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FINAL OVERALL REPORT
FOR
COMPARATIVE ANALYSIS OF DUAL DENSITY DRILLING SYSTEMS TO REDUCE DEEPWATER DRILLING COSTS

TASK 6 & 7 REPORT

(July 2003 – September 2004)

Prepared by:

John Rogers Smith, Darryl A. Bourgoyne, John Shelton, Mikolaj Stanislawek, Anuj Gupta, Andrew K. Wojtanowicz, and Julius P. Langlinais

Craft and Hawkins Department of Petroleum Engineering
Louisiana State University
Baton Rouge, LA 70803-6417

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RPSEA Project Manager
Robert W. Siegfried
Vice-President, Unconventional Gas Technology

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John Rogers Smith, Darryl A. Bourgoyne, Mikolaj Stanislawek, John Shelton, Anuj Gupta, Andrew K. Wojtanowicz, and Julius P. Langlinais

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Craft and Hawkins Department of Petroleum Engineering
Louisiana State University
Baton Rouge, LA 70803-6417

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Research Partnership to Secure Energy for America
1650 Highway 6, Suite 300
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This report summarizes the work performed to establish whether further research concerning dual density drilling systems based on use of low density fluids, either liquid or gas, is justified. The major achievements of this research were to

1. show that the cost benefits of a riser gas-lift approach to dual density drilling are significant and of essentially the same magnitude as the cost benefits for a dual gradient system based on the use of sea floor mud lift pumps,
2. perform simulations indicating the practical feasibility of well control operations with a riser gas lift system, and
3. demonstrate the potential feasibility of a liquid dilution based system and the potential advantages of using hydrocyclones in lieu of centrifuges to perform the separation of riser mud into dilution and drilling fluids.

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SUMMARY

Development of our nation's deepwater gas resources is currently limited by the high capital costs involved in developing these resources. Dual gradient drilling methods have been proposed as a means to provide simpler, safer, more economic well designs and therefore increase the ultimate development and utilization of deepwater gas resources. Two dual density drilling concepts, riser dilution with a low density liquid and riser gas lift, were investigated in this project as potential means to implement a dual gradient system. The overall objective of the project was to establish whether further research concerning dual density drilling systems based on use of low density fluids, either liquid or gas, is justified.

The research was intended to begin answering four critical questions about the practical feasibility and commerciality of these two dual density drilling methods. The first is the probable cost benefit relationship for each. The second is whether effective well control methods can be defined. The third question is the practicality of separating the low density and high density components of the mixed fluid that returns to the surface in the riser for reuse. The fourth question is whether a riser gas lift or liquid injection system can be controlled to allow all of the major drilling operations to be conducted safely and predictably.

This report summarizes the answers developed from our research to begin addressing these questions. The answer to the first question is the primary focus of this report. Riser gas lift was found to provide a cost reduction of at least 9 per cent, and most likely 17 to 24 per cent, versus estimated trouble-free costs for conventional drilling practices for the three example wells selected to represent future deepwater Gulf of Mexico operations. In addition, a riser gas lift approach also increased the feasibility of drilling deep wells in deepwater that might otherwise be impossible. Well control with riser gas lift was also found to be feasible using methods generally analogous to conventional operations or use of a subsea mudlift pump. Riser dilution using liquids was also concluded to reduce costs versus conventional operations, by 7 per cent for the example studied. The practicality of separating and reusing mud returning from the riser was only partially investigated. However results from both our work and that done by de Boer (2003) indicate that mud separation for a riser dilution system is possible. The broader question of controlling all operations has not been addressed, but specific kinds of operations such as well control during connections has been investigated and no technical barriers precluding required operations were identified.

INTRODUCTION

OBJECTIVE

The overall objective of this project was to establish whether more comprehensive research concerning dual density drilling systems based on use of low density fluids, either liquid or gas, is justified. The project was intended to continue the research initiated by LSU and Petrobras on the riser gas lift method and to begin assessing injection of unweighted liquid into the riser as another alternative. These methods are intended to offer alternative methods of achieving a dual gradient deepwater drilling system that utilize more standard equipment than the separate industry projects focused on the use of seafloor pumps to achieve the advantages of a dual gradient method.

DESCRIPTION

The focus of the project has been to evaluate and develop the operational concepts for two dual density methods that can be applied using current riser-supported subsea drilling systems: riser gas lift and injection of unweighted liquid into the riser. The results are intended to provide the first step in beginning to answer four critical questions about the practical feasibility and commerciality of these systems.

The first question is what the probable cost benefit relationship would be for each of the two alternative concepts if applied to representative deepwater Gulf of Mexico development and exploratory wells. This question will be addressed explicitly, and in detail, in this report. The basis for the well descriptions selected as being representative of future Gulf of Mexico deepwater drilling was explained in the Task #2 report by Smith and Bourgoyne (2004). The second question is whether an effective well control method can be defined for a system containing so many different density fluids and different flow paths. This question was addressed in detail for the riser gas lift alternative and was addressed in the Task #3 report by Stanislawek and Smith (2004) and in a masters thesis by Stanislawek (2004). The third question is the practicality of separating the low density and high density components of the mixed fluid that returns to the surface for reuse. This question was introduced in the Task #4 report by Shelton and Smith (2004) and addressed more rigorously in the Task #5 report by Shelton, Gupta, and Smith (2005). The fourth question is whether a riser gas lift or liquid injection system can be controlled to allow all of the major drilling operations to be conducted safely and predictably. This question is too broad to have been considered rigorously in this study. However, the specific emphasis was to be on mud properties, which were addressed in Task Reports #4 and #5. In addition, some other specific considerations have been identified and discussed in each of five task reports that have already been submitted. All of this work was supported by a comprehensive review of related engineering literature that was documented in the Task 1 report by Smith, Stanislawek, and Shelton (2003).

RATIONALE

The rationale for investigating these dual density drilling methods is based on the expectation that development of deepwater natural gas reserves will contribute significantly to new gas reserves in the lower 48 states over the next fifteen years according to recent GTI baseline projections. However, the current economic significance of deepwater gas production is constrained by the substantial capital costs of deepwater development. Although a great deal of effort has been expended on new technologies to reduce the cost of deepwater production facilities and on building new deepwater drilling rigs, no major new technologies have been commercialized to reduce drilling costs by improving the drilling and well design concepts. Even though wells have been drilled in water as deep as 10,000 feet, the riser inside diameter can severely limit the number of casing strings that can be used and consequently the maximum practical well depth when conventional well designs are used. These limits become more severe with increasing water depth. Specific geologic conditions, such as long salt intervals or a lack of significant overpressures, or more costly rig and well equipment, such as a larger riser or use of expandable tubulars, can offset these limitations. Nevertheless, some deepwater resources will be left unexplored or undeveloped because the current well design technology is too limited or too costly to be used.

A simpler, potentially more cost effective, well design would use a moderate density fluid in the annulus of the riser and a higher density fluid in the wellbore to provide a more favorable pressure profile in the well, specifically a pressure profile closer to what naturally exists in the subsurface formations. The drilling system that would allow these two different fluid gradients in the well has been called the dual density or dual gradient system. An example of how the fluid gradients and casing points in this kind of well design would match up with formation pressure gradients is provided in Figure 1.

This example assumes that the fluid gradient from the surface to the mudline is a seawater gradient and that the mud gradient below the mudline is adequate to provide overbalance for a trip margin. The dual density well design has the advantages of fewer casing strings for lower well cost, larger mud weight margins for improved safety, a larger production casing size for increased production and revenue rates, and reduced riser tension requirements which would allow longer risers to be used with existing tensioning systems. Ultimately the benefit to gas consumers of implementing dual density deepwater drilling methods should be an increased supply of domestic natural gas providing reliable, cost effective energy and chemical feedstock to the U.S. economy.

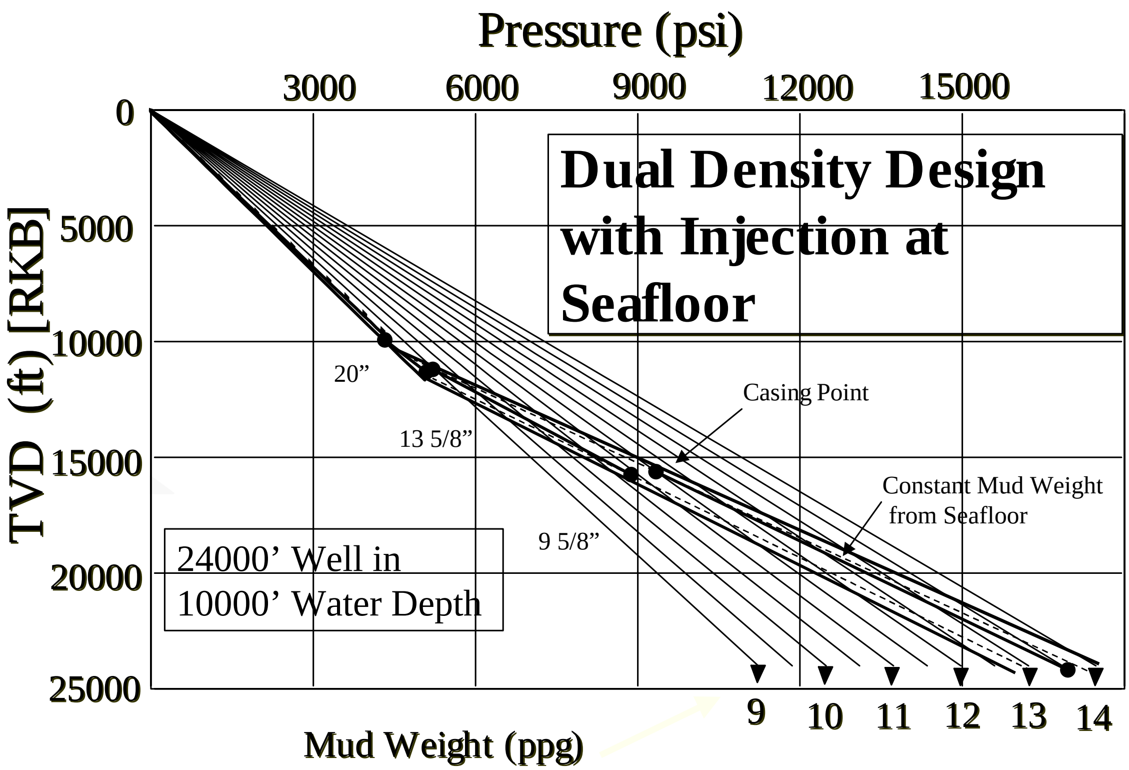

Figure 1 - Well Design for 24,000' Gulf of Mexico Well in 10,000' of Water Using the Dual Density Concept

POTENTIAL BENEFITS OF PROPOSED WORK

The ultimate benefits of the proposed project should be increased domestic natural gas reserves and the decreased cost of gas that result from a reduced cost of finding and developing deepwater gas resources. In 2001, over 50% of the oil production and over 20% of the gas production in the Gulf of Mexico was from water depths greater than 1000 feet. GTI has previously forecast nearly 2000 wells per year to be drilled there in coming years. One report suggests that there are 6 billion barrels of oil equivalent undiscovered in the ultra deepwater Gulf of Mexico, which would be roughly 350 TCF if it were all gas. These factors suggest that the number of wells to be drilled in deepwater in the future will increase. If it is assumed that only 100 to 200 wells per year are drilled in water depth greater than 2000 feet and that the savings per well is $1/2 to 2 million per well, as indicated in an earlier feasibility study by Lopes (1997), the average annual savings from implementing the dual density drilling system would be on the order of $100 million per year.

Environmental and safety benefits would also result from implementation of the dual density system. The larger kick and trip margins possible would reduce the risk of well control events occurring and of subsequent loss of control. These reduced risks would improve personnel safety and decrease the frequency of hydrocarbon spills that could cause environmental damage.

The dual density systems studied herein rely primarily on new applications of existing drilling rigs, circulation systems, solids control equipment, and gas handling equipment. Consequently, if any of these technologies are economically feasible, they could be faster to implement than the riserless drilling system, which requires continued development of new subsea pumping equipment.