Paraffin Wax: Formation, Mitigation Methods & Remediation Techniques

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Paraffin precipitation and deposition in flowlines and pipelines is an issue impacting the development of deepwater subsea hydrocarbon reservoirs. The buildup of paraffin deposits decreases the pipeline cross-sectional area, restricts operating capacities, and places additional strain on pumping equipment.

Introduction to Paraffin Wax

Waxes are typically long, linear or branched n-paraffin chains within produced hydrocarbons and primarily consist of paraffin hydrocarbons (C18 - C36) and naphthenic hydrocarbons (C30 - C60).

Hydrocarbon components of wax can exist in various states of matter (gas, liquid or solid) depending on their temperature and pressure. When the wax freezes, it forms crystals referred to as macrocrystalline wax. Those formed from naphthenes are known as microcrystalline wax. The solid forms of paraffin, called paraffin wax, are from the heaviest molecules from phytane ($C_{20}H_{42}$) to lycopane ($C_{40}H_{82}$).

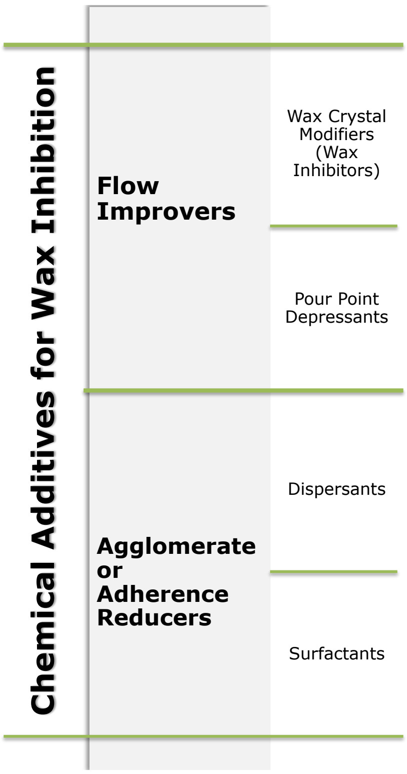
Paraffin wax is a white, odorless solid with a typical melting point between about 115°F and 154°F (46 and 68°C) having a density of around 0.9 g/cm^3 . Waxes have low thermal conductivity, a high heat capacity, and are insoluble in water. While constant deposition of wax can block production lines, it can also act as insulation due to its low thermal conductivity and high heat capacity, resulting in higher arrival temperatures during steady flowing conditions and longer cooldown times during shutdowns. Paraffin wax is soluble in ether, benzene and certain esters, while being unaffected by most common chemical reagents.

Paraffin Wax Formation & Growth

At temperatures below the cloud point, the n-paraffin components begin to crystallize into solid wax particles. These can adhere to each other when the wax-containing hydrocarbon comes in contact with any surface that has a temperature below the wax appearance temperature (WAT) and provides a heat sink. Although WAT and cloud point are often used interchangeably, the distinction is that the cloud point refers to the temperature at which the first wax crystals are observed in solution. The WAT is generally a slightly lower temperature that represents the point at which the bulk of the wax crystalizes. Pour point is another paraffin-related temperature and is the point at which the oil begins to solidify and will not flow without applying force.

The predominant mechanisms proposed to describe paraffin deposition are shear dispersion and molecular dispersion. Shear dispersion describes the relationship between deposition rate and shear rate. Shearing of the wax molecules occurs due to the hydrodynamic drag of the flowing fluid and depends mostly on the flowrate and viscosity of the fluid. Higher viscosity and low flowrates result in high wax deposition rates. However, in highly turbulent flow, deposition rates decrease with increased flow as wax is mechanically sheared off the deposits on the pipe wall. As the deposit thickness increases, so does the shear rate due to the decrease in the flow area and increase in flow velocity. This increase in shear rate causes an increase in the shear stress on wax molecules and formed wax crystals which serves to diminish the overall wax deposition rate.

Molecular diffusion describes the process by which the radial temperature gradient in the line causes a concentration gradient of dissolved paraffin components in the liquid phase. This concentration gradient causes paraffin to diffuse to the pipe wall, where it is assumed to deposit. The widely recognized transport methods contributing to wax thickness on the pipe wall are molecular diffusion of dissolved wax, particle transport of precipitated wax, and sloughing of previously deposited wax.



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Paraffin Wax Management

Paraffin deposition can cause a multitude of operational challenges including:

- Reduction of the internal diameter of the pipelines, which restricts and can ultimately block flow.
- Increased surface roughness on the pipe wall which causes increased back-pressure and reduced throughput.
- Accumulations that fill process vessels and storage tanks, leading to system upsets and labor/OPEX-intensive cleanup and disposal problems.
- Interference with valve and instrumentation operation.
- Increased risk of sticking pigs in the line and interference with the in-line inspection of flowlines and export lines by tools such as gauge pigs, caliper pigs and intelligent pigs.

All of these problems may result in production shutdowns, hazardous conditions, and damage to equipment. Hence, it is important to study wax mitigation and remediation techniques.

Paraffin wax mitigation/prevention can be either preventive or corrective. Preventive practices take steps to avoid paraffin deposits and growth. Corrective practices require the periodic removal of any deposits. A cost/benefit analysis of these solutions should be conducted before the final selection of a paraffin management strategy is made, where a combination of these approaches may be required in order to provide an optimized wax control strategy.

Paraffin Wax Mitigation & Prevention Techniques

Some common wax mitigation/prevention techniques are:

- Optimized pipeline sizing and layout.
- Insulating the line to prevent heat loss and maintain flowing temperatures above the WAT.
- Injection of paraffin inhibitors, dispersants or solvents. Inhibitors need be injected above the WAT to be effective. Solvents can be used on existing wax deposits and dispersants when it is not possible to inject above the WAT.
- Controlled production of wax deposits by carefully monitoring the wax layer thickness.
- Use of non-metallic pipe linings and coatings to reduce the frictional drag and thereby reduce the effects of shear dispersion and molecular diffusion.
- Selection and use of a suitable pig design and periodic pigging of the line.

Paraffin Wax Remediation Techniques

The primary paraffin wax blockage remediation techniques common in the oil and gas industry are as follows:

- Mechanical removal by using progressive pigging programs to remove accumulated deposits while ensuring that the use of an overly-aggressive pig will not result in the pig becoming stuck behind the wax accumulation.
- The addition of heat to melt wax by the injection of hot oil, steam or hot water or the use of electrical heating to melt the wax deposits. When using this strategy it should be noted that the wax disappearance temperature (WDT) is typically higher than the WAT.
- Usage of solvents and dispersants, such as diesel, xylene or kerosene to dissolve the deposit.

Conclusion

The increasing exploitation of deepwater fields makes it important to understand the mechanism of wax deposition and the methods available to prevent and remediate wax deposits in both production systems and export systems. This often involves a combination of chemical treatments, pigging and insulation to deliver a fit for purpose wax control and management strategy suitable for a particular development.

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