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An Experimental Study of Well Control Procedures for Deep Water Drilling Operations

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ABSTRACT

As the search for petroleum reserves has moved into the deep water offshore environment, the blowout control problem has continued to increase in complexity. Several special well control problems for floating drilling operations stem from the need for long subsea choke lines connecting the subsea blowout preventer stack at the sea-floor to the surface well-control system. The magnitude of these problems are made worse by the very low effective formation fracture gradients generally associated with drilling operations in deep water.

A research facility has been designed and constructed to model the well-control flow geometry present on a floating drilling vessel operating in 3000 feet of water. The main features of this facility are: (1) a highly instrumented 6000 ft well equipped with a packer and triple parallel flow tube at 3000 feet to model a subsea BOP stack with connecting subsea choke and kill lines, (2) a choke manifold containing several 15,000 psi adjustable drilling chokes of varying design features, (3) a conventional mud circulating system powered by a triplex pump, and (4) an instrumentation and control house.

Flow tests were conducted for several drilling chokes and the behavior of each choke was described using a frictional area coefficient correlation. Several types of experiments were conducted in which gas kicks were simulated by the injection of nitrogen into the bottom of the well. Alternative procedures studied and evaluated included techniques for compensating for choke-line frictional pressure loss during pump start-up and techniques for handling rapid gas zone elongation when the kick reaches the sea floor. The results obtained differ significantly from those predicted by computer simulation of the test conditions studied. It was found that the demands placed upon a choke operator during well control operations in deep water were not as severe as anticipated from computer simulation studies and could be managed with existing equipment by an experienced choke operator.

References and illustrations at end of paper.

INTRODUCTION

In the late 1940's, the search for oil and gas accumulations first moved offshore to the shallow marine environment. Since that time, drilling operations have been extended steadily across the continental shelf. More recently, developments in the technology for drilling from floating drilling vessels have allowed exploratory drilling beyond the limits of the continental shelf and into the relatively deep water of the continental slopes. In 1974, the first well was drilled in a water depth in excess of 2000 feet.[1] Figure 1 shows how rapidly drilling operations have progressed into deeper water depths. In 1979, a well was drilled offshore from Newfoundland in a water depth of 4876 feet.[2] Future plans in the Ocean Margin Drilling Program of the National Science Foundation call for scientific ocean drilling during the next decade in water depths of 13,000 feet.[3]

As the search for oil and gas is extended to greater water depths, the number of wells drilled each year in deep water is also increasing. Figure 2 shows the number of wells drilled each year in water depths in excess of 2000 feet. In 1980 alone, nineteen wells were drilled. At least in a global sense, deep water drilling operations are becoming routine.

Like many other aspects of drilling operations, the problem of blowout prevention increases in complexity for floating drilling vessels operating in deep water. Several special well control problems stem from a greatly reduced fracture resistance of the marine sediments and from the use of long subsea flow lines extending vertically from the blowout preventer (BOP) stack at the sea floor to the choke manifold and other well-control equipment located at the surface. Shown in Figure 3 is the approximate effect of water depth on fracture resistance, expressed in terms of the maximum mud density which can be sustained during normal drilling operations without hydrofracture. Note that the maximum mud density which can be used with casing penetrating 3500 feet into the sediments decreases from about 13.9 ppg on land to about 10.7 ppg in 1500 feet of water, and to about 9.8 ppg in 13,000 feet of water. The lower fracture resistance results