be 75°C.

Figure 3.1. Represented the effect of temperature on the wax precipitation. The figure shows that the wax appearance at 62 ºC for Wateesh well, the wax precipitation increase when the temperature decrease.

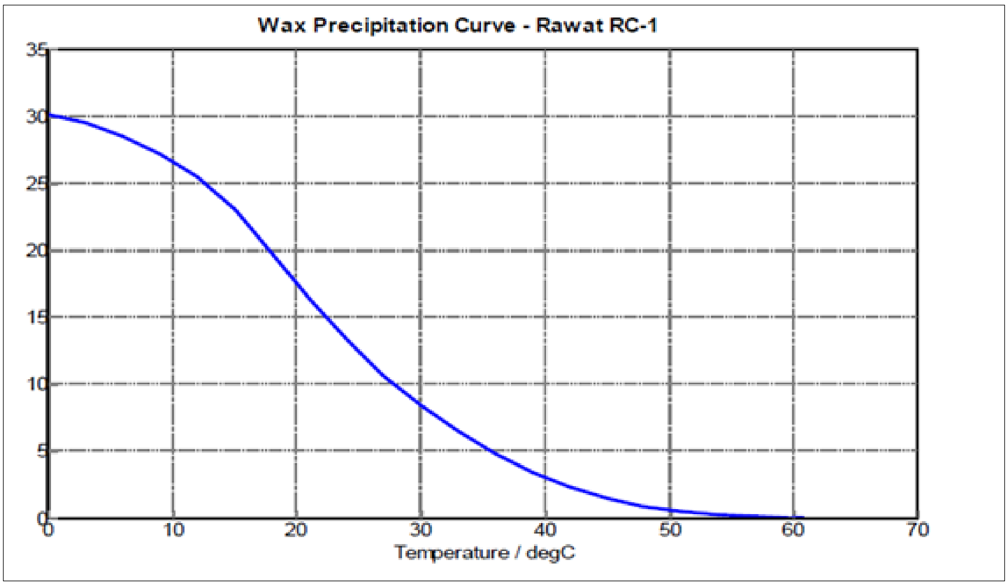

Figure 5 Effect of Temperature on the Wax Precipitation for Rawat-1 field

Figure 3.2. Represents the effect of temperature on the wax precipitation. The figure shows that the wax appearance at 58°C for Rawat-1well, the wax precipitation increase when the temperature decrease.

3.3. Simulation Cases

3.3.1. Case-1 Pipe line Without Insulation at Winter Condition:

Design flow rates from all the 13 producer wells with initial proposed size of 4 inch for the flow lines and 6 inch for the trunk line. Normal water cut of 14% for Rawat field and 19% for Wateesh field will be considered. Insulation and heat tracing requirements will be predicted based on the minimum temperature of produced fluid in the flow lines/trunk line.

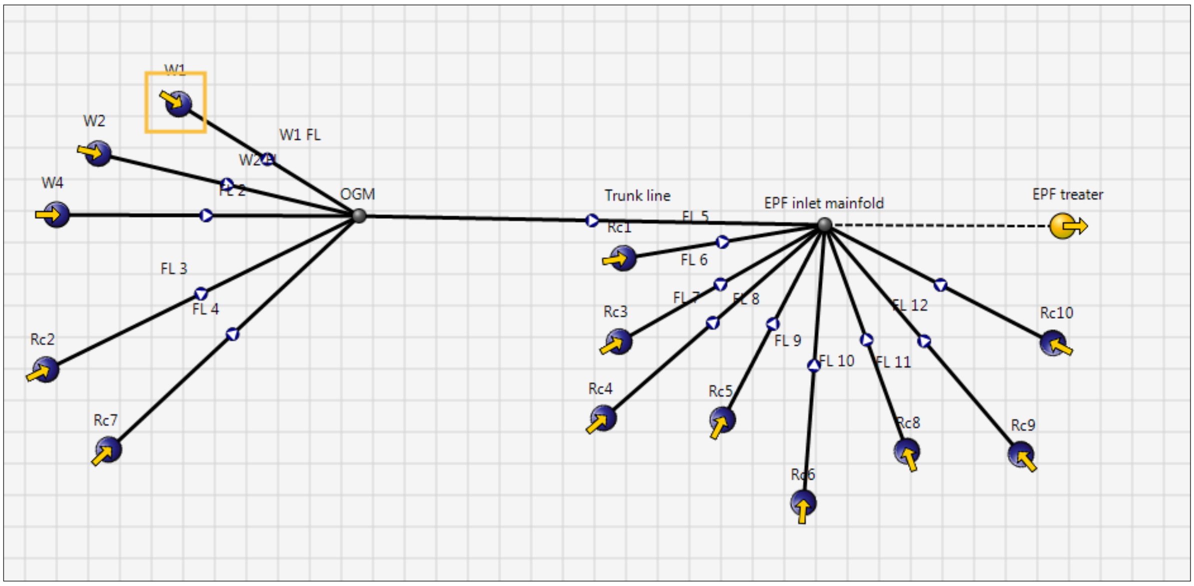

Figure 6 The net work pipeline for Rawat/Wateesh field in PIPSIM Software

Table 5 The Simulation Results for Simulation Case-1

Well name	Total Liquid Flow Rate (bbl/day)		Nominal size (inch)	Line velocity (m/s)	Temperature	
	Max flow rate	With 10% margin			In (ºC)	Out (ºC)
W-1	500	550	4	0.1	75	56
W-2	200	220	4	0.1	75	37
W-4	500	550	4	0.1	75	56
RC-2	300	330	4	0.1	75	34.7
RC-7	300	330	4	0.1	75	34.9
RC-1	750	825	4	0.2	75	67
RC-3	1000	1100	4	0.3	75	66.2
RC-4	1500	1650	4	0.4	75	66.5
RC-5	1500	1650	4	0.4	75	68
RC-6	1500	1650	4	0.4	75	64
RC-8	1000	1100	4	0.3	75	62.5
RC-9	750	825	4	0.2	75	58
RC-10	750	825	4	0.2	75	55
TL	1800	1980	6	0.2	47.1	39.9

The simulation results findings are given below:

- The flowing liquid temperature is falling below the wax precipitation temperature in all the well flow lines and trunk line due to heat transfer.
- Fluid temperature is falling below the crude oil pour point in the flow lines connected to the OGM 1 and in the trunk line due to heat transfer.

Hot insulation of the well flow lines and trunk line is therefore required to keep the fluid temperature above the required level of minimum 54°C. Also in order to keep the well fluid temperature above the wax precipitation temperature and to avoid gelling of the fluid during stagnant period Electrical Heat Tracing is also recommended.

Temperature plot for the selected (worst cases) well flow lines and trunk line are attached below:

Temperature vs. Distance Plot for Well RC-2 Flow Line

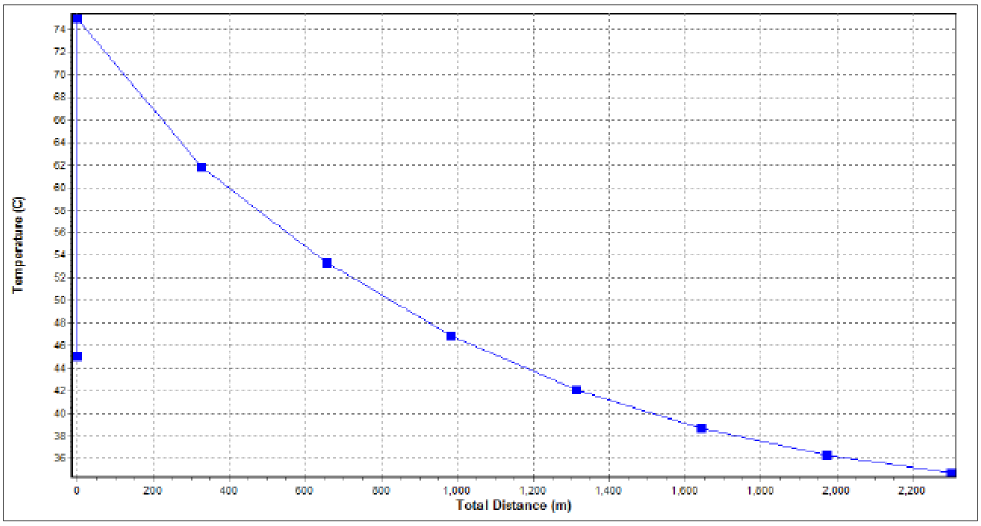

Figure 7 Temperature Vs. Distance Plot for Rawat-2 Flow Line Case-1

Relation between Temperature and Distance Plot for Trunk Line

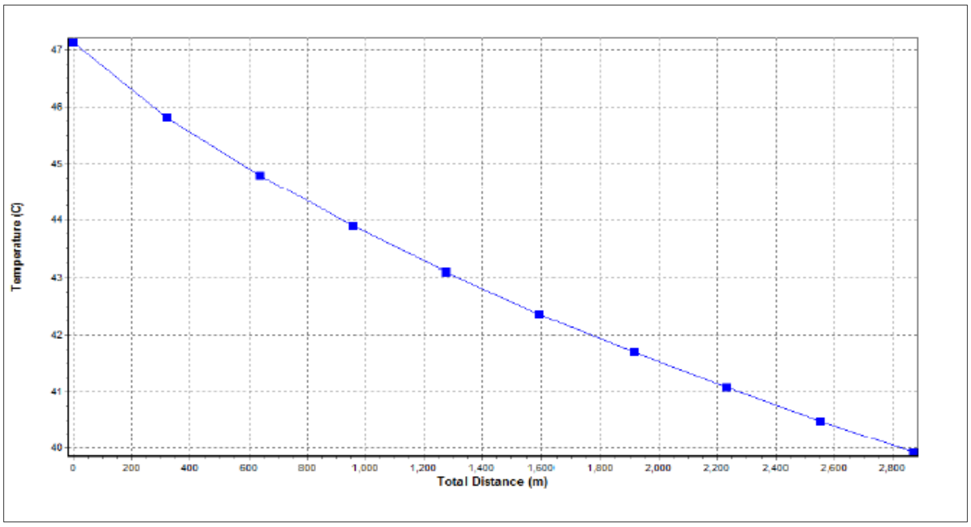

Figure 8 Temperature vs. Distance Plot for Trunk Line Case-1

3.3.2. Case-2 Insulated Pipeline at Winter Condition

Design flow rates from all the 13 producer wells with initial proposed size of 4 inch for the flow lines and 6 inch for the trunk line, normal water cut of 14% for Rawat Field and 19% for Wateesh field will be considered. 6 Brag Landing Pressure at EPF. In this case is the pipeline is insulated.

Simulation results are given below

Table 6 The Simulation Results for Simulation Case-2

Well name	**Total Liquid Flow Rate (bbl/day)**		**Nominal size (inch)**	**Line velocity (m/s)**	**Temperature**	
	Max flow rate	**With 10% margin**			**In (ºC)**	**out (ºC)**
W-1	500	550	4	0.1	75	69.4
W-2	200	220	4	0.1	75	62.2
W-4	500	550	4	0.1	75	68.5

RC-2	300	330	4	0.1	75	57.4
RC-7	300	330	4	0.1	75	57.4
RC-1	750	825	4	0.2	75	73
RC-3	1000	1100	4	0.3	75	73
RC-4	1500	1650	4	0.4	75	73.1
RC-5	1500	1650	4	0.4	75	73.8
RC-6	1500	1650	4	0.4	75	72.3
RC-8	1000	1100	4	0.3	75	72.2
RC-9	750	825	4	0.2	75	70.4
RC-10	750	825	4	0.2	75	69.4
TL	1800	1980	6	0.2	61.4	57.9

The simulation results findings are:

- The lowest temperature estimated is 57.4°C at the tie-in of RC-2 and RC-7 flow lines in OGM1. However this is higher than the allowable minimum temperature of 54°C. Therefore the insulation provided is adequate to keep the fluid temperature above the crude oil pour point.

In addition to the hot insulation, the above ground piping will be provided with electrical heat tracing to maintain the temperature of the fluid. Temperature plot for the selected (worst cases) well flow lines and trunk line are attached below:

Temperature Vs. Distance Plot for Well Trunk Line

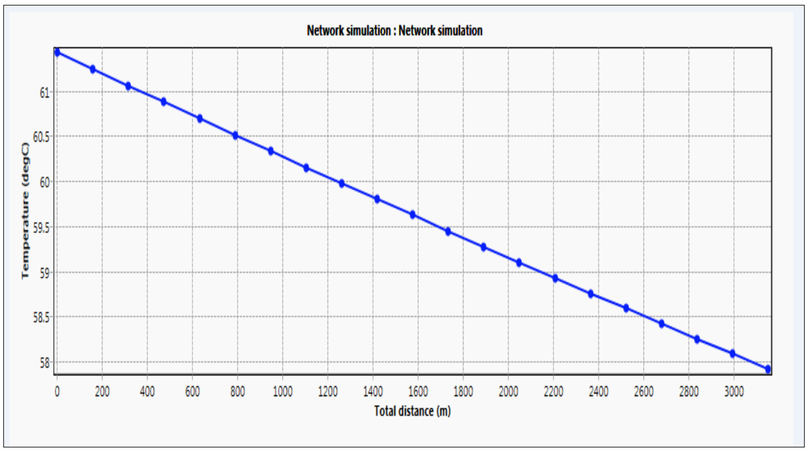

Figure 9 Temperature vs. Distance Plot for Trunk Line Case-2

3.3.3. Case-3 Minimum Flow rate in Summer Condition

Minimum flow rates from all the producer wells with initial proposed size of 4 inch for the flow lines and 6 inch for the trunk line. Water cut will be assumed as 14% for Rawat Field and 19% for Wateesh field. 6 Barg Landing Pressure at EPF.

This case runs in summer condition

Simulation results are given below:

Table 7 The Simulation Results for Simulation Case-3

Well name	Total Liquid Flow Rate (bbl/day)	Nominal size (inch)	Line velocity (m/s)	Temperature	
	Min flow rate			In (ºc)	out (ºc)
W-1	100	4	0.02	75	58.39
W-2	50	4	0.01	75	49.64
W-4	100	4	0.02	75	56.46
RC-2	100	4	0.02	75	48.26
RC-7	100	4	0.02	75	48.26
RC-1	200	4	0.05	75	69.76
RC-3	200	4	0.05	75	68.19
RC-4	200	4	0.05	75	65.29
RC-5	200	4	0.05	75	68.70
RC-6	200	4	0.05	75	61.60
RC-8	200	4	0.05	75	65.60
RC-9	200	4	0.05	75	63.59
RC-10	200	4	0.05	75	61.60
TL	450	6	0.05	55.5	46.3

Table 3.4 represents the simulation results for simulation Case-4. The table shows the effect of the minimum flow rate on the line velocity and the outlet temperature. The outlet temperature varied from 48.6ºC for Rawat-2 to 68.7ºC for Rawat-5.

The simulation results findings are given below:

- Liquid velocity is very low in all the flow line and trunk line because of low flow rate.
- Low temperature is occurring in W-2, RC-2 and RC-7 well flowlines and in the trunk line where the temperature is falling below the crude oil pour point. However considering that electrical heat tracing is provided for the above ground portion of the pipelines.

Temperature plot for the selected (worst cases) well flow lines and trunk line are attached below:

4. Conclusion

The flow system was built for Rawat field which is consists of (13) wells in the Rawat/Wateesh field with 4" flow line size. Rawat wells RC-1, RC-3, RC-4, RC-5, RC-6, RC-8, RC-9 and RC-10 were located close to the EPF and therefore flow lines from these wells connected directly to EPF inlet manifold. Wateesh field wells W-1, W-2 & W-4 and Rawat field wells RC-2 & RC-7 were located far from EPF location and therefore OGM considered at the Wateesh field to connect these wells, From OGM the gathered fluid pumped to the EPF inlet manifold through a 6" trunk line. The line size, line velocity and heat duty of the system have been predicted.Moreover five cases were analyzed for evaluating the falling of temperature through the pipe line in different flow rate and different condition.

The objective for this project has been achieved by using the PIPESIM simulation software. There are still several other simulation software that can be used in predicting wax deposition in pipelines and flow lines such as PVTsim and OLGA. Unfortunately, these software are not available to be used in this projects.

In this studies a series of cases were carried out at different flow rates, ambient temperature to study falling temperature through flow rate and trunck line to predict the wax deposition process inside the pipeline.Pressure drop and velocity were based on the maximum forecast oil rates. Pump discharge pressure was been below design pressure of the pipeline. EPF landing pressure was 600 kPag. The minimum temperature criteria for pipelines werebeen equal to the fluid pour point temperature plus 3°C margin at minimum which is 54C. The determined flowline size was 4” and for trunk line is 6”.Wax precipitation analysis results indicate that the minimum wax precipitation temperature for Wateesh was approximately 62°C and the same for Rawat RC-1 well were approximately 58°C.

All the flow lines and trunk line needs to be insulated for heat conservation to keep the fluid temperature above the crude oil pour point temperature to prevent wax precipitation and Electrical heating is required at the well head to head the fluid to 75 Deg C to maintain the temperature of produced fluid above the wax appearance temperature of the crude oil.

Compliance with ethical standards

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Disclosure of conflict of interest

I have declared that no conflict of interest.

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