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LITERATURE REVIEW SUMMARY
FOR
COMPARATIVE ANALYSIS OF DUAL DENSITY DRILLING SYSTEMS TO REDUCE DEEPWATER DRILLING COSTS

TASK #1 REPORT

(July – December 2003)

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13. ABSTRACT (Maximum 200 words)
An extensive bibliography was assembled to assist the evaluation of whether riser gas lift and riser dilution with a low density liquid may be developed as practical, commercial dual density drilling systems. Each reference is identified in the bibliography and described with a short abstract. The bibliography is sorted by major subject area: dual gradient drilling, underbalanced drilling, well control, drilling fluids, and miscellaneous related references. Extensive references on the subsea mudlift drilling concept are included and are relevant both for comparison to dual density methods and for defining specific equipment and operating techniques that are common to both approaches. References for riser gas lift and riser dilution with liquids are much less evident. Nevertheless, adequate information has been collected to establish the state of the public knowledge about these systems and to begin extending that knowledge toward better conclusions about their practical feasibility.

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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, are being investigated in this project as potential means to implement a dual gradient system. The overall objective of the project is to establish whether further research concerning dual density drilling systems based on use of low density fluids, either liquid or gas, is justified.

This research is 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 information found in currently existing technical literature that addresses or provides background for addressing these questions.

The search concentrated on information directly relating to 1) all of the alternative dual gradient drilling methods that have been proposed, including the seafloor pump systems that have received the most development, 2) underbalanced drilling as an analogy to riser gas lift, 3) synthetic based drilling fluids which will most likely be used in either of these systems, and 4) well control which is potentially the most challenging operation to implement successfully if these systems are being used. Information relating directly to riser gas lift and riser dilution was relatively scarce, but substantial information on seafloor pump approaches to dual gradient drilling and providing background for evaluating operations with the systems of interest was found. An extensive, annotated bibliography of these references is included as the primary content of this report.

INTRODUCTION

The overall objective of this project is 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 is 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.

The focus of the project is 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. It is intended to provide a first step in beginning to answer four critical questions about the practical feasibility and commerciality of these systems. The first is the probable cost benefit relationship for each of the two alternative concepts if applied to representative deepwater Gulf of Mexico development and exploratory wells. The second is whether an effective well control method can be defined for a system containing so many different density fluids and different flow paths. In particular, we will compare the conventional approach of circulating against a surface choke to the more dynamic approach of using the dense fluids already in the well to regain an overbalance and to the potential use of a seafloor choke. 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. 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.

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 most 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 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.

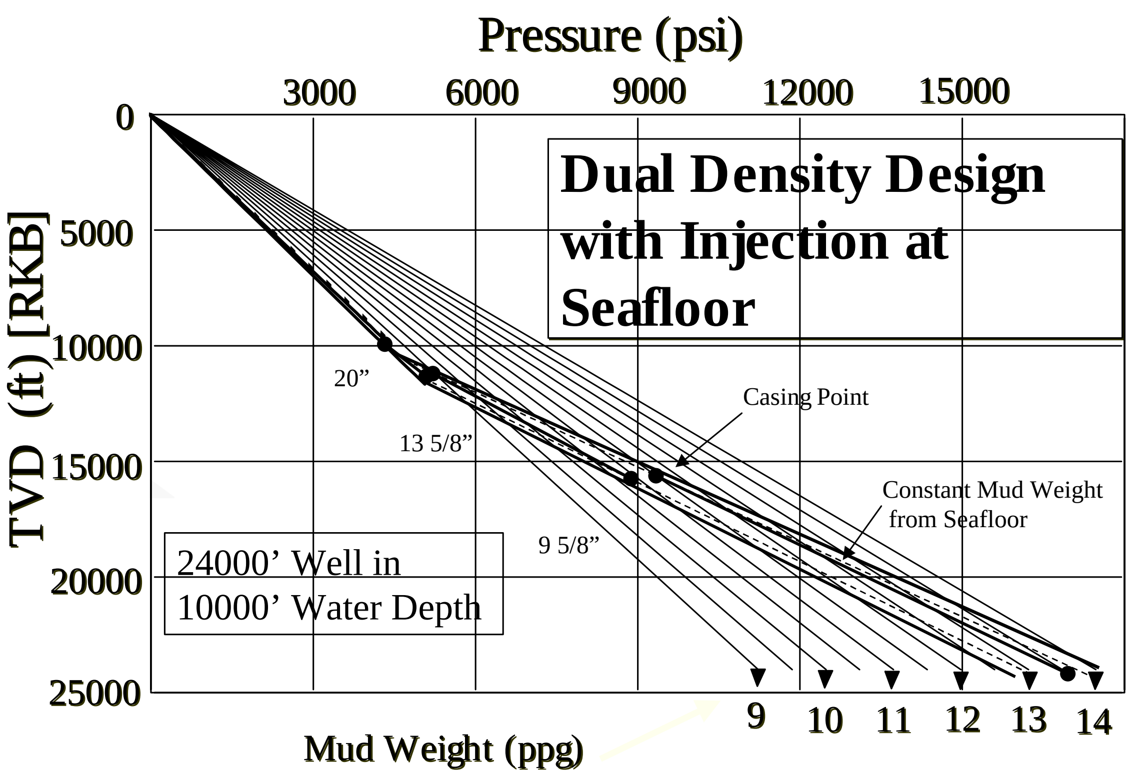

Figure 1 - Well Design for 24,000' Gulf of Mexico Well in 10,000' of Water Using the Dual Density Concept

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.