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## **Application and Recycling of Sodium and Potassium Formate Brine Drilling Fluids for Ghawar Field HT Gas Wells**

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### **Abstract**

This paper describes the benefits and lessons learned from drilling 44 deep gas reservoir sections with sodium and potassium formate brine drilling fluids in Saudi Arabia's prolific Ghawar field from 2004 through 2008.

Initially in Saudi Aramco, the formate brine drilling fluids were used primarily to prevent formation damage across the pre-Khuff sandstone reservoirs. As formate use burgeoned, their ancillary benefits such as stuck pipe mitigation, better bit performance, better than expected reservoir performance, lower pump pressures, torque and drag, solids content and enhanced temperature stability; use as a completion fluid and recyclability became evident.

The fluids have been used in a variety of reservoir drill-in fluid applications in the pre-Khuff, Jauf and Unayzah sandstones with bottom hole temperatures (BHT) up to 323°F. The formates have also been used by Saudi Aramco in the Khuff carbonates for single and dual lateral horizontal wells where the drilling fluid overbalance to formation pressure sometimes exceeds 1,400 psi.

In addition to the return permeability testing conducted prior to actually drilling the first wells with formates, the fluids non-damaging properties were proved up in the case of the Tinat-A well, a Unayzah-A re-entry/horizontal sidetrack, that had to be shut in for three years, due to a mechanical obstruction in the completion, with a 90 pounds per cubic foot (pcf) sodium/potassium formate completion fluid left in the hole as kill fluid. After removing the obstruction via a snubbing unit workover the well initially tested at 30 mmscfd with 4,320 psig FWHP, which was much higher than estimated.

In a JFYN Unayzah B/C well, JFYN-A, only 1,214 ft of 5-7/8" hole was cut across the reservoir using a recycled 92 pcf potassium formate and the well flowed back at 45 mmscfd with 358 bopd oil on a 44/64" choke, which was also much higher than expected.

Laboratory return permeability to gas test with Khuff-C cores showed 91% return permeability after flowing through the cores with potassium formate drilling fluid with 2% commercial lubricant as compared to 40% return permeability for the KCl Polymer drilling fluids of the same density normally used across the Khuff-C.

The formates have also been used in combination with fine, medium and coarse calcium carbonate functioning as a bridging agent to drill in extreme overbalance situations across the Khuff-C reservoirs. The best example of this practice is UTMN-J, a Khuff-B re-entry sidetrack, where an 81 pcf sodium formate brine served as the base drilling fluid to drill and complete the 3675 ft horizontal section. The well was flowed back at a rate of 35 mmscfd without enzyme treatment or acid stimulation.

An area of the Shedgum Mud Plant, a major Saudi Aramco fluids storage and handling facility, has been converted to a formate recycling center, complete with solids control equipment, mud lab and resident mud engineers. The formate muds are routinely transported back from the rig to the Shedgum Mud Plant after a well is completed. There the mud is screened, centrifuged, chemically treated and given ample time for solids settlement by gravity segregation and stored until required for