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Crude Oil Pipeline Scale Deposition: Causes and Removal Methods

Omer. E. Eltaib[1], Ali A. Rabah[2]

[1] Department of Chemical Engineering, Faculty of Engineering University Khartoum

[2]Department of Chemical Engineering, Faculty of Engineering University of Khartoum Khartoum, Sudan (E-mail: rabahssr@uofk.edu)

Abstract: This work investigated the causes of scale formation and removal methods on 107 km crude oil pipeline of Diffra oil field of Muglad basin as a case study. The study is based on well and pipeline historical data of three years (2007, 2008 and 2009). The data included production data (net oil and water cut), choke opening, pipeline pressures, water qualities and scale composition. The study revealed that the main cause of scale formation is the presence of Ca+2 and Mg+2 in produced water and wax in oil. The scale consists of 78 % Ca+2, 12 % Mg+2 and 10 % wax. Investigations on removal methods revealed that the currently employed chemical removal method is effective; however the downtime (well shut down) is high making significant production cut. A method to reduce the cleaning down time is proposed. The pipeline is divided into two sections: aboveground and underground. The aboveground line is characterized with the presence of valves, choke and pipe reductions (i.e. non uniform cross section). The underground section is uniform in cross sectional area. For the aboveground section the current practice of chemical cleaning is recommended to be maintained however, with provision of a bypass line. For underground section the standard practice of pigging is recommended. The proposed cleaning method of the whole pipeline eliminates the downtime completely. In addition it is uncomplicated, with economical operation and installation cost. The method also make significant cut in chemical used hence reduces the hazard and environmental impacts.

Keywords: *Crude oil pipeline; scale formation; scales removal.*

1. INTRODUCTION

Scale is one of the critical problems and challenges in oil and gas fields, it is known as the precipitation of adherent deposits on metal surface. A mineral salt deposit that may occurs on surface and subsurface equipments. In severe conditions, scale creates a significant restriction or even a plug. Normally, precipitation of scale occurs when solubility are exceeded because of high concentration due to changing in pressure and temperature condition. The main sources of deposits include mineral content such as Ca+2 and Mg+2 with produced water. Water can carry large quantities of scaling minerals (Brown M, 1998). The water in carbonate and calcite cemented sandstone reservoirs usually contains an abundance of divalent calcium (Ca+2) and magnesium (Mg+2) cations. Sandstone formation fluids often contain barium (Br+2) and strontium (Sr+2) cations. The most common scale deposits include CaCO3 and CaSO4. (Bittner et al, 2000)

Scale begins to form when the solubility limit for one or more components is exceeded. Minerals solubility themselves have complicated dependence on temperature and pressure. The changing in temperature or pressure, out gassing, a PH shift, or contact with incompatible water can attract minerals to precipitate (Bittner et al, 2000). Physical evidence of scale exists as samples of scale or X-ray evidence from core analysis, and chemical modeling, wellhead parameter also can give indication of scale accumulation when the pressure reading increased rapidly (Bamforth et al, 1996). The onset of water production is often a sign of potential scale problems; especially if it coincides with simultaneous reduction in oil production. The scale is causing great impact and loss on production, creates huge energy loss and also increases erosion.

The best scale removal technique depends on knowing the type and quantity of scale, and its physical composition or texture. A poor choice of removal method can actually promote the rapid recurrence of scale. Scale purity affects its resistance to removal methods. Scale may occur as single mineral phases, but more commonly a mixture of similar compatible compounds. Chemical scale removal is often the first and lowest cost approach, especially when scale is not easily accessible or exists where conventional mechanical removal methods are ineffective or expensive to deploy. In the formation matrix, it can be treated by use of strong chelating agents, compounds that beak up the scale metallic ions within their closed ring-like structure (Martel et al, 1952). Although hydrochloric acid is usually the first choice for treating calcium carbonate scale, the rapid acid reaction may hide a problem: spent acid solutions of scale by products are excellent initiators for reformation of scale deposits, chemical that dissolve and chelate calcium carbonate can break re-precipitation cycle (Kotler et al, 1998). Ethylene Diamene Tetra Acetic acid (EDTA) was an early candidate to answer the need for improved chemical removal, and is still used today in many forms. While EDTA treatments are more expensive and slower than hydrochloric acid, they work well on deposits that require a chemical approach. EDTA and variations on its chemical structure are also effective in noncarbonated scale removal, and show promise for removal of calcium sulfate and mixtures of calcium-barium sulfate.

Mechanical means to remove scale deposits offer a wide array of tools and techniques applicable in wellbore tubular and at the sand face. Like chemical techniques, most mechanical approaches have a limited range of applicability, so selecting the correct method depends on the well and scale deposit. Mechanical approaches, though varied, are among the most successful methods of scale removal in tubular (Jonson et al, 1998). One of the earliest scale removal methods was an outgrowth of the use of explosive to rattle, string shots, fluid mechanical jetting methods, abrasive slurries, sterling beads abrasives, scale blasting technique (Johnson et al, 1998).

In most cases, scale prevention through chemical inhibition is the preferred method of maintaining well productivity. Inhibition techniques can range from basic dilution methods, to the most advanced and cost-effective methods of threshold scale inhibitors (Wigg and FletcherM, 1995). In addition to dilution, there are literally thousands of scale inhibitors for diverse applications ranging from heating boilers to oil wells. Most of these chemicals block the growth of scale particles by “poisoning “the growth of scale nuclei (Powell et al, 1995).

2. MATERIAL AND METHODS

2.1 Study area

Diffra field is located at about 106 km SW of Heglig central processing facility (CPF). The pipe line is divided into two sections as above and underground pipelines as shown figure 1. The current practice is the chemical cleaning of the pipeline.

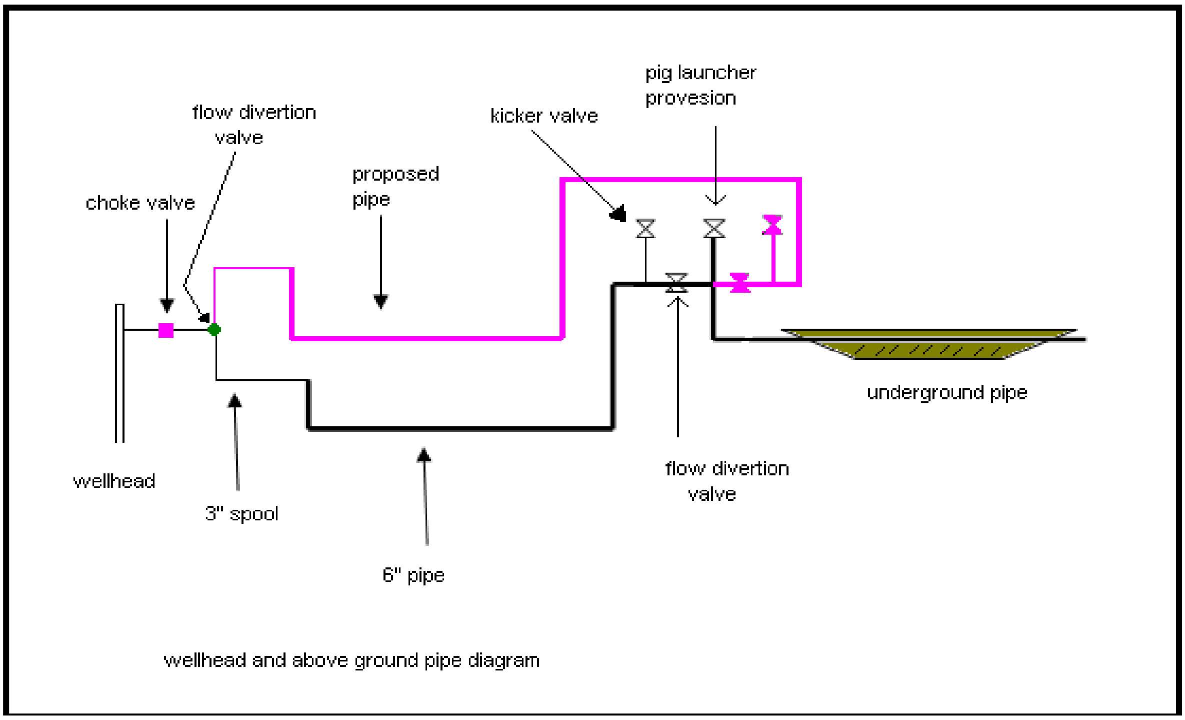

Figure (1). Diffra pipeline

2.2 Methodology

Historical production data for the year 2007 to 2009 (3 years) are collected. The collected data include production data, scale chemical composition, produced water properties. The production data include well production, net oil, water cut, choke opening and pressure down and up the choke.

3. Result and discussion

3.1 Scale identification

Scale generally deposits at the surface hence reduce the cross-sectional area of the pipeline.

The direct consequences are the loss of throughput and pressure drop in the pipeline.
However, in crude oil pipeline the pressure drop may be due to other factors such back pressure from other wells and stuck up valve.
Figure 2 shows a picture of the deposited scale. The thickness of the deposit layer is about 3 in. This layer reduces the pipeline cross sectional area by more than 58%.

Fig (2). Flow line Clogged by Scale

Table 1 shows production data for three years (2007 to 2009). It can be seen the net oil drops to very low level in every three to five months depending on water cut. The point at which the through put drops significantly is made bold in Table 1. At this point the pressure drops significantly. For example in May of 2007 the pressure drops dramatically from 868.0 psi to 552.0 psi and the through put drops to 507 bbd from 751 bbd.

Table (1). Production and Wellhead Parameters

Moth	Gross bbl/d	Net oil bbl/d	Net water bbl/d	W/C%	Choke Size mm	CHP psi	THP psi	FLP psi	FLT °C
				2007					
1	3665.6	751.0	2914.6	79.6	26.0	260.0	875.0	875.0	111.5
2	3533.5	885.5	2648.1	74.9	25.3	260.0	876.7	876.7	111.7
3	3144.9	707.0	2437.9	77.5	24.0	270.0	950.0	950.0	110.0
4	3078.1	819.1	2259.0	73.9	26.0	263.3	1010.0	1000.0	110.7
5	3905.9	507.4	3398.5	84.9	24.0	276.0	868.0	552.0	111.4
6	6041.5	1445.9	4595.6	76.1	22.0	260.0	365.0	145.0	112.8
7	5992.2	1272.9	4719.3	78.8	22.0	270.0	360.0	140.0	114.0
8	5642.5	1308.1	4334.4	76.8	22.0	270.0	435.0	110.0	110.0
9	5252.0	824.4	4427.6	83.9	24.9	281.4	470.0	131.4	112.9
10	4529.9	787.7	3742.2	85.1	26.0	280.0	340.0	133.3	113.3
11	4523.4	455.4	4068.0	89.9	26.0	300.0	590.0	450.0	112.0
12	4615.6	140.8	4474.8	96.9	26.0	300.0	605.0	450.0	113.5
				2008					
1	5144.4	451.1	4693.3	91.5	27.3	268.3	421.7	360.0	113.0
2	5619.2	513.3	5106.0	90.9	30.0	280.0	237.5	120.0	113.0
3	5321.9	772.8	4549.1	85.6	30.0	320.0	230.0	116.7	113.0
4	4847.9	465.4	4382.5	91.1	30.0	326.7	341.7	136.7	112.7
5	3685.0	218.8	3466.2	94.2	30.0	180.0	380.0	110.0	112.5
6	2915.0	1188.3	1726.8	62.4	30.0	98.3	321.7	123.3	112.3
7	3081.8	553.5	2528.3	82.1	30.0	105.0	395.0	105.0	112.0
8	2310.2	411.3	1899.0	73.3	30.0	110.0	435.0	123.3	112.3
9	2082.8	324.0	1758.8	83.2	30.0	130.0	515.0	105.0	109.0
10	2832.8	379.9	2452.9	86.7	30.0	135.0	145.0	115.0	111.0
11	2852.1	232.0	2620.1	91.9	28.0	140.0	135.0	100.0	110.5
12	2874.0	245.0	2629.0	91.5	28.0	140.0	130.0	100.0	111.0
				2009.0					
1	2622.2	175.9	2446.4	93.2	28.0	150.0	175.0	99.5	110.0
2	2739.5	236.5	2503.1	91.4	28.0	105.0	210.0	100.0	110.0
3	2625.2	47.8	2577.4	98.2	28.0	80.0	350.0	100.0	110.0
4	4322.8	413.2	3909.6	90.5	27.0	42.5	230.0	105.0	109.5
5	4372.3	143.8	4228.5	96.8	28.7	40.0	250.0	113.3	112.0
6	2543.9	179.7	2364.2	92.6	30.0	50.0	370.0	105.0	112.0
7	4389.7	153.5	4236.2	96.5	30.0	55.0	260.0	120.0	112.0
8	3550.8	197.5	3353.3	94.4	30.0	80.0	180.0	110.0	112.0
9	3208.8	183.7	3025.2	94.3	24.0	80.0	220.0	110.0	112.0
10	3068.5	307.2	2761.2	90.0	18.0	90.0	276.7	120.0	112.0
11	2823.9	368.6	2455.3	87.0	26.0	113.3	333.3	116.7	111.7
12	2438.5	293.5	2145.0	87.9	26.0	106.7	573.3	116.7	109.3

3.2 Scale characteristics

There are mainly two methods of scale removal or cleaning. These are chemical and mechanical methods. However, the selection of appropriate method depends on the type of scale. Table 2 shows the quality of produced water and Table 3 shows the scale composition. It can be seen that the TDS is 2282 ppm; TDS is defined as the contribution of Ca^{2+} and Mg^{2+}. Calcium represents about 78% and Magnesium 12% of the scale deposit, the balance is wax as shown in Table 3.

Table (2). Produced Water Characteristics

Parameter	Value	Unit
pH	8.2	-
Conductivity	3260	μS/cm
TDS	2282	ppm
Total Hardness	20	ppm
Carbonate alkalinity	150	ppm
Bicarbonate alkalinity	1820	ppm

Table (3). Scale Composition

Ca^{+2}	78%
Mg^{+2}	12%
Wax	10%

3.3 Scale cleaning methods

Chemical cleaning is currently employed in the study area where hydrochloric and caustic soda are generally employed. Chemical cleaning is found to be very effective in the scale removal. However, the washing of the pipeline with chemical requires well shut down which extend for at least 24 hours depending on the magnitude of scale. This shut down is a loss of production which is a dollar loss.

This work proposes the division of the pipeline into two sections: above ground and underground. In the above ground section there are valves, a choke and pipe reduction (non uniform cross section of pipe line). The underground line is a uniform pipeline with no valves and pipe reduction. For uniform pipeline section the standard mechanical cleaning method of pigging is recommend. In fact pigging method is used in the pipeline beyond the CPF. For the aboveground section chemical cleaning is recommended. In this section, to overcome the problem of well shell down, a bypass pipeline is to be installed between the well head and pigging launcher point as shown in Fig 2. It should be identical to the existing portion. The bypass line is simple and requires only pipes works. This solution has the following benefits. It completely eliminate the downtime hence avoid loss of production. Reduce the amount of chemicals used for cleaning the whole pipelines. The cut in chemical consumption will definitely reduce the environmental hazards.

4. Conclusion

The work has established that the main cause of the scale is the presence of calcium and magnesium in produce water. The work proposes the use of both chemical and mechanical methods at different part of the pipeline. The propose methods are standards one. These methods make possible the avoidance of huge economical loss due to well shut down for cleaning. They also make significant saving in the chemical used and reduce the environmental hazards.

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