Distinguished Lecturer Program

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The Society is grateful to those companies that allow their professionals to serve as lecturers

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Ways to Successfully Reduce Well Blowout Events

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Petróleo Brasileiro S.A. - Petrobras

Society of Petroleum Engineers
Distinguished Lecturer Program
www.spe.org/dl
Motivation for the Lecture

Blowouts in Brazil During Drilling Operations

Before 1988

After 1988

Number of Blowouts

Year

1980 1990 2000 2010
To show how a major oil company can act to preserve its personnel, assets and image from the consequences of a well blowout in drilling and production operations.
# Presentation Outline

- **Introduction**

- Well Control Training and Certification Program

- Well Control in Drilling and Production Operations

- Well Control in Deep and Ultra-Deep Waters

- Research and Development in Well Control in Ultra-Deep Waters

- Conclusions
• Kicks – Undesirable flow from the formation into the well that happens when the pressure inside the well becomes less than the pressure of that formation.

• Blowouts – Uncontrolled flow from the formation into the well and then to the atmosphere, sea bottom or other uncased formations.
Blowouts Classification

- Surface Blowout
- Underground Blowout
- Cratering
Examples of Blowouts
Consequences of a Blowout

- Loss of Human Lives
- Loss of Reserves
- Loss of Equipment
- Production Discontinued
- Environmental Aggression
Human Factors Review for Offshore Blowouts

- No direct human error involved: 8
- Inattention to operations: 25
- Improper planning: 12
- Improper method procedure: 11
- Inadequate documentation: 2
- Improper installation / inspection of equipment: 2
- Improper maintenance of equipment: 20
- Inadequate supervision / work supervision: 20

Source: Aberdeen Drilling School HPHT Manual
Introduction

Well Control Training and Certification Program

Well Control in Drilling and Production Operations

Well Control in Deep and Ultra-Deep Waters

Research and Development in Well Control in Ultra-Deep Waters

Conclusions
Well control training starts in 1971

In 1993, the Well Control Certification and Training Program is created and conducted by Petrobras University

The program is accredited by WellCAP of IADC in July, 1996
## WellCAP Certificates Issued

Until 31 December, 2009

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<thead>
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<th>LEVEL</th>
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<th>FUNDAMENTAL</th>
<th>SUPERVISION</th>
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Trained/Certified People

Number of Certified/Trained People

Year

1980 1990 2000 2010
• Introduction
• Well Control Training and Certification Program
• Well Control in Drilling and Production Operations
• Well Control in Deep and Ultra-Deep Waters
• Research and Development in Well Control in Ultra-Deep Waters
• Conclusions
Well Control in Drilling and Production Operations

<table>
<thead>
<tr>
<th>Personnel (Well Control Team)</th>
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<tbody>
<tr>
<td>• Monitoring of well control certificates</td>
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<tr>
<td>• Drills at the rig site</td>
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</table>

<table>
<thead>
<tr>
<th>Well Control Equipment (Well Control Team)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Rig inspections upon receiving it</td>
</tr>
<tr>
<td>• Monitoring of well control equipment and kick detection tests</td>
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</table>
Development of Well Safety Standards

- Creation of a committee to review, elaborate and approve internal well safety standards
- There are 17 standards approved and in use

Operations (Well Control Team)

- Elaboration and approval of operational procedures especially in deep waters
- Reinforcement of the use of these operational well safety procedures and standards
• Introduction

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• Conclusions
• Low fracture gradients
• Excessive frictional pressure inside the choke line
• Low temperatures
• Hydrate formation
• Gas in riser
Low Fracture Gradients

• Fracture pressures in deep waters are lower than those found onshore or in shallow waters

• The overburden pressure is lower due to the seawater

• Narrow operational window for the mud weight
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<tr>
<th>Well</th>
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<th>Fracture Pressure (lb/gal)</th>
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</table>
Narrow Operational Window

- **Pore Pressure**
- **Fracture Pressure**
- **Shallow Water**
- **Deep Water**
- **Sea Floor**
- **Sea Level**
Excessive Frictional Pressure Losses Inside the Choke Line

- The frictional pressure losses inside the choke line can be excessive during a kick circulation.
- Small inside diameter of the choke line and its long length.
- The problem is aggravated by the low seawater temperature.
Hydrate Formation

- High pressure and low temperature at the wellhead are favorable for hydrate formation.
- Hydrate can plug the kill and choke lines, the annulus space and the BOP cavities.
- Hydrate formation can be prevented using inhibitors such as salt and glycol.
• In ultra-deep waters, there are chances of the gas has passed through the BOP and into the riser before well closure

• The use of synthetic oil based mud increases these chances
Presentation Outline

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• Conclusions
• A strategic in-house corporate research program dedicated to ultra-deepwater exploitation systems has been created

• Important research projects portfolio in well safety:

  Drilling Hydraulics and Gas Migration
  Gas Solubility in Synthetic Oil Based Mud Kick Simulator for Field Application
  Study of Ultra-Deepwater Blowouts
• **Objective:** to obtain downhole pressures and temperatures during simulated drilling operations

• **Issues Addressed:** riser hydraulics and temperatures; critical pressure effects (surge and swab); and gas migration

• **Results:** comparison of gathered data with computer models
• Research conducted through a JIP coordinated by RF - Rogaland Research that used a drillship Campos Basin (Brazil) in a water depth of 2714 m

• The drilling string was equipped with six sensors for recording pressures and temperatures

• Gas migration experiments were done through nitrogen injection with the bit just above the BOP
Sensor # 1 - 1 acquisition/s - 4368 m

Sensor # 2 - 1 acquisition/s - 4254 m

Sensor # 4 - 1 acquisition/s - 4135 m

Sensor # 5 - 1 acquisition/3s - 2596 m

Sensor # 6 - 1 acquisition/3s - 1706 m

Bit @ 4370 m
Gas Solubility in Synthetic Oil Based Mud

- **Objective**: to understand the interaction between a gas kick and a synthetic oil based mud

- **Issues Addressed**: experimental determination and modeling of thermodynamic properties

- **Results**: experimental data of gas solubility (methane), density and formation volume factor for n-paraffin, ester, emulsions and drilling fluids
• Research conducted at UNICAMP (Campinas State University) in a PVT cell with an operating capacity of 177 °C and 10000 psi

• The current experiments aim at expanding the ranges of pressure and temperature using a new PVT cell with an operating capacity of 200 °C and 15000 psi
The New PVT Cell
Gas Solubility in the Unweighted Drilling Fluid at 70ºC

- 63% NP no additives
- 63% NP with additives
- 78% NP no additives
- 78% NP with additives

Pressure [MPa] => 1450 psi
Density of the Unweighted Drilling Fluid at 70ºC

- 78% NP no additives
- 78% NP with additives
- 63% NP no additives
- 63% NP with additives

10 MPa => 1450 psi
Objective: to develop a software to assist the drilling engineer in well control issues on an ultra-deepwater drilling rig

Issues Addressed: estimation of pressure behavior inside an ultra-deepwater well during a gas kick circulation and calculation of kill sheets

Result: a software to be used by the drilling personnel at rig site
Kick Simulator Output
Objective: to study ultra-deepwater blowouts and their control through the dynamic kill method using relief wells

Issues Addressed: pressure behavior and gas flow rate during blowouts and the application of the dynamic kill method

Products: two simulators, one for blowout events and the other for dynamic kill method
Dynamic Kill from a Relief Well

GAS FLOW RATE (mmScf/day)

TIME (s)

2000 gpm
1000 gpm
1500 gpm
Conclusions

- Effective preventive actions make onshore and offshore drilling and production operations safer.
- Training, well control equipment tests and elaboration of safety standards are some of these actions that were responsible for the decrease of the number of blowouts in Brazil.
- Research projects enhanced the understanding of the well safety processes.
Questions?
Your Feedback is Important

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http://www.spe.org/events/dl/dl_evaluation_contest.php