Dual Gradient Drilling
The System

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With DGD, We Literally Replace the Mud in the Drilling Riser with a Seawater-Density Fluid and Use a Denser Mud Below the Mudline.

Dual Gradient Drilling: Working WITH Nature, Not Against Her

Conventional

Dual Gradient

Heavier Mud w/ Seawater Density Above Mudline

Single Mud Weight
Impact in Deepwater: Casing Point Reduction

5 Casing Points Conventionally

- Seafloor
- Depth
- Pressure
- Single Gradient Density at TD
- Fracture Pressure
- Seawater Hydrostatic
- Pore Pressure

TD
Casing Points – Dual Gradient

3 Casing Points

- TD
- Seawater Hydrostatic
- Pore Pressure
- Fracture Pressure

Dual Gradient Density at TD
Dual Gradient Drilling Defined Major Components

Subsea Rotating Device (SRD)

MudReturn Line

Solids Processing Unit (SPU)

Drill String Valve (DSV)

MudLift Pump (MLP)
Normal Drilling – The U-tube Is Balanced

Sea Level

Drillstring

Annulus

Mud Line

Bit

Bottom Hole
DGD Drilling – The U-tube Is Unbalanced

- Drillstring
- Annulus
- Bit
- Bottom Hole
- Sea Level
- Mud Line
The Drill String Valve Arrests the Natural U-Tube

- Valve in BHA
- 3 Sizes
- Evaluating two Major Companies’ Designs
- Will be Tested in Top-hole Operations

(JIP Design)
About the Drill String Valve

- Not “essential”
- Makes operations easier
- Arrests the U-tube
  - Faster connections
  - More certainty in kick detection
  - Easier to stop the MLP
  - Helpful in flow rate management
  - Helpful in well control pressure reading
- Run above the BHA, you can’t wireline through it
- Two builders
- Mechanism of operation, not intuitive
DGD Subsea Component Stack-Up
(Not to Scale)

- Subsea Rotating Device (SRD)
- Solids Processing Unit (SPU)
- MudLift Pump (MLP)
- Subsea Manifold
- Standard BOP Stack
The World’s First DGD-Ready Rig, the Pacific Santa Ana, will be Delivered in 1Q12.
Surface Changes

- Six rig pumps
  - Three for power fluid and Three for mud
  - One back-up for each fluid stream
- Additional trip tank (riser fluid)
- More piping for handing up to 3 fluids at once
- Pits divided for multiple fluids
Two trip tank systems

- Two trip tank systems
  - One for riser fluid
  - One for mud in the hole below
  - Both are circulating trip tanks
Return Line Manifold And A Drilling Choke

- Provides a way to divert mud to:
  - The pits
  - MGS
  - Rig choke
  - Drilling Choke

- Drilling Choke prevents uncontrolled expansion of return line gas
Tripping and Displacement Manifold

- Allows for management of fluids in:
  - Choke and Kill Line
  - Riser
The Drilling Riser is Modified

• MudLift Pump is Seawater-Powered, so Riser Modifications are Needed

• Two Six inch Lines
  • Seawater Power
  • Mud Return

• No Boost Line

• 3.5MM lb Flange rating

• Standard 15K C&K lines
DGD Subsea Component Stack-Up
(Not to Scale)

- Subsea Rotating Device (SRD)
- Solids Processing Unit (SPU)
- MudLift Pump (MLP)
- Subsea Manifold
- Standard BOP Stack
The Subsea Rotation Device (SRD)

- Provides a interface between riser and the wellbore
- Has the SRD Bypass built into it
- Mechanical latching mechanism on the Bearing insert
- Rated for:
  - Pressure from below - 2,000 psi Static 1,000 psi rotating
  - Pressure from above - 1,000 psi static and rotating
- Controlled by the MLP control system
- Choke and Kill lines pass through it
SRD Joint and Insert
Subsea Rotating Device Separates Mud from Riser Fluid

- Located above the Solids Processing Unit in the DGD System
- The “Active” guts: seals and bearings are retrievable
- Seals pressure from both below and above, typically 50 psi, up to 1000 psi WP
- Maintains the gradient “interface”
- Allows for rapid Managed Pressure Drilling type operations
SRD and SPU Must Fit Through the Rotary

Santa Ana has a 72” rotary
DGD Subsea Component Stack-Up
(Not to Scale)

- Subsea Rotating Device (SRD)
- Solids Processing Unit (SPU)
- MudLift Pump (MLP)
- Subsea Manifold
- Standard BOP Stack
The Solids Processing Unit (SPU)

Part of a riser specialty joint

Provides feed of mud to MLP

Sizes solids to 1-1/2” or smaller

Controlled and powered by the MLP control system

Choke and Kill lines pass through it
Tears Everything to Pumpable Sizes

- Sits in Riser below SRD
- Two separate feed paths
- Can be flushed in multiple ways
• Subsea Rotating Device (SRD)
• Solids Processing Unit (SPU)
• MudLift Pump (MLP)
• Subsea Manifold
• Standard BOP Stack
The Heart: GE’s MudLift Pump Delivery in 3Q2011

- (2) Triplex modules
- 80 gallon chambers
- 1800 gpm max rate
- 10,000’ WD rating
- 18.5 ppg mud
About the MLP

• Built by GE/ Hydril
  • Made the original unit that was field tested
  • Modernized
• About 18’ x 18’ x 30’ high
• About 450,000 lbs
• MULTIPLE redundancies
  • Operates with six cylinders, five, four, three or even two in a pinch
• Powered by SEAWATER
Emergency Disconnect

- BOPE systems are NOT changed
- Disconnect is at the LMRP and MLP comes with the LMRP
- Disconnected dynamics are similar to conventional
Pump Modularization

- Pump can be broken into separate lifts for initial lift onto rig

- Triplex Modules are Interchangeable Mirror Images
Reliability - Initial Endurance Testing Complete.

- Pumping Continuously
- Pumped 500,000 Cycles
- The equivalent of 3 wells/~1 year!
- Tear Down and X-rays revealed NO CHANGES in Diaphragms
- Phase II Testing Underway
• Subsea Rotating Device (SRD)
• Solids Processing Unit (SPU)
• MudLift Pump (MLP)
• Subsea Manifold
• Standard BOP Stack
Subsea Manifold

- Most Valves are 5K
- Provides Versatility
- Most operations conducted offline
- Redundant Flow Paths
DGD Subsea Component Stack-Up (Not to Scale)

- Subsea Rotating Device (SRD)
- Solids Processing Unit (SPU)
- MudLift Pump (MLP)
- Subsea Manifold
- Standard BOP Stack
Subsea Stack

- The BOP Stack is unchanged
- Once extra valve placed in the Choke line for improved operations
- Still have complete “conventional” Well Control available.
People Preparation is Extensive

- Drilling Engineers: How to Design DGD Wells and Secure Permits
- Drill Site Managers, Field Drilling Engineers, FDE’s and Rig Crews: How to Perform DGD Operations (Routine and Well Control)
- Offshore Support Personnel: How to maintain, troubleshoot and repair equipment
People Preparation Starts with HAZOPS

HAZOPS

JIP Drilling Procedures

Well Control Procedures

Simulator

FORMS BASIS FOR:
- New detailed procedures,
- Well design tools/software,
- Revised training material,
- Improved simulator
- Valve manifold layout,
- Specialized drilling equipment mods,
- DGD System Control philosophy and screen layouts, etc.
Initial HAZOPS Were Completed in 2010

- 9 months Effort Feb 10 – Oct 10
- ~ 22 All-Day HAZOPS covering nearly 50 DGD operations and well control procedures have occurred.
- Tremendously valuable learning exercise.
- Total Man-years to date: ~20!
We’re Building Well Design Tools to Facilitate Well Design for our New DGD Drilling Engineers
Control Philosophies are Agreed and Driller’s Panel Layouts are the Result

- Setting Level Alarms
- Recording Trends
- Monitoring Trends
- Picking Mode of Operation
All of these Things are Incorporated into Training Programs and the Pre-Spud Meeting
# DGD Project Schedule

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DGD: The Future is Here!
It’s Only Just Beginning!