Go with the flow

Rebecca Roth, INTECSEA, USA, explains how direct electrical heating (DEH) can provide new possibilities for field development.

Advancement in flow assurance technology is bringing viable new development options to challenging oil and gas fields. One technology proving its worth is direct electrical heating (DEH).

DEH improves the flow of heavy oil, prevents and remediates hydrates and paraffins, extends shutdowns with limited use of chemical injection or hot oil circulation, reduces the infrastructure for such chemical injection and hot oil circulation, reduces Capex and Opex, handles high water-cut during tail end production periods and aids in planning for third-party tie-ins with poorly-defined composition.

Conventional answers to hydrate and wax formation

Hydrate and/or wax formation is often a limiting factor in development of deepwater, ultra deepwater, heavy oil and Arctic fields. Marginally profitable oil and gas fields often become economically viable only if the costs of a local host can be avoided. Tie-back lengths are increasing in order to transport the production stream from the subsea field to an existing nearby host or to a new host shared by a number of reservoirs spread over a large area.

Because of the greater distances, the product's temperature drops along the length of the flowline, which results in a relatively cool topsides arrival temperature compared to the reservoir and wellhead temperatures. In deepwater or Arctic developments, the heat lost from the production flow to the cold seawater causes a very low arrival temperature, even in shorter flowline lengths.

As the production flow temperature drops in these deep and Arctic waters or over the long tie-back lengths of the marginal fields, the product forms hydrate crystals, similar to ice flakes.

For reservoirs with heavy oil, the product's temperature along the flowline and riser also must be maintained to make sure the

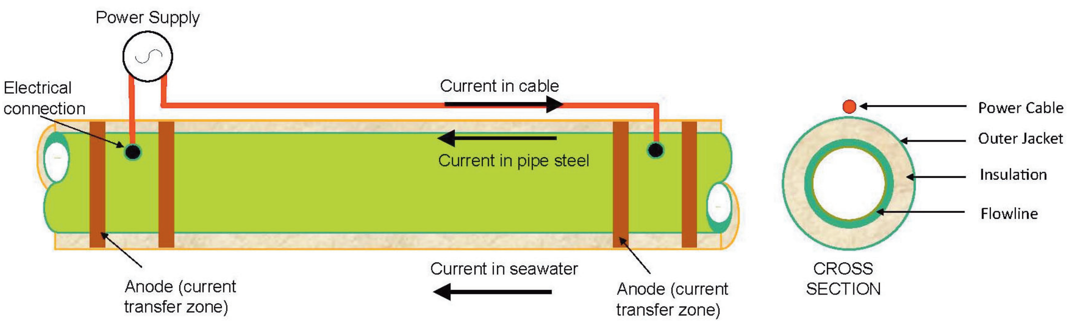

Figure 1. *Open loop (wet insulated) direct electrical heating.*

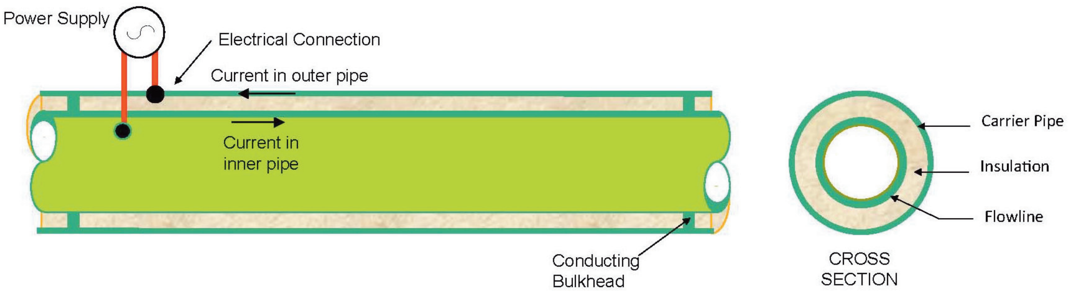

Figure 2. *End-fed pipe-in-pipe direct electrical heating.*

flow is suitable. Otherwise, wax content in the production fluid can produce wax deposits, which coat the flowline walls and, eventually, restrict flow.

During a shutdown of fields in shallower depths or with reduced flowline distances, the hot flow from the reservoir ceases. Whether these shutdowns are planned or unplanned, hydrate formation probability is high.

Conventional flow assurance methods for hydrate and wax prevention include high-performing thermal insulation, chemical injection with hydrate and wax inhibitors and dead oil circulation during shutdown. However, in deepwater, the Arctic and long tie-backs, conventional methods may not be adequate.

Advantages of DEH

Using (DEH) on flowlines is an alternative to conventional flow assurance techniques. The efficiency of a DEH system is calculated by comparing the useful heat generated in the flowline to the overall power dissipated in the circuit. By providing heat directly to the flowline generated by an electrical current in the pipe wall, the DEH current causes the steel to warm up due to the electrical resistance of the metal. Through thermal conduction, the heat is then transferred from the pipe wall to the production fluid, thereby raising the temperature of the flow above the critical wax and/or hydrate temperatures.

Looped flowlines or a service line can be eliminated since DEH can serve as an alternative to dead oil circulation. Many capital and operational costs of chemical injection and handling equipment can also be avoided by reducing the amount of chemicals required for the flowlines. However, non-electrically-heated production facilities, such as subsea trees, manifolds and jumpers may still require chemical injection during shutdowns.

Types of DEH systems

There are three types of DEH systems currently in operation:

- Open loop (wet insulated).
- End-fed pipe-in-pipe (dry insulated).
- Centre-fed pipe-in-pipe (dry insulated).

Wet insulation systems are exposed to seawater. Over the course of time, the integrity of these systems can be affected if they are not properly insulated.

Dry insulation systems are well insulated and isolated from seawater, but their higher capital costs can be an important consideration when selecting a system.

In an open loop DEH system (Figure 1), a single core electrical cable piggy-backs on the flowline and carries the total DEH current. The return current is split between the flowline in parallel with the surrounding seawater and sea floor. The electrical power supply is connected to both ends of the flowline, either directly or through wet-mateable connectors.

Typically, the open loop DEH system has multiple anodes attached to the flowline to maintain the surface current density below a level at which AC corrosion is induced. This corrosion, which results from the AC current transferring from the flowline to the seawater, generally occurs near the submerged electrical connections.

Efficiency calculations for an open loop DEH system include the piggyback cable, power connections, seawater return path and flowline.

An open loop DEH system is in use for Statoil's Asgard, Huldra, Kristin, Urd and Tyrihans developments as well as Canadian National Resources' Olowi, which has a continuous flowing DEH.

For an end-fed pipe-in-pipe (PIP) DEH system (Figure 2), the inner and outer pipes are used as electrical conductors. Connected electrically at the subsea end by a conducting bulkhead, the two pipes allow current to flow down one pipe and return in the other. At the host end, where the power supply is located, an isolating joint forms part of the flowline such that an electrical supply can be connected across the flowline and carrier pipe without the near end bulkhead creating a short circuit. The power supply is also isolated from the topside structure.

Since a PIP DEH pipeline is essentially a coaxial cable, skin and proximity effects are both present. The skin effect is the tendency of AC current to flow at the surface of a conductor. The proximity effect is the tendency of AC current to move in close proximity to AC current flowing in the opposite direction.

Because of these effects, the current flows on the outer surface of the inner pipe and the inner surface of the outer pipe (on the annulus surfaces) (Figure 3). Other than anodes for conventional corrosion protection, no special precautions or electrical insulation material are required along most of the flowline to prevent stray current flowing into the seawater since the current is drawn into the annulus.

However, if the current density is sufficiently large, AC corrosion can potentially occur in areas where the system is

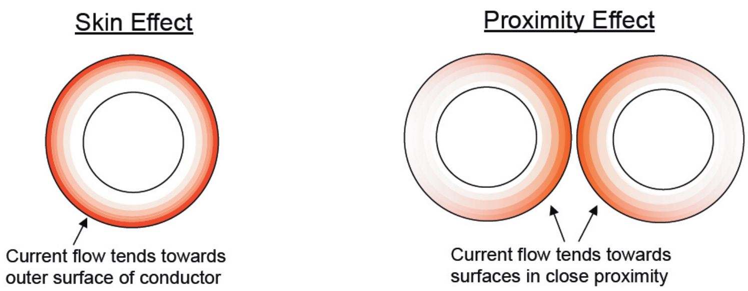

Figure 3. *Skin and proximity effects.*

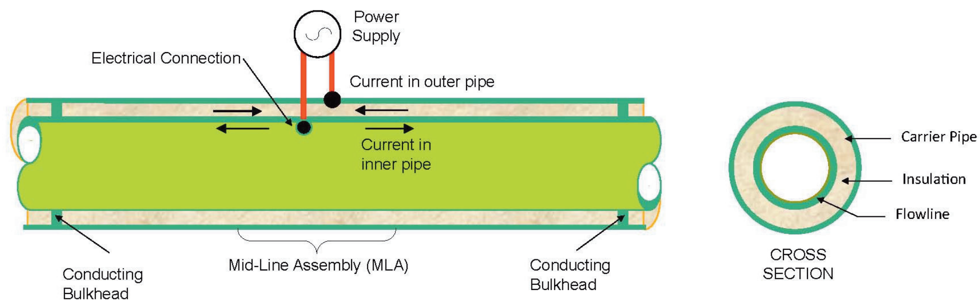

Figure 4. *Centre-fed pipe-in-pipe direct electrical heating.*

not coaxial in nature, namely the surface of the outer pipe near the conducting bulkhead. To reduce the current density, multi-layer coating or 3 - 4 m of bare pipe near the bulkhead is recommended (adequate anode protection required).

Efficiency calculations for this PIP DEH system include the inner pipe, outer pipe, bulkhead and power connectors.

Increased resistance of an object will cause greater heating for the same amount of current. PIP DEH systems have a higher AC resistance than open loop systems due to an increase in current density when the skin and proximity effects draw the current into a very thin layer on the pipe surface. Therefore, PIP DEH systems are considerably more efficient than the open loop system even though almost half the power is dissipated in the outer pipe. Also, there are no piggyback cable power losses or seawater power losses as compared with the open loop system, and heat losses are very low for dry insulation compared to wet insulation.

Shell's Serrano and Oregano lines use the end-fed PIP DEH system.

For a centre-fed PIP DEH system (Figure 4), the inner and outer pipes are used as electrical conductors in a similar manner to the end-fed system. However, in the centre-fed configuration, steel bulkheads are installed at both ends of the segment and the power source is connected at the mid-point via the mid-line assembly (MLA). The power is connected to the inner pipe using a flexible connection to the pipe itself, and a wet-mate connector to isolate the current from the MLA housing.

This system can be designed for long flowlines that can be broken down into discrete heated segments, each with an MLA. It can also be used for high gel temperature oil where continuous heating is required. End-fed systems cannot be used for continuous heating because water in the produced fluid could create a short circuit across the isolating joint.

Portable power supplies can be used to service flowline segments located at considerable distances from the topside supply if the DEH is required on a temporary basis. However, if continuous operation is needed, then the MLA must be tied back to the host.

Projects that feature the centre-fed PIP DEH include the Shell/BP Na Kika field and the Shell Habanero development.

Most currently-installed DEH systems maintain temperatures during shutdown. If the DEH system is immediately activated to preserve the heat in the flowline, there is no delay in the prevention of hydrates and wax, unlike conventional flow assurance methods, which require operators' time to circulate dead oil or inject chemicals.

DEH technology is constantly being stretched to enable ever more challenging field developments. Studies are underway regarding its use for hydrate plug remediation, how to design the system for continuous flowing conditions, and maximising the length of a DEH-heated flowline. All of these questions and opportunities are under consideration as the technology continues to evolve. OT