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PARAFFIN PROBLEM TREATING ALONG THE FLOWLINE (STUDY CASE: FROM WELLHEAD “X” TO THE SEPARATOR”)

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Abstract -- *Paraffin deposition becomes a problem in the crude oil transportation system in surface production facilities, especially in oilfield flowline. The cause is big pressure drop which can inhibit the fluid flow rate. Paraffin problem occurrence is affected by specific factors, such as crude oil characteristics, flowing pressure and oil temperature drop below the oil pour point. From the parameter mentioned before, the potential of experiencing paraffin deposition in the flowline from the wellhead to the separator needs to be analyzed. From the physical properties analysis, paraffin deposition occurs when the temperature is decreased below the oil pour point (43 ^{O}C). In this case, the wellhead temperature is 65 ^{O}C. Paraffin problem countermeasures are being done by installing insulation along the flowline to resolve the fluid heat loss. If the previous countermeasure method could not solve the problem, a sand heater is needed to be installed to heat up the fluid inside the flowline in a certain point of distance.*

Keywords: *Insulator; Oil pour point; Paraffin deposition; Sand heater*

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INTRODUCTION

One of a problem that often experienced in producing oil is paraffin problem. Oil characteristics analysis, temperature and pressure drop, can cause paraffin problem (Wang and Gu, 2018; Hammami and Raines, 1999; Carnahan, 1989). If the temperature and pressure of the fluids decreased below the pour point, it would cause the paraffin deposition. Paraffin problem potential analysis will be done along the flowline in the oil field that has paraffin problem potential. Oil density, oil API, and oil pour point needs to be analyzed along the flowline in the oil field that has paraffin problem potential (Firdaus and Ma’arif, 2016; Sanjay et al., 1995; Hunt, 1962). Specific factors that affected the pressure drop along the flowline are pipe diameter, pipe length, pipe roughness, elevation and fluids properties like fluid density, and fluid viscosity (Shiu and Beggs, 1980).

In this study case, two different production wells are analyzed, which one of this two wells has paraffinic oil. Two different types of oil are produced and unify in the manifold. Then it will stream to the separator. Fluid properties that need to be evaluated from the wellhead to the manifold are fluid physical properties, pressure and temperature drop, and the countermeasures which will be done.

In this paper, paraffin occurrence analysis based on the temperature loss that affected pressure loss along the flowline is done by calculating the fluid density and viscosity. It will prove that temperature loss related to pressure loss along the flowline. Then, the right steps to treat the paraffin problem based on temperature and pressure factor is obtained

METHOD

Paraffin is a production problem that caused by certain factors, to be specific oil characteristics, the fluid temperature below the pour point so that the fluid pressure will be decreased along with the flow rate.

The Effect of Temperature Drop

If the temperature drops below the pour point, paraffin will be deposited in the flowline. Pour point temperature is the lowest temperature which a liquid remains pourable (still behave as a fluid). Freezing point is a temperature below the pour point, where the oil can not fly or with another word freeze. Oil temperature along the flowline can be calculated with Karge method as (Ma et al., 2017; Arnold et al., 1986):

$$\frac{T_0 - T_1}{T_2 - T_1} = e^z \quad (1)$$

Where,

$$z = \frac{2{,}54 x \pi x K x D x L}{Q x Cp x 10^5} \quad (2)$$

T_0 = oil initial temperature, ºC

T_1 = ambient temperature, ºC
T_2 = pour point temperature, ºC
K = coefficient heat fluids separation from pipes, Kcal/m^2/hour/ ºC
D = pipe outside diameter, m
L = pipe length, m
Q = flowing amount, m^3/hour

The Effect of Pressure Drop

Fluid inside the pipe will flow if the pressure drop is less than the initial pressure. Oil is a non-newtonian fluid, which explains that oil will be flowing if the pressure is beyond a certain pressure limit. It is different with Newtonian fluid where Newtonian fluid will flowing if it got pressure. The time the oil beyond the pour point, it can be said that it still got pressure to flow.

Pressure loss inside the pipe can be determined by determining the fluid density first. The fluid density is needed to calculate fluid Specific Gravity (SG), then the fluid specific gravity will be used to calculate the fluid viscosity. Viscosity is effected by the amount of pressure drop and temperature drop. In other words, the temperature drop is related to pressure drop. The following equation describes the calculation steps:

1. Determining the mix density by converting field unit to British unit (lb/ft3)

$$\rho mix = \left[\left(\frac{Qoil}{Qmix}\right) xSGoilx\rho w60^{O}F\right] + \left[\left(\frac{Qoil}{Qmix}\right) xSGwx\rho w60^{O}F\right] \quad (3)$$

$$SG_{mix}=\rho_{mix}/\rho_{water} \quad (4)$$

2. Determining the mix viscosity by converting field unit (centistoke) to British unit (lb/ft-sec).

$$\mu\ oil = SG_{mix} \text{ x Kinematic Viscosity} \quad (5)$$

3. Determining velocity in British unit (ft/sec).

$$V = \frac{Q}{0{,}25x\pi x(ID/12)^2} \quad (6)$$

4. Determining the Reynold Number.

$$\mathrm{Re} = \frac{\rho xVxd}{\mu} \quad (7)$$

Where :
Re = Reynold number
ρ = fluid density, ppg
V = velocity, ft/sec
D = pipe inside diameter, inch
μ = fluid viscosity, lb-sec/ft

Reynold Number (NRe) can determine the type of fluid flow, where:
a. Laminer flow, Nre < 2000
b. Transition flow, 2000 < Nre < 4000
c. Turbulen flow, Nre > 4000

5. Determining the friction factor (f).

$$f = \frac{64}{\mathrm{Re}} \quad (8)$$

6. Determining the pressure differential with a Darcy-Weissbach method.

$$\Delta P = \frac{\rho xfxLxV^2}{144xDx2g} \quad (9)$$

Where :
ΔP = pressure differential, psia
ρ = fluid density, ppg
L = pipe length, ft
D = pipe inside diameter, ft
f = friction factor
G = gravity constanta

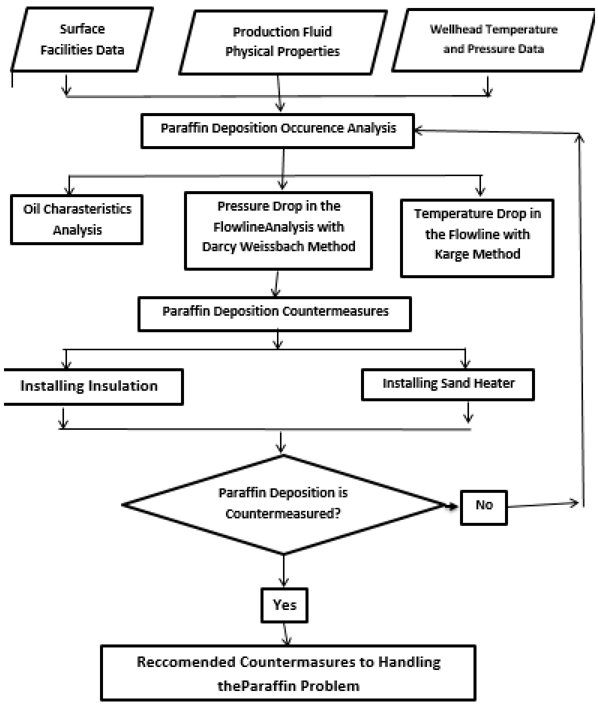

Figure 1. Analysis and Countermeasures Paraffin Problem Flowchart

This research is done by doing certain steps as described in Fig. 1. First: collecting needed data, namely surface facilities data, production fluid physical properties, temperature and pressure data. Surface facilities data are pipe length from the wellhead to the manifold, pipe diameter from the wellhead to the manifold, pipe diameter from the manifold to the separator, and pipe conductivity. Production fluid physical properties data are Qo, Qw, oil specific gravity, and oil pour point. Pressure and temperature data are wellhead pressure and temperature, and ambient temperature.

After collecting data needed, temperature loss along the flowline is analyzed. Analyse the temperature loss by calculating the temperature drop with the pour point amount is 43 ^{O}C. If the temperature is dropped below the pour point, then paraffin problem is experienced. After that, pressure loss analysis is done by calculating the pressure drop. If the pressure drop is higher than the initial pressure, it can indicate that there is no flow and paraffin problem has occurred.

From the analysis mentioned before, if the paraffin problem is experienced, countermeasures are needed. The first countermeasure is by installing calcium silicate insulation with 10mm thickness and covered by aluminum along the flowline from the paraffinic oil well's wellhead (Well JB-2) to the manifold. The second countermeasure is by installing sand heater along the flowline from 960m after the wellhead where the fluid's temperature at that point is 48 ^{O}C. The temperature where the sand heater installed is designed by giving 5 ^{O}C safety factor beyond the pour point. After the two countermeasures installed, the next step is analyzing the most suitable paraffin problem countermeasures from the wellhead to the manifold and separator in field JB.

RESULTS AND DISCUSSION

In this study case, two production well models analysis is performed. There are Well JB-1 and JB-2 (NN, 2017). Where JB-1 has oil type that doesn't have paraffin problem potential, and on the other hand, Well JB-2 has paraffin problem potential. This two different types of oil unified in the manifold and streamed to the separator. So, paraffin problem countermeasures are needed, and in this study case, the heating method is procured. After the countermeasures installed, paraffin deposition won't be experienced is hoped.

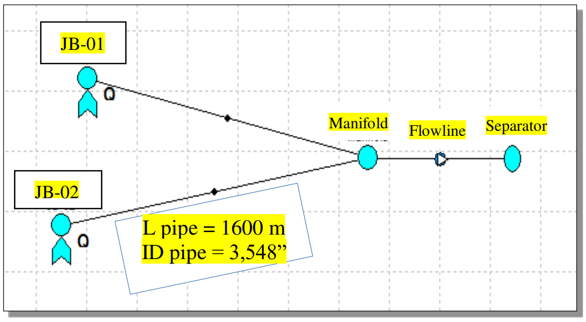

Figure 2. Flowline Scheme until Separator

Fig. 2 explained about the analysis that will be conducted on two production wells in JB field, namely JB-01 and JB-02 wells. Where JB-1 well has a type of oil that does not have the potential paraffin. Meanwhile, the JB-2 well has a paraffinic oil type.

Surface Facilities Data

Surface facilities data will be explained in Table 1.

Table 1. Surface Facilities Data

Well	Manifold Unit		Separator Unit	
	Pipe Length (m)	**ID Pipe**	**Pipe Length (m)**	**ID Pipe**
Well JB-01	1125	3,548"	600	6,065"
Well JB-02	1600	3,548"	600	6,065"

Table 1 explains the surface data facilities available in t JB field for JB-01 well and JB-02 well. With the existing data of surface facilities, we can calculate the pressure and temperature drop with the physical properties data of the fluid production and the pressure and temperature data in the wellhead.

Physical Properties of Production Fluids Data

The production fluid data at JB-01 and JB-02 wells can be seen in Table 2. The tendency of paraffin precipitate in JB field production well is found in JB-02 well.

Table 2. Oil Physical Properties of Well JB-01

Well	Parameters	Units	Results
Well JB-01	Q oil	BOPD	70,36
	Q water	BWPD	15,00
	Qtotal	BFPD	85,36
	SG @60 ºF	-	0,85
	API @60 ºF	-	35,4
	Viscosity Kinematic	cSt	20,80
	Pour Point	ºC	35
	BS & W	% vol	0,01

Table 3. OilPhysical Properties at Well JB-02

Well	Parameters	Units	Result
	Q oil	BOPD	54,37
	Q water	BWPD	13,00
	Qtotal	BFPD	67,37
	SG @60 ºF	-	0,8676
Well	API @60 ºF	-	31,6
JB-02	Viscosity Kinematic	cSt	84,90
	Pour Point	ºC	43
	BS & W	% vol	0,05

Table 2 and Table 3 explains the well fluid characterization data of JB-01 and JB-02 wells. In the physical properties data of the production, fluid shows that JTB-02 well tends paraffin precipitate potential because it has higher pour point oil viscosity, and more sediment content than JTB-01 well. Thus, the possibility of paraffin potency occurring at JTB-02 well.

Pressure and Temperature Data

Pressure and temperature data of well JB-01 and JB-02 at the wellhead as follows:

JB-01

Wellhead Pressure = 105 psia
Wellhead Temperature = 80 ºC

JB-02

Wellhead Pressure = 130 psia
Wellhead Temperature = 65 ºC

From the parameters above can be identified the tendency of paraffin in flowline according to pressure and temperature drop.

Calculation of Temperature Drop

The decreasing inflow temperature is a major factor that causes paraffin precipitate. If the oil flow temperature falls below the pour point, there will be paraffin precipitate, and to determine the tendency of paraffin precipitation, a profile of flowline decrease in the flowline is made. The equation used to determine the temperature loss by the Karge Method is by Equ. (1) and (2) as follows:

$$z = \frac{2{,}54x3{,}14x0{,}75x3{,}548xL}{0{,}4462x0{,}248x10^5}$$

= 0,00192 L

$$\frac{T_0 - T_1}{T_2 - T_1} = e^{0{,}00192L}$$

Finding the flow temperature over the distance is used at L various prices. Flow temperature calculations are performed at the total pipe length from a wellhead to the manifold, where L_{total} = 1600 m

Table 4. Oil Temperature Analysis JB-02

Distance from well (m)	Temperature (ºC)	Description
0	65,00	*Wellhead*
400	44,22	
1000	31,82	
1400	28,72	
1600	27,86	*Manifold*

$$\frac{T_0 - T_1}{T_2 - T_1} = e^{0{,}00192x1600}$$

$$\frac{65-26}{T_2 - 26} = e^{0{,}00192x1600}$$

T_2 = 27,86 ºC

Fluid heat separation from pipes, Table 4. Temperature Decrease at Well JB-2

A certain temperature drop at specific distance can be determined by calculations above, whereL_{total} = 1600 m and the temperature is = 27,86ºC with pour point temperature 43 ºC that can be found with:

$$\frac{T_0 - T_1}{T_2 - T_1} = e^{z}$$

$$\frac{65-26}{43-26} = e^{0{,}00192L}$$

Ln 2,29412 = 0,0019 L
L = 436, 51 meter

From the analysis of temperature lossy, there is a decrease in flow temperature at well JB-2 that exceeds the temperature pour point limit. The distance calculation above is the distance at the temperature of pour point = 43 ºC, from the calculation, it can be analyzed that the paraffin precipitation will occur if the temperature drop across the pour point temperature that can happen at a greater distance 436.51 m from the wellhead. Thus, it can be indicated that there is a tendency for paraffin problems from that distance. Furthermore, the analyzer will continue with pressure loss.

The Calculation of Pressure

Changes in pressure or decreased flow pressure will cause a mild fraction to leave the oil, and leave the oil with heavy fraction, and this is what causes the tendency of paraffin precipitation in paraffin. Flow pattern can be known using Darcy-Weisbach method. Based on actual conditions at the moment, the parameters above can be calculated with the following steps:

a. Mixed density can be calculated by Equ. (3):

$_{mixed}$ = [(54,37/67,37)x0,8676x62,4] + [(13/67,37)x1,0x62,4]

$_{mixed}$ = 55,7324 lb/ft^3

Mixed SD can be calculated by Equ. (4):

$SG_{mixed} = \rho_{mixed}/\rho_{water}$

$= 55{,}7324 lb/ft^3/62{,}4\ lb/ft^3$

$= 0{,}8931$

b. Mixed viscosity can be calculated by Equ. (5):

μ *oil* = 0,8676 x 87,9 Cst
= 76,2620 cp
= 0,05125 lb/ft-sec

μ *water* = 1,0 x 87,9 Cst
= 87,9 cp
= 87,9/1488 = 0,05907 lb/ft-sec

μ mixed = 0,8931x 87,9 Cst
= 78,5077 cp
= 0,05276 lb/ft-sec

c. *Velocity* can be calculated by Equ. (6):

$$V = \frac{Q(BFPD)x42(gal/bbl)x0{,}13368(cuft/gal)}{0{,}25x\pi x(3{,}548/12)^2 x86400(day/\sec)}$$

$$= \frac{67{,}37\ x42x0{,}13368}{0{,}25x3{,}14x(3{,}548/12)^2 x86400}$$

= 0,0638 ft/sec

d. *Reynold Number* is calculated by Equ. (7):

$$\mathrm{Re} = \frac{55{,}7324\ x0{,}022307\ \ x(3{,}548/12)}{0{,}05276}$$

Re = 19,925

e. Flow Type

nRe < 2000 = laminer flow, nRe = 19,925 for well JB-2, so the flow type is laminer.

f. Determine the friction factor (f), can be calculated with Equ. (8):

$$f = \frac{64}{19{,}925} = 3{,}212$$

g. Pressure drop for two phases from dari wellhead-manifold, with L = 5248 ft, can be calculated with Equ. (9):

$$\Delta P/100 = \frac{55{,}7324\ x3{,}6213x5248x(0{,}0638)^2}{144x\left(3.548/12\right)x2x32{,}2}$$

ΔP = 1,3945 psia/100 ft

h. Pipe length wellhead-manifold = 9680 ft

Pressure Loss = 9680 ft * 1,3945 psia/100 ft
= 134,98 psia

Pressure at Manifold= Pwh – Pressure Loss
= 130 – 134,98 psia
= -4,98 psia

Based on the calculation using the equation (Shiu and Beggs, 1980) of flow pressure drop, the value of pressure loss is 134,98 psia while pressure at the wellhead is 130 psia. From the calculation, it shows that the pressure loss in the pipes from the wellhead to the well manifold JB-2 is greater than the pressure in the JB-2 wellhead. Thus, it can be indicated from the analysis of temperature loss and also pressure loss (Carnahan, 1989) on the pipeline of the JB-2 wellhead until the manifold occurs paraffin problem at that specific distance. Furthermore, the act to overcome the paraffin problem is needed.

Treating Paraffin Problem

The main purpose of treating paraffin is to maintain heat in the flow of oil so it remains stable above its pour point temperature so that the oil does not freeze and the paraffin precipitate does not form along the flowline, and the oil continues to flow to the collecting station by maintaining the heat loss and adding temperature to certain points.

Treating the paraffin precipitation can be done with two methods:

1. Installation of insulation on the flowline of JB-02 wellhead to manifold with 10 mm calcium silicate with an aluminum coating.
2. Installation of one sand heater at a distance of 960 m is higher than the JB-02 wellhead on the insulated flowline.

Treating with Insulation

The first step will be done by installing insulation calcium silicate type with a thickness of 10 mm and coated by aluminium with a conductivity of calcium silicate of 0.063 W/m/K in the pipe of the wellhead JB-02 to the manifold with the following scheme:

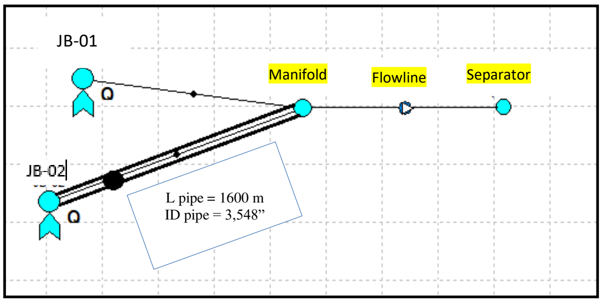

Figure 3.Flowline Scheme Using Insulation from Wellhead JB-2 to Manifold

Fig. 3 explains the description of the first step of treating that being performed on the flowline of the wellhead JB-02. In the scheme is shown that the insulation at the flowline of the wellhead JB-02 due to paraffin analysis on the flowline of the wellhead JB-02 obtained the following results:

Table 5. Temperature Drop at Well JB-02

The Distance from Well (m)	Temperature (ºC)	Notes
0	65,00	*Wellhead*
320	58,27	
1280	44,24	
1404,77	43,00	
1600	41,06	*Manifold*

Table 5 shows a decrease in oil flow temperature after insulation. From the calculation, analyzed in the flow pipe of JB-02 wellhead with a length of 1600 m of the pipe there is a decrease in temperature smaller than before the treating is being done, but still experiencing paraffin. Because the temperature in the manifold is below the temperature of the pour point of oil that is equal to 41.06 ºC, with oil pour point 43 ºC. The result of insulation control is obtained by decreasing the temperature that exceeds the pour point at 1404.77 m distance from the JB-02 wellhead. Thus, in this type of treating, it is said that it has not succeeded in overcoming the paraffin precipitate because the sediment still occurs at a distance of 1404.77 m. Therefore, a second countermeasure is required with insulation and sand heater.

Treating with Sand Heater

The second type of treatment is the installation of the sand heater in the flowline at flow pipe with the distance 960 m that being insulated from the JB-02 wellhead where the temperature at a distance is 48 ºC is designed with a safety factor 5 ºC above the pour point with the following scheme:

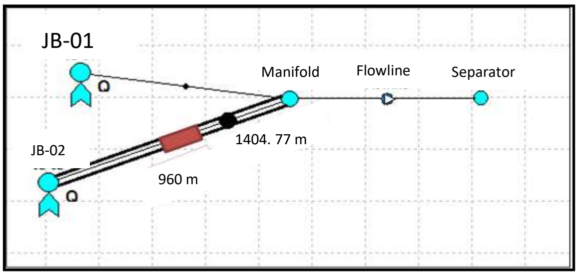

Figure 4. Scheme of Flowline Using Insulation and Sand Heater to Manifold

Fig. 4 explain the description of the second countermeasures to be performed on the flowline of the JB-02 wellhead. In the scheme has been done the countermeasures by insulation installation on the flowline of the wellhead JB-02 and the installation of the sand heater at a distance of 960 m from the wellhead. Where paraffin precipitation occurs at a distance of 1404.77 m greater than JB-02 wellhead with pipe length from wellhead JB-02 to manifold along 1600 m when insulation is made in the first step and obtained the second result as follows:

Table 6. Temperature Drop at Well JB-02

The Distance from Well (m)	Temperature (ºC)	Notes
0	65,00	*Wellhead*
320	58,27	
640	52,69	
960	66,07	
1280	62,24	
1404,77	61	
1600	59,06	*Manifold*

Table 6 shows a decrease in oil flow temperature after insulation. From the calculation, it is analyzed with a length of 1600 m pipes until the manifold there is a decrease in temperature that is smaller than before the treating is being done, and does not have paraffin precipitate. Because the temperature in the manifold is above the temperature of the oil pour point with 59.06 ºC, the temperature of the oil pour point of 43 ºC.

And the length of the pipe 100 m from the manifold to the separator also does not have paraffin precipitate, where the temperature in the separator is obtained at 57.39 ºC. The result of insulation and sand heater did not contain paraffin precipitation at a distance until separator. Thus, in this type of testing, is said to be successfully overcoming paraffin in JB-02 well-flowing pipe.

CONCLUSION

Based on the temperature analysis of JB-02 well with pipe length 1600 m, the temperature drop is passed the pour point. The temperature of the end pipe is 27.86ºC with pour point 43ºC. This condition shows there are possibilities of paraffin happened.

After the temperature analysis has shown the possibilities in paraffin happened, the pressure analysis should be done. At JB-02 well, the pressure drop is higher than the initial pressure at the wellhead. The wellhead pressure value is 130 psia and pressure drop till the end of the pipe is 134.98 psia. This condition shows that there is no flow in the pipe because of paraffin deposition. The first treatment to solve paraffin problem is by equipping calcium silicate insulator type with a thickness of 10 mm and coated aluminum. This treatment is not too useful because there is still happened paraffin deposition at 1404.77m from the wellhead

The second treatment is applied to sand heater installation at the flowline with safety factor 5ºC above oil pour point at 960m. The safety factor is used to avoid the pressure drop at night or rain. The second treatment can countermeasures the paraffin problem successfully from wellhead till manifold. The temperature at the manifold is 59.06°C which is still greater than oil pours point = 43°C.

The next analysis is to examine the paraffin problem from the manifold to the separator, there is a change of the fluid composition, so the pour point becomes 35 ºC, but there is no paraffin precipitation because sand heater installation has successfully overcome it before the manifold, so the installation of insulation after manifold is needed to keep the temperature still above the pour point.

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