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Dealing with Flow Assurance-Associated Deposition Problems in Offshore Production Systems: A Case History

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Abstract
The deposition of paraffin solids and other organic and inorganic debris in the subsea flowlines is ubiquitous and can jeopardize the crude oil production in deepwater scenarios. The X field, offshore Espirito Santo State, fits with this scenario. So, a robust operational strategy was implemented for this field aimed at dealing with the deposition of wax and other solids in subsea flowlines. Pigging operational facilities for X field subsea and surface flowlines were designed and built according to a master flow assurance plan. Operational procedures for pigging the subsea lines were set up and have been executed as scheduled. Despite of this well-detailed approach, which has been efficient to keep the problem at bay along the time, a restricted-access underneath section of the topside processing circuit ended up completely blocked by wax, The problem has emerged just after a rigid pig was ran on a subsea flowline, prior to running an inline inspection pig to record a suite of geometric information about this flowline. Both the pig and a paraffin plug ended up getting stuck in the topside section of the pipeline and where there is no room to operate a conventional pumping hookup nor a Coiled Tube Unit to get rid of the blockage. We describe a solution employed to un-block this line. The solution comprises the use of saturated steam to get the paraffin solids melted inside the surface line, thus recovering its entire flow capacity. The steps taken to carry out this challenging job are detailed in this manuscript. To our best understanding, we had never used steam to un-block lines clogged by paraffins neither in field X nor in other offshore scenarios.

Introduction
First, it is not within the scope of this work to present a wide discussion on the organic deposition phenomena nor on pigging operations/practices. Valuable pieces of information on both issues can be found elsewhere[1-5].

Broadly speaking, any crude oil production system depends on a well-planned flow assurance strategy to suitably deal with paraffin and other solids deposition problems that unavoidably take place during the lifetime of the production process[6-7]. Arguably, many families of crude oil components can go through phase equilibrium transitions, which can lead to solids formation and deposition, especially inside the long subsea flowlines operating in low temperature environments, such as the bottom of the sea. The accumulation of such solid materials on the inner wall of these lines creates ever-growing limitations on the full production capacity of the wells.

Based on the argument that paraffin, and other solids, deposition from crude oil is governed by diffusion, which is essentially a thermodynamic phenomenon, one must realize that one can change the kinetics of the deposition phenomenon but cannot prevent it from happening during the production process at all.

Before delving into the actual field problem, it is valuable to briefly describe the applications & limitations of pigging operations[4], as follows:

- Physical separation (spacing out) of different fluid batches flowing through the same pipeline.
- Internal cleaning of rigid or flexibles lines for different purposes.
- In-line inspection (by smart, intelligent pigs).
- Recording geometric information relating pipelines.
- Widely adopted by the oil production industry.
- Effective to scrapping organic deposits from pipelines.
- Pigging is an intrinsically high-risk operation.

Furthermore, pigging operational data must be built up, and recorded, to provide an actual history of a given production line. The objective of this data gathering effort is to come up with a tailored pigging procedure. Conversely, the inherent risk of a pigging operation is that pigs can (easily) get stuck at points of debris build-up, and this can lead to severe problems, such as the one that took place in the offshore X field surface line. Stuck (jammed) pig problems can be costly and hard to deal with. Therefore, the expertise of field personnel is of paramount importance for carrying out a suitable pig pumping schedule for each one of the flowlines that make up the production system on a regular basis.

Despite its intrinsically high risks, it is indisputable that pigging operations are the most adopted approach by the offshore crude oil production industry to deal with the appearance of solid phases in the well´s produced fluids. In a perfect storm situation, nothing can be more suitable than mechanically scrapping organic deposits from a pipe.

The operation to clean out the offshore X field surface line.

First, a sample of the deposit (See Fig. 1) that was clogging the surface line, was collected and sent to our laboratory, where it was characterized by Differential Scanning Calorimetry (DSC). We rely on this quantitative analytical tool[8-9] to determine the phase transitions of paraffins deposits such as its initial and final melting points, which enables us to set the lowest temperature to melt the paraffins deposits.

According to the DSC results the initial and final melting points of the (predominantly) waxy sample are 80 ºC and 100 ºC. respectively.

Figure 1 – Physical aspect of the solid material that was clogging the surface line in the offshore X field.

Based on these DSC results (See Fig. 2) , an *ad-hoc* task force was created to study the problem, and design and execute an environmentally friend operation to clean up the surface line. With the aid of the valuable expertise provided by the X field operational crew, our P&D professionals, and following meticulously our HSE guidelines; we came up with a robust, simple, and straightforward line cleanup project, which consists of application of saturated steam to melt and drain the paraffin deposit out of the stuck line. As scheduled, small segments of the surface line were treated in separate pumping steps to permit a better operational control and minimize the operational and environmental risks.

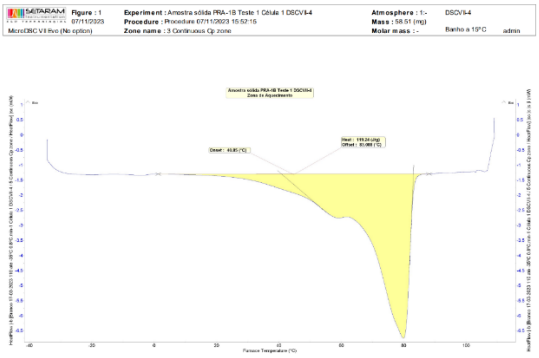

Figure 2 – DSC results showing the initial melting point (80 ºC) of the solid material collected from the surface line. Obs.: The final melting point (100 ºC) was confirmed with the aid of a Petri plate.

With the aid of a skid-mounted steam generator unit, plus a kit of insulated flexible hoses, we managed to pump steam into the surface line (See Fig. 3)

Figure 3 – The (descending) flexible steam hose screw-connected to the top vent valves of the paraffin-clogged line.

An operational limit temperature of 110 ºC was set for the saturated steam, which is high-enough to melt the waxy deposit. This limit temperature was also adopted to assure the integrity of the pipeline materials. Appropriately, saturated steam was injected through the top vent valves of the clogged line while the mixture of melted paraffin + debris + condensed water, was collected through the

existing bottom-pipe drain valves, and from there, diverted and stored in 200-L drums. Later, these drums were properly locked, packed in pallets, and shipped to an HSE-certificated treating plant yard.

The whole operation, from head to tail, lasted *circa* 15 days and was executed according to our best HSE guidelines and practices. It worth mentioning that neither operational problems nor environmental ones, such as oil spills or leakages, were observed and/or registered during the whole operation. Unquestionably, this pioneer operation of wiping out organic from a surface flow line, located in a not-easily-accessed (confined) area, with aid of saturated steam, was 100 % successful.

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Responsibility Note

The authors are the only responsible for the elaboration of this manuscript.

Conclusions

Among the conclusions that can be drawn from this successful operation are:

- The success of pigging operations is above-all dependent on well-designed field practices and on field personnel skills/capability.
- The laboratory tests carried out with the organic deposits were of paramount importance to design the pipeline clean-out job. The high quality laboratory data allowed to spark a straightforward action to work out the pipeline clogging problem.
- A successful steam-assisted line cleaning operation was carried out to unblock a confined surface line of the X field that was initially clogged by produced organic solids (plus a stuck pig).
- The whole pipe cleanup operation was carried out “by the book”, in accordance with our best HSE guidelines & practices. The surface line ended up fully open to flow, and operational, at the end of the cleaning job.
- In accordance with our master flow assurance plan, our operational practices must be elaborated and reviewed on a permanent basis by a highly skilled group of flow assurance specialists.
- Our perspective is always assuring the best field-proven pigging practices and have a well-trained 100%-focused team of operators on board, to rule out the possibility of operational flaws.
- To our best understanding, saturated steam has never been applied before to get rid of organic deposits from surface lines of our offshore fields.
- An in-house expertise is available to design - and execute – a robust operational strategy to clean up lines clogged by organic deposits.

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