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Shale Inhibition Strategies for Reservoirs Containing Reactive Clay - Experiences Drilling High Angle Wells in Bohai Bay

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Abstract

The Cao Fei Dian (CFD) field located in Bohai Bay, China contains numerous commercial oil fields comprising shallow multi-layered reservoir sands in the Ming and Guantao formations. The depositional basins containing the Ming and Guantao sands are inter-bedded with reactive clays in the hydrocarbon-bearing formations, with multiple pay zones being isolated by similarly reactive shale zones. The development plans for the fields called for predominantly horizontal openhole gravel-pack completions, requiring highly inhibitive drilling and completion fluids to counter the reactive nature of the formations. A secondary area of concern was the interaction between drilling fluid filtrate and completion brines with the crude oil. A cost-benefit analysis indicated the option for oil-based mud, the preferred completion method and costs associated with a zero-discharge environment, was not feasible due to the environmental restrictions.

Prior to development of the first commercial field, extensive laboratory studies were conducted on cuttings and crude oil samples collected from exploration and appraisal wells. This series of tests helped to determine the preferred drilling and completion fluid program for the field, resulting in a highly successful Phase 1 development project for the CFD 11-1 and CFD 11-2 fields. Prior to commencing drilling and completion operations on offsetting fields, additional testing was undertaken to confirm the fluids of choice were satisfactory. This second series of tests proved surprising in that the fluids used in Phase 1 were inappropriate for offset development projects due to unsatisfactory shale inhibition and adverse crude oil reactions.

A new series of tests were required to determine optimal shale inhibition and prevention of crude oil emulsification. This paper discusses in detail the specific tests performed to optimize production from the fields prior to drilling, together with specific examples of the benefits gained from the fluid testing during execution of the drilling and completion program. To date more than 40 post-Phase 1 development wells have been completed successfully in the on-going development project, including record step-out wells for Bohai Bay, together with an additional eight exploration and appraisal wells drilled in the exploration phase.

Introduction

In 1999 the CFD 11-1-1 exploration well was drilled, producing high flows of oil and gas from the Guantao Formation. High yield also was shown in the Lower Ming. After the drilling success of the CFD 11-1-1 well, two follow-up evaluation wells were drilled: CFD 11-1-2 and CFD 11-1-3. Both evaluation wells encountered commercial oil flow in the Upper Tertiary.

Further evaluation wells were drilled during 2000 and 2001 and seismic, well test and log data were analyzed before launching the Phase 1 CFD 11-1 and CFD 11-2 development campaigns.

The first development well was spudded in November 2003 and the CFD 11-1 and 11-2 development phase continued until early 2006 with a total of 42 wells drilled and completed. These wells primarily were drilled in interval batches. The general well design includes a driven conductor followed by 17½-in hole section by 13⅜-in casing, 12¼-in hole by 9⅝-in. casing followed by a horizontal 8½-in openhole interval completed by running premium screens and gravel packing.

In 2005 and early 2006 three new fields were planned for development: CFD 11-3/5, CFD 11-6D and 12-1E. While these wells use approximately the same well design to penetrate the same reservoirs encountered in CFD 11-1/2, and are geographically close to the CFD 11-1 and 11-2 fields, significant differences in properties of the reservoir interbedded shales were noted as well as variations in the produced crude.